# APOLLO

## GUIDANCE, NAVIGATION AND CONTROL

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SYSTEM STATUS REPORT

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E-1142
(Rev. 45)

# SYSTEM STATUS REPORT

## ABSTRACT

The System Status Report is distributed on the 15th of each month. The areas of activity reported on in this month's revision include, but are not limited to, the following for the Block I 100 Series and Block II Command Modules and Lunar Excursion Module equipment: configuration weight, weight trend information, centers of gravity, moments of inertia, reliability failure rates, electrical power requirements, and computer programming status.

by Apollo Staff
June 15, 1966

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# ACCURACY

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

# INTRODUCTION

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

Section 1 - Configuration Weight
Reported Weight Changes
Weight Trend Information

Section 2 - Centers of Gravity
Moments of Inertia

Section 3 - Glossary and System Definition

Section 4 - Reliability - Failure Rates

Section 5 - Electrical Power Requirements

Section 6 - Computer Programming Status

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

# SECTION 1

# WEIGHTS

Weights are reported to the nearest tenth of a pound on a component level. Each component weight is identified as estimated, calculated, or measured in order of increasing accuracy. These terms are defined as follows: estimated weights (E) are based on rough calculations; calculated weights (C) are based on detailed calculations made from final production drawings that will be used to build flyable equipment; measured weights (M) are actual weights of equipment built to the production drawings.

Tables 1, 2, and 3, respectively, present the weight of all CM Block I 100 Series, CM Block II, and LEM Guidance and Navigation equipment based upon the most current information. These tables offer a comparison of present component weight values with those listed in last month's revision of the System Status Report. The weights tabulated for Block II CM and LEM configuration represent operational flight hardware.

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

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

When applicable, the tables will be followed by a discussion of reported weight changes and weight trend information. Each weight increase or decrease is accompanied with an explanation for the change and the effectivity by system number. Weight trend information describes future component changes presently being studied with an emphasis on weight reduction proposals.

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

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

| Command Module G&N Equipment | Status 5/66 | Change | Status 6/66 | Design Load Weight* |
|---|---|---|---|---|
| LOWER EQUIPMENT BAY | | | | |
| CDU Assy | 16.9 (M) | 0.0 | 16.9 (M) | 18.0# |
| Optical Subsystem | | | | |
| SXT and gearing<br>SCT and gearing<br>Optical Base and gearing | 47.6 (M) | 0.0 | 47.6 (M) | |
| NVB and Resilient Mounts | 25.7 (M) | 0.0 | 25.7 (M) | 155.0** |
| Bellows Assy | 12.7 (M) | 0.0 | 12.7 (M) | |
| IMU | 61.2 (M) | 0.0 | 61.2 (M) | |
| Coolant Hoses (Two) | 0.9 (M) | 0.0 | 0.9 (M) | |
| Power Servo Assy | 65.4 (M) | 0.0 | 65.4 (M) | 120.0 |
| G&N Interconnection Assy | 26.1 (M) | 0.0 | 26.1 (M) | |
| Optical Shroud | 3.1 (M) | 0.0 | 3.1 (M) | 4.5 |
| G&N to S/C Interface Assy<br>AGC (with 6 rope modules) | 90.8 (M) | 0.0 | 90.8 (M) | 100.0 |
| Optical Eyepiece Storage Assy<br>Condition Annunciators<br>SXT Normal Relief Eyepiece<br>SCT Normal Relief Eyepiece<br>SCT Long Relief Eyepiece | 13.1 (M) | 0.0 | 13.1 (E) | --- |
| D&C Electronics Assy | 2.6 (M) | 0.0 | 2.6 (M) | 5.0 |
| Control Electronics Assy | 1.8 (M) | 0.0 | 1.8 (M) | 4.0 |

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

| Command Module G&N Equipment | Status 5/66 | Change | Status 6/66 | Design Load Weight* |
|---|---|---|---|---|
| G&N Indicator Control Panel | 10.9 (M) | 0.0 | 10.9 (M) | 15.0 |
| IMU Control Panel | 2.9 (M) | 0.0 | 2.9 (M) | 5.0 |
| Signal Conditioner Assy | 4.8 (M) | 0.0 | 4.8 (M) | 8.0 |
| DSKY | 24.5 (M) | 0.0 | 24.5 (M) | 26.0 |
| MAIN PANEL AREA | | | | |
| DSKY | 25.3 (M) | 0.0 | 25.3 (M) | 26.0 |
| LOOSE STORED ITEMS | | | | |
| Optics Cover | 2.1 (M) | 0.0 | 2.1 (M) | 2.5 |
| Horizontal Hand Holds (Two) | 0.3 (M) | 0.0 | 0.3 (M) | 1.0 |
| TOTAL | 438.7 | 0.0 | 438.7 | --- |
| The reported total weight for this month is 8.7 pounds more than the 430.0 pound total control weight † | | | | |
| Bare Guidance Systems - IMU, AGC, IMU portions of the CDU's and IMU Support electronics | | | 206.4 | --- |

*Design Load Weights are taken from ICD MH01-01256-416 signed 3 June 1965, submitted by MIT in letter AG 478-65.

**This design load weight includes only 1/2 the weight of the Bellows Assembly.

† The Total Control Weight is specified in NASA letter EG-151-44-65-55 dated 10 February 1965. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.

# This design load weight taken from IRN 3677, submitted by MIT in Letter AG 407-66 dated 9 May 1966.

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

| Command Module GN&C Equipment | Status 5/66 | Change | Status 6/66 | Design Load Weight* |
|---|---|---|---|---|
| LOWER EQUIPMENT BAY | | | | |
| CDU Assy | 36.2 (E) | 0.0 | 36.2 (E) | 50.0 |
| Optical Subsystem<br>SXT and gearing<br>SCT and gearing<br>Optical Base and gearing | 47.6 (M) | 0.0 | 47.6 (M) | 150.0 |
| NVB and Mounts | 14.9 (E) | 0.0 | 14.9 (E) | |
| Bellows Assy | 12.7 (E) | 0.0 | 12.7 (E) | |
| IMU | 42.5 (M) | 0.0 | 42.5 (M) | |
| Coolant Hoses (Two) | 0.9 (E) | +0.3 | 1.3 (M) | |
| Power Servo Assy | 49.4 (E) | 0.0 | 49.4 (E) | 58.0 |
| PIPA Electronics Assy | 9.0 (E) | 0.0 | 9.0 (E) | 12.0 |
| G&N Interconnect Harness Group | 30.0 (E) | 0.0 | 30.0 (E) | 40.0 |
| AGC | 65.0 (E) | 0.0 | 65.0 (E) | 80.0 |
| Optical Shroud | 3.1 (M) | 0.0 | 3.1 (M) | 4.5 |
| Optical Eyepiece Storage Assy<br>SXT Normal Relief Eyepiece<br>SCT Normal Relief Eyepiece<br>SCT Long Relief Eyepiece | 11.1 (E) | 0.0 | 11.1 (E) | 15.0 |
| G&N Indicator Control Panel | 11.5 (M) | 0.0 | 11.5 (M) | 17.0 |
| DSKY | 17.5 (E) | 0.0 | 17.5 (E) | 25.0 |
| Signal Conditioner Assy (Operational Flights) | 8.0 (E) | 0.0 | 8.0 (E)** | 8.0 |

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

| Command Module GN&C Equipment | Status 5/66 | Change | Status 6/66 | Design Load Weight* |
|---|---|---|---|---|
| MAIN PANEL AREA | | | | |
| DSKY | 17.5 (E) | 0.0 | 17.5 (E) | 25.0 |
| LOOSE STORED ITEMS | | | | |
| Horizontal Hand Holds (Two) | 0.3 (M) | 0.0 | 0.3 (M) | 1.0 |
| SXT Long Relief Eyepiece | 0.4 (E) | 0.0 | 0.4 (E) | --- |
| TOTAL | 377.6 | +0.3 | 377.9 | --- |
| The reported total weight for this month is 22.1 pounds less than the 400.0 pound total control weight † | | | | |
| Bare Guidance Systems - IMU, AGC, IMU portions of the CDUs and IMU support electronics | | | 168.1 | --- |

*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 9.6 (E) 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.

Coolant Hoses (Two) (+0.3 lb)

IMU coolant hoses of the Block II CM configuration have been weighed at MIT/IL. The weight breakdown follows:

| | |
|---|---|
| Coolant Hose and a connector (Left) | 205 grams |
| Coolant Hose and a connector (Right) | 205 grams |
| Entrapped coolant in two hoses | 136 grams |
| TOTAL WEIGHT | 546 grams |
| or | 1.20 pounds |

Thus the net increase is 0.3 lb.

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

| LEM PGNCS Equipment | Status 5/66 | Change | Status 6/66 | Design Load Weight* |
|---|---|---|---|---|
| IMU | 42.4 (M) | 0.0 | 42.4 (M) | 80.0 |
| AOT (including eyepiece and bellows) | 23.1 (E) | 0.0 | 23.1 (E) | |
| NVB | 4.0 (E) | 0.0 | 4.0 (E) | |
| HARNESS "B" Supported by the NVB | 0.6 (E) | 0.0 | 0.6 (E) | |
| HARNESS "B" Supported by the PTA | 0.8 (E) | 0.0 | 0.8 (E) | 21.0 |
| HARNESS "B" Supported by the structure | 3.1 (E) | 0.0 | 3.1 (E) | |
| PTA | 14.3 (E) | 0.0 | 14.3 (M) | |
| HARNESS "A" | 14.6 (E) | 0.0 | 14.6 (E) | 22.0 |
| LGC | 65.0 (E) | 0.0 | 65.0 (E) | 65.0 |
| DSKY | 17.5 (E) | 0.0 | 17.5 (E) | 20.0 |
| AOT Control Unit (CCRD) | 2.0 (E) | -0.4 | 1.6 (M) | 2.0 |
| CDU | 37.3 (E) | -0.3 | 37.0 (M) | 37.0 |
| PSA | 19.2 (E) | -1.6 | 17.6 (E) | 28.2 |
| SCA (Operational Flights) | 7.2 (E) | 0.0 | 7.2 (E) | |
| TOTAL | 251.1 | -2.3 | 248.8 | --- |
| The reported total weight for this month exceeds the 240.0 pounds total control weight by 8.8 lbs.† | | | | |
| Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics | | | 158.8 | |

*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 9.2 (E) pounds.

†The Total Control Weight is specified in NASA letter EG-151-44-65-55 dated 10 February 1965.

## Reported LEM Weight Changes

Button Box (-0.4 lb)

The Computer Control Reticle Dimmer has been weighed at MIT/IL. A comparison between the MIT measured value and the AC Electronics Acceptance Data Package weights follows:

| | |
|---|---|
| MIT Prototype | 1.62 pounds |
| AC ADP SYSTEM 601 | 1.58 pounds |
| AC ADP SYSTEM 602 | 1.57 pounds |
| AC ADP SYSTEM 604 | 1.58 pounds |

PTA (0.0 lb)

The acceptance data package for LEM System 604 reports a weight of 14.26 lbs for the PTA. This weight supports the MIT estimate.

CDU (-0.3 lb)

The acceptance data package for LEM System 604 reports a weight of 36.97 lbs for the CDU.

PSA (-1.6 lb)

The weight of an operational flight PSA has been re-estimated in view of the measured weights of pre-production PSAs in acceptance data packages for LEM Systems 601 and 602.

## SECTION 2

# CENTERS OF GRAVITY AND MOMENTS OF INERTIA

The centers of gravity and moments of inertia are summarized in tabular form. This data has been prepared for MIT/IL designed equipment with respect to the reference axes of the Block II Command Module and the Lunar Excursion Module. MIT assumes that all hardware is in the proper configuration for Thrusting Modes; therefore, the eyepieces (3) will be located in the Optical Eyepiece Storage Assembly. North American Aviation will provide storage for the astronaut's Horizontal Handholds (2). Since this storage information is not available at MIT/IL, it is suggested that NAA supply the centers of gravity and moments of inertia for these items.

MIT Letter AG 261-66 dated 23 March 1966, proposed that NAA provide storage for the SXT Long Relief Eyepiece in the Block II Command Module.

Each assembly has a percentage reflecting the error in the values recorded incurred in the calculation methods employed. Analytical values will be verified by experiment (Tri-Filar Pendulum Moment of Inertia Test) when flight hardware is available.

TABLE 4. COMMAND MODULE BLOCK II GN&C MASS PROPERTY DATA

| Command Module G&N Equipment | Center of Gravity - Inches | | | | Moment of Inertia - Slug-ft$^2$ | | | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$ | $\bar{y}$ | $\bar{z}$ | ±Error | $I_x$ | $I_y$ | $I_z$ | ±Error |
| CDU Assy | 39.0 | 15.6 | 42.3 | 5% | 17.85 | 28.78 | 15.34 | 2% |
| Optical Subsystem<br>SXT & gearing<br>SCT & gearing<br>Optical Base & gearing | 69.7 | 0 | 33.6 | 10% | 11.77 | 61.99 | 50.25 | 2% |
| NVB & Mounts<br>Bellows Assy | 65.5 | 0 | 39.8 | 10% | 10.02 | 35.56 | 26.15 | 5% |
| IMU<br>Coolant Hoses (two) | 55.8 | 0 | 40.9 | 10% | 15.41 | 43.96 | 28.67 | 5% |
| Power Servo Assy | 44.2 | 0 | 44.4 | 5% | 22.77 | 44.04 | 22.09 | 1% |
| PIPA Electronics Assy<br>G&N Interconnect Harness Assy | 64.2 | -14.0 | 37.6 | 5% | 3.12 | 10.70 | 8.39 | 2% |
| AGC<br>Optical Shroud | 38.0 | -4.0 | 46.2 | 5% | 32.11 | 52.93 | 21.49 | 1% |
| Optical Eyepiece Storage Assy<br>SXT Normal Relief Eyepiece<br>SCT Normal Relief Eyepiece<br>SCT Long Relief Eyepiece | | | | | | | | |
| G&N Indicator Control Panel | 54.5 | 0 | 36.5 | 5% | 3.61 | 11.27 | 7.91 | 4% |
| DSKY (L.E.B.) | 61.5 | 17.1 | 36.5 | 5% | 6.14 | 19.31 | 15.39 | 1% |
| Signal Conditioner Assy | 72.5 | 15.1 | 31.6 | 5% | 2.12 | 10.79 | 9.46 | 2% |
| DSKY (Main Panel) | 68.0 | -13.9 | -20.5 | 5% | 2.32 | 19.06 | 18.21 | 2% |
| Horizontal Handholds (Two)<br>SXT Long Relief Eyepiece | | See text on the preceeding page. | | | | | | |
| TOTAL | | | | | | | | |

TABLE 5. LUNAR EXCURSION MODULE PGNCS MASS PROPERTY DATA

| LEM GN&C EQUIPMENT | Center of Gravity - Inches | | | | Moment of Inertia - Slug-ft$^2$ | | | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$ | $\bar{y}$ | $\bar{z}$ | ±Error | $I_x$ | $I_y$ | $I_z$ | ±Error |
| IMU | 307.0 | 0 | 49.9 | 5% | 22.90 | 886.76 | 863.97 | 1% |
| Navigation Base | 309.0 | 0 | 54.4 | 5% | 2.57 | 3.39 | 0.86 | 1% |
| AOT | | | | | | | | |
| Button Box | | | | | | | | |
| PTA | | | | | | | | |
| Harness "B" | | | | | | | | |
| DSKY | 254.0 | 0 | 58.6 | 10% | 12.98 | 256.47 | 243.50 | 1% |
| LGC | 266.0 | 0 | -22.9 | 5% | 8.24 | 1034.57 | 1027.81 | 1% |
| CDU | 252.2 | 0 | -22.8 | 10% | 4.69 | 553.63 | 549.28 | 2% |
| PSA (not integral unit) | 240.0 | 0 | -22.8 | 5% | 3.04 | 308.63 | 305.88 | 5% |
| Signal Conditioner Assy | | | | | | | | |
| Harness "A" | | | | | | | | |
| TOTAL | | | | | | | | |

# SECTION 3

## GLOSSARY AND SYSTEM DEFINITION

A description of what constitutes MIT supplied hardware for the guidance and navigation equipment in Block I (100 Series) and Block II Command Modules and Lunar Excursion Module is contained in this section.

Apollo Guidance Computer (AGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDU's. Does not contain the associated displays and controls.

The AGC consists of one case containing factory replaceable electronic modules. The weight estimate includes a cover for moisture-proofing and the G&N to S/C Interface Assembly which is located in the adjacent area. The weight of the necessary cold plate is not included.

Bellows Assembly

Consists of two flexible metal bellows forming a pressure seal between CM and optical subsystem for penetration of hull.

Coupling Data Unit (CDU) Assembly

The CDU provides the necessary signal interface among the IMU gimbal angles, optics gimbal angles, angle registers in the AGC, and the spacecraft autopilot attitude error signals.

The assembly contains five interchangeable gear boxes each with necessary motor tachometer, resolver synchros, and encoder. The CDU does not include associated electronics. (This electronics is located in the Block I PSA.) A frame assembly encloses the CDUs in a moisture-proof container and mounts them to the spacecraft structure.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer (NAA).

Control Electronics Assembly

Consists of one power transformer, one relay and diode module and a bracket end connector mounted behind G&N indicator control panel to support display and control functions. Includes moisture-proofing.

Coolant Hoses

Consists of: (1) three steel-flex coolant hoses between IMU and spacecraft, (2) line transition piece, (3) bracket assembly screws and clamp, and (4) entrapped coolant. (The line transition piece makes two of the hoses a single unit.)

DSKY (D&C/AGC)

Number displays and keyboard control associated with the operation of the AGC. Two functionally identical and parallel operating units: one in lower equipment bay and one on main panel between left and center couches. The main panel DSKY has a piece of fail-safe alarm detection equipment called a "nightwatchman".

D&C Electronics Assembly

Consists of a chassis, a relay and diode module, a demod. elect. module, a saturable reactor, a time delay module, a connector, and wiring and is mounted behind the G&N Indicator Control Panel. Used to support display and control functions. Connectors will be moisture-proofed.

G&N Indicator Control Panel

Consists primarily of controls and displays for the operation of the optics, IMU temperature control, panel brightness control, and attitude impulse control. It includes display and control elements, panel, panel wiring, supporting hardware, and moisture-proofing.

G&N Interconnection Assembly

Consists of an interconnect wiring harness, which electrically ties together the assemblies that constitute a completely integrated system. The weight of the PSA End Connector is included with this item. This term does not include weights of harness support brackets, which are an NAA responsibility.

G&N to S/C Interface Assembly

This assembly provides the electrical interface between the spacecraft wiring channel, the computer connector, and the PSA end connector assembly. There are no active electronics in the assy. The weight of this item is included with the Block I computer.

Horizontal Handholds (Two)

These handholds are part of the body tethering system for use during navigation sightings. Two handholds are mounted on the G&N Indicator Control Panel and will be removed when not in use. The weight reported includes the mounting screws.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on the innermost gimbal of a three degree-of-freedom gimbal structure. The size 14 IMU (14-inch case diameter) gimbal assembly including all parts inside hermetic case, entrapped coolant, and heat exchanger insulation are included in the weight.

IMU Control Panel

Consists of panel, wiring, attitude error meter, CDU transfer switch, manual alignment switch, CDU mode control switches, connector, supporting hardware, and associated moisture-proofing.

NVB and Resilient Mounts

Rigid beryllium structure supporting the IMU and the optical subsystem with its associated hardware. The NVB is attached to the spacecraft using flexible resilient mounts to prevent spacecraft strains from distorting the NVB and the alignment between the IMU and optics. These mounts also provide shock and vibration attenuation.

Optical Eyepiece Storage Assy (ESU)

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal relief, SCT normal relief, and SCT long relief eyepieces. The condition annunciator assembly is part of the compartment structure. The weight also includes a protective cover or door. The assembly is located in the area vacated by the M&DV.

Condition Annunciator Assy: This unit visually displays the status of G&N System. This function was previously part of the Map and Data Viewer.

Normal Relief Eyepieces: Removable SXT eyepiece and SCT eyepiece.

Long Relief Eyepiece: A SCT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of normal eyepiece of SCT.

Optical Subsystem

The subsystem consists of a sextant, scanning telescope, and an optical base, each with associated hardware. An equipment definition follows:

Sextant (SXT): A two line-of-sight, narrow field-of-view, two degree-of-freedom sextant with its attached gearing.

Scanning Telescope (SCT): A single line-of-sight, wide field-of-view, two degree-of-freedom articulation optical instrument with its attached gearing.

Optical Base: A base for the SXT and SCT with its associated gearing.

Optical Shroud & Cover Assembly

Consists of the optical shroud and protective cover.

Power Servo Assembly (PSA)

The PSA includes most of the support electronics: power supplies; IMU, Optics, and CDU servos; IMU temperature control; accelerometer pulse torquing and gyro pulse torquing. Replaceable modules are placed in each of the 10 trays. Moisture protection is provided for each tray individually by a gasket and a connector cover with mounting screws. A beryllium front toe plate is included in the PSA weight.

The PSA end connector is the electrical interface between the 10 PSA trays, the G&N Interconnection Assy, and the G&N to S/C Interface Assy. The end connector weight is reported in the G&N Interconnection Assembly value.

Signal Conditioner Assembly

This assembly buffers and conditions signals for transmission to telemetry.

Apollo Guidance Computer (AGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDU's. Does not contain the associated displays and controls.

Consists of one case containing factory replaceable electronic modules. Includes cover for moisture-proofing, but does not include the necessary cold plate.

Many Block I modules have been redesigned and repackaged in a separate case. Memory capacity increased over Block I.

Bellows Assembly

Consists of two elastomeric, semi-toroidal, strain isolation, pressure vessel penetration seals between the CM hull and the optical subsystem.

Coupling Data Unit Assembly (CDU)

The coupling data unit provides central data conversion between the G&N analog subsystems (inertial and optics sextant), and in addition certain spacecraft analog control and display functions. The CDU is an all-electronic device that employs analog computational techniques in conjunction with digital counters and control logic to perform both analog to digital (A/D) and digital analog (D/A) conversion.

Moding of various Guidance and Control system functions that operate in conjunction with the CDU signals is accomplished by the computer through the CDU control and synchronizing logic.

The weight includes all the support electronics, the 4 V power supply, and the header mounted adjacent to the AGC.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer. (NAA).

Coolant Hoses

Consists of: (1) two steel-flex coolant hoses, between IMU and spacecraft and (2) two hose connectors, and (3) entrapped coolant. Bracket assembly, screws and clamps will be supplied by NAA.

DSKY (D&C/AGC)

Number displays and keyboard control associated with the operation of the AGC. Two functionally identical and parallel operating units: one in lower equipment bay and one on main panel between left and center couches.

Mechanically and electrically similar to Block I but smaller configuration because of smaller relays. The Block II displays and keyboard controls will be sealed by encasing the unit in a container and using pressurized O-rings.

G&N Indicator Control Panel

Consists of controls and displays for optics, condition lamps, telemetry, and Mastr Alarm. Also contains attitude impulse switch and hand controller. Has integral illuminated computer instructions. The condition lamps replace the Block I Condition Annunciator Assembly.

G&N Interconnect Harness Group

This assembly consists of eight cables that electrically tie together the hardware that makes up the GN & C system and also provides the electrical interface with the spacecraft. The cables are defined as follows:

| | |
|---|---|
| HARNESS A | AGC-CDU to Left Hand Bracket and S/C |
| HARNESS B | PSA to Optics (SXT) and Optics Resolver |
| HARNESS C | PSA to Upper and Lower IMU & PIPA |
| HARNESS D | PSA to Left Hand Bracket (AGC-CDU) |
| HARNESS E | PSA to G&N Panel |
| HARNESS F | PSA to Optics (SCT) |
| HARNESS G | PSA to Signal Conditioner and S/C Right Hand Bracket |
| HARNESS H | PSA to DSKY, Left Hand Bracket and Right Hand Bracket (Power) |

The estimated weights include the group shielding, potting compound, connectors, wire, cable clamps, and clamp brackets.

Horizon Photometer - Star Tracker (Experimental Basis Only)

An earth horizon brightness photometer and automatic star tracker used for navigation measurements against the earth's illuminated limb. The sensors are incorporated into the head of the SXT, the weight of which includes this function. The PSA includes all support electronics for the horizon photometer.

Horizontal Handholds (Two)

These handholds are part of the body tethering system for use during navigation sightings. Two handholds are mounted on the G&N Indicator Control Panel and will be removed when not in use. The reported weight includes the mounting screws.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on innermost gimbal of a three degree-of-freedom gimbal structure. The size 12.5 IMU (12.5-inch case diameter) gimbal assembly including all parts inside the hermetic case, entrapped coolant, and heat exchanger insulation are included in the weight.

NVB & Mounts

A polyurethane filled aluminum skinned structure functionally similar to Block I but lighter and will provide for mounting the size 12.5 IMU. The Block II NVB is attached to the spacecraft by use of strain isolation hardmounts and will have a transition piece as a result of the re-orientation of the NVB so that the IMU axes will be parallel to the Command Module axes.

Optical Eyepiece Storage Assembly (ESU)

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal relief, SCT normal relief, and a SCT long relief eyepiece. The weight also includes a protective cover or door. This assembly is located in the area vacated by the M&DV. There is no provision for a condition annunciator as part of the compartment structure.

Normal Relief Eyepieces: Removable SXT eyepiece and a SCT eyepiece.

Long Relief Eyepieces: A SCT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of SCT normal eyepiece.

Optical Subsystem

The subsystem consists of a sextant, scanning telescope, and an optical base each with associated hardware. An equipment definition follows:

Sextant (SXT): A two line-of-sight, narrow field-of-view, two degree-of-freedom sextant with its attached gearing. The horizon photometer and automatic star tracker sensors are incorporated into the SXT head. (See the experimental Horizon Photometer - Star Tracker)

Scanning Telescope (SCT): A single line-of-sight, wide field-of-view, two degree-of-freedom articulation optical instrument with its attached gearing.

Optical Base: A base for the SXT and SCT with its associated gearing.

Optical Shroud & Cover Assembly

Contains an optical shroud. The optics cover is to be used also as a work table during the flight. NAA has design responsibility for the "optics cover - work table".

PIPA Electronics Assembly (PEA)

Consists of electronics which directly support the function of the PIPA loop, including the calibration modules, containing selected components, assigned to each IMU. This sealed assembly is located in the Block I CDU location.

Power Servo Assembly (PSA)

The PSA consists of a single-plane matrix header with a cold plate mounted on top and the modules plugging in from beneath. A cover is required to protect the modules from moisture. The assembly is similar in function to the Block I PSA; however, many of the modules have been redesigned and repackaged.

The support electronics for the PIPA loop has been transferred to the PIPA Electronics Assembly. The CDU servos are deleted because the Block II CDU is an electronic package. The PSA includes electronics used to support the display and control functions previously identified with the Block I Control Electronics Assy and D&C Electronics Assy. The operational modules of the Horizon Photometer-Star Tracker have been replaced by equivalent dummy modules.

SXT Long Relief Eyepiece

A SXT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of SXT normal eyepiece. The present MIT proposal suggests that this eyepiece be stored in a bay with other loose stored items.

Signal Conditioner Assembly (SCA)

This assembly buffers and conditions signals for transmission to telemetry. These modules are located in the same volume occupied by the Block I lower equipment bay DSKY.

Apollo Guidance Computer (LGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDUs. Does not contain the associated displays and controls.

Consists of one case containing factory replaceable electronic modules. Includes cover for moisture-proofing, but does not include the necessary cold plate.

Except for computer programs, the LGC is identical to the CM Block II AGC.

Alignment Optical Telescope (AOT)

The AOT is a three-position periscope with a single degree-of-freedom, manually read recticle. The weight estimate includes a normal eye-relief eyepiece and a bellows assy between the AOT and the LEM hull. The bellows assy is an elastomeric, semi-toroidal, strain isolation, pressure vessel penetration seal. The AOT reticle is used for alignment of the IMU.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer. (GAEC)

AOT Control Unit (Computer Control and Reticle Dimmer)

Located on GAEC Supplied Hardware protecting the AOT. Contains illuminated push button controls mark "x", mark "y", and "reject" mark. Also has an AOT reticle dimmer.

Coolant Hoses

The coolant hoses for the LEM IMU will be supplied by the spacecraft manufacturer. (GAEC)

Coupling Data Unit (CDU)

The coupling data unit provides central data conversion between the computer and G&N analog subsystems (inertial and radar), and in addition certain spacecraft analog control and display functions. The CDU is an all-electronic device that employs analog computational techniques in conjunction with digital counters and control logic to perform both analog to digital (A/D) and digital to analog (D/A) conversion.

Moding of various Guidance and Control system functions that operate in conjunction with the CDU signals is accomplished by the computer through the CDU control and synchronizing logic.

The LEM CDU uses modules identical to those used in the CM Block II but mounted on a different header. The weight includes all the support electronics, the 4V power supply, and the header mounted adjacent to the AGC.

DSKY

Number Displays and Keyboard controls associated with the operation of the LGC. The DSKY will be sealed by encasing the unit in a container and using pressurized O-rings. Identical to the Block II DSKY except only a single unit is required.

Harness "A"

Harness "A" provides electrical interconnection in the CDU, AGC, and PSA areas. The estimated weights include the connectors, wire, insulation, shielding, and cable clamps.

Harness "B"

Harness "B" provides the electrical interconnection in the IMU and PTA areas. The estimated weights include the connectors, distribution box, wire, insulation, shielding, and cable clamps.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on the innermost gimbal of a three-degree-of-freedom gimbal structure. The size 12.5 LEM IMU is physically identical to the Block II. The weight value includes the gimbal assembly (and all parts inside the hermetic case), entrapped coolant, and the heat exchanger insulation.

Lens Cleaning Kit

Not specifically defined but appropriate cloths for cleaning the accessible surfaces of the optics lens.

NVB and Mounts

A toroidal aluminum ring with: (1) four tubular aluminum posts to provide for IMU mounting, (2) four tubular aluminum posts for AOT mounting, and (3) three aluminum inserts to provide strain isolation ball mounting to the GAEC structure.

Power Servo Assembly (PSA)

The PSA consists of a single-plane matrix header mounted on a cold plate with the modules plugging in from the top. A cover is required to protect the modules from moisture. The assembly consists of electronics modules similar to those identified in the Block II PSA; however, many of the modules have been redesigned and repackaged.

Support electronics for the PIPA and IRIG loops are not included. See "Pulse Torque Assembly". Support electronics for the optical subsystem is not identified.

Pulse Torque Assembly (PTA)

This assembly consists of electronics contained in the PIPA and IRIG loops, including the pulse torque power supply and PIPA and IRIG calibration modules. The PIPA calibration modules, containing selected components, are assigned to each IMU. This sealed assembly is located adjacent to the IMU in LEM.

Signal Conditioner Assembly (SCA)

This assembly buffers and conditions signals for transmission to telemetry. This assembly is located "piggyback" on top of the LEM PSA.

SECTION 4

# RELIABILITY - FAILURE RATES

The current status of reliability failure rates are reported in summary form as a chart.

The following chart contains tabulations of the failure rates associated with each major configuration of G&N systems. These have been derived from the parts count of each assembly using generic type part failure rates, modified only by the stress applied to each part and its singular application in the system. From these data, estimations of mission success probabilities may be calculated. Continual updating is accomplished and will be reported monthly in this report.

G&N MISSION FAILURE RATE ANALYSIS

FAILURE RATES EXPRESSED IN "FAILURES PER $10^6$ HOURS"

| SYSTEM - MISSION \ HARDWARE | IMU Assembly | IMU Electronics | Optics Assembly | Optics Electronics | IMU CDU | Optics CDU | AGC | DSKY | D&C |
|---|---|---|---|---|---|---|---|---|---|
| | ON / STBY | ON / STBY | ON / OFF | ON / OFF | ON / OFF | ON / OFF | ON / STBY | ON / STBY | ON / OFF |
| Block II CM Design Reference Mission | 129 / 10.2 | 110 / 6.3 | 94 / 0 | 77 / 0 | 155* / - | 91* / - | 235 / 60.5 | 2.3 / 0 | 22 / 0 |
| LEM Design Reference Mission | 129 / 1.6 | 110 / 0 | 38 / - | 1.33 / - | 155* / - | 112* / - | 235 / - | 110 / - | 1.2 / - |
| G&N #17 AS-202 Unmanned | 185 / - | 224 / - | 0† / - | 0† / - | 111 / - | 0† / - | 257 / - | 12 / - | 6 / - |
| G&N #601 AS-206 Unmanned LEM | 129 / - | 110 / - | 0† / - | 0† / - | 155 / - | 0† / - | 235 / - | 12 / - | 0 / - |

NOTES:

*When inertial and optics subsystems work simultaneously.

†Optical units cannot be used during flight for unmanned missions.

CODE:

0 represents no failure

- represents a non-existent standby mode

## SECTION 5

# ELECTRICAL POWER AND ENERGY

Electrical power and energy reporting is based upon the inflight spacecraft sequence of events for the Design Reference Mission as developed by the Apollo Mission Planning Task Force (AMPTF). (Reference GAEC Report Volume III - LED-540-12, dated 30 October 1964.)

The accompanying tables present the magnitude and distribution of power dissipated on a subsystem level. It is assumed that power is drawn from the spacecrafts' primary +28VDC supply and a 400 cps - 115 VAC single phase inverter.

Intermittent power peaks can exist, particularly during operation of displays and controls at random times. The energy content in these peaks is considered negligible.

All values (except those mentioned above) are actual expected levels of power. No margin factor has been applied to protect against possible differences between actual loads which will be experienced and the calculated levels quoted. Thus, these values should not be taken as "not to exceed" extremes.

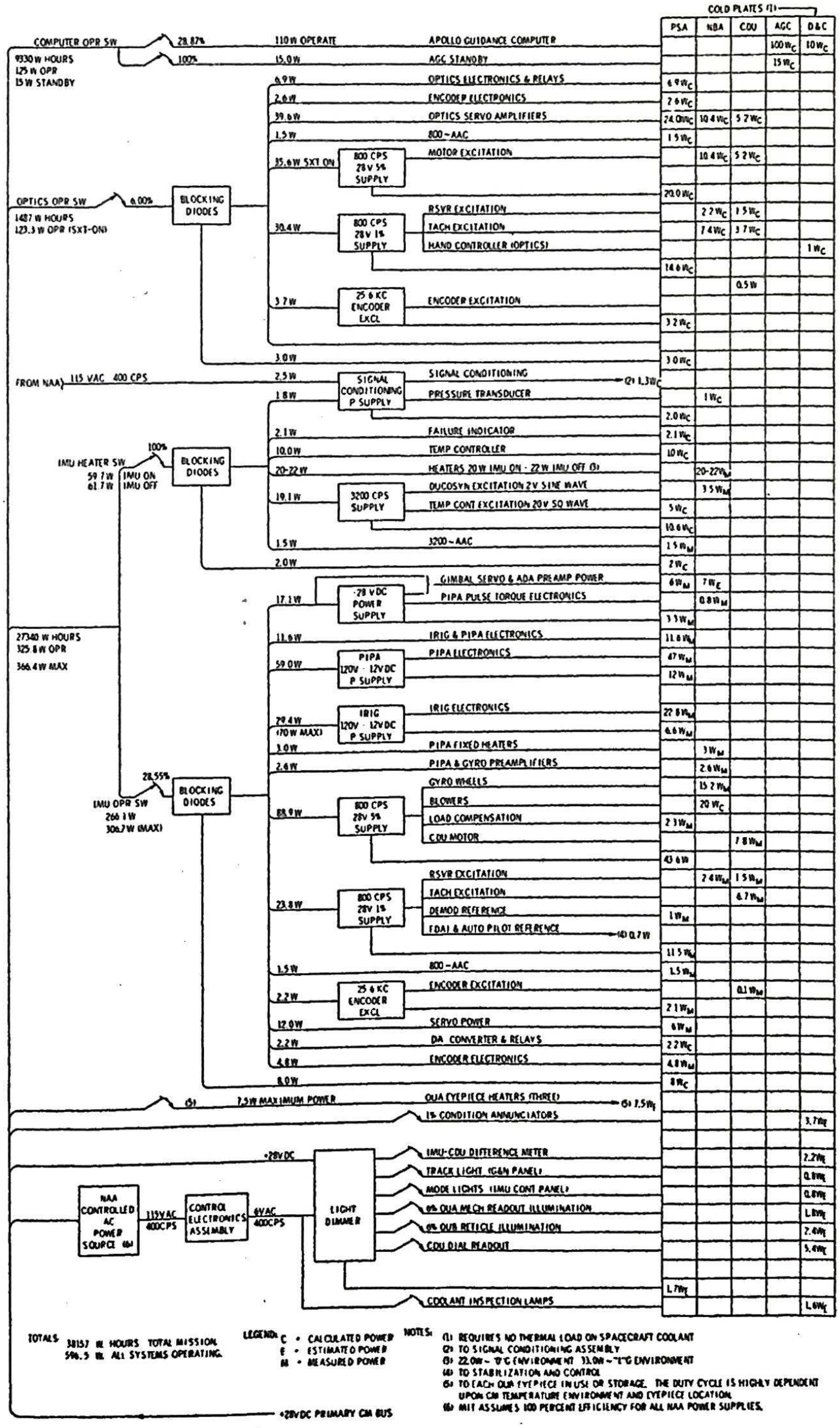
Interface Control Documents serve as the guidelines for reporting power figures.

| | |
|---|---|
| CM Block I 100 Series | MH01-01227-216 "G & N Electrical Input Power" signed 11 June 1965 |
| CM Block II | MH01-01327-216 "G & N Electrical Input Power" signed 15 July 1965 |
| LEM | LIS-390-10002 "PGNCS Prime Power Requirements and Characteristics" signed 30 July 1965 |

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

BASED UPON 1985 HOUR (82.7 DAY) LUNAR MISSION
DESIGN REFERENCE MISSION

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




TOTALS 38137 W HOURS TOTAL MISSION
596.5 W ALL SYSTEMS OPERATING

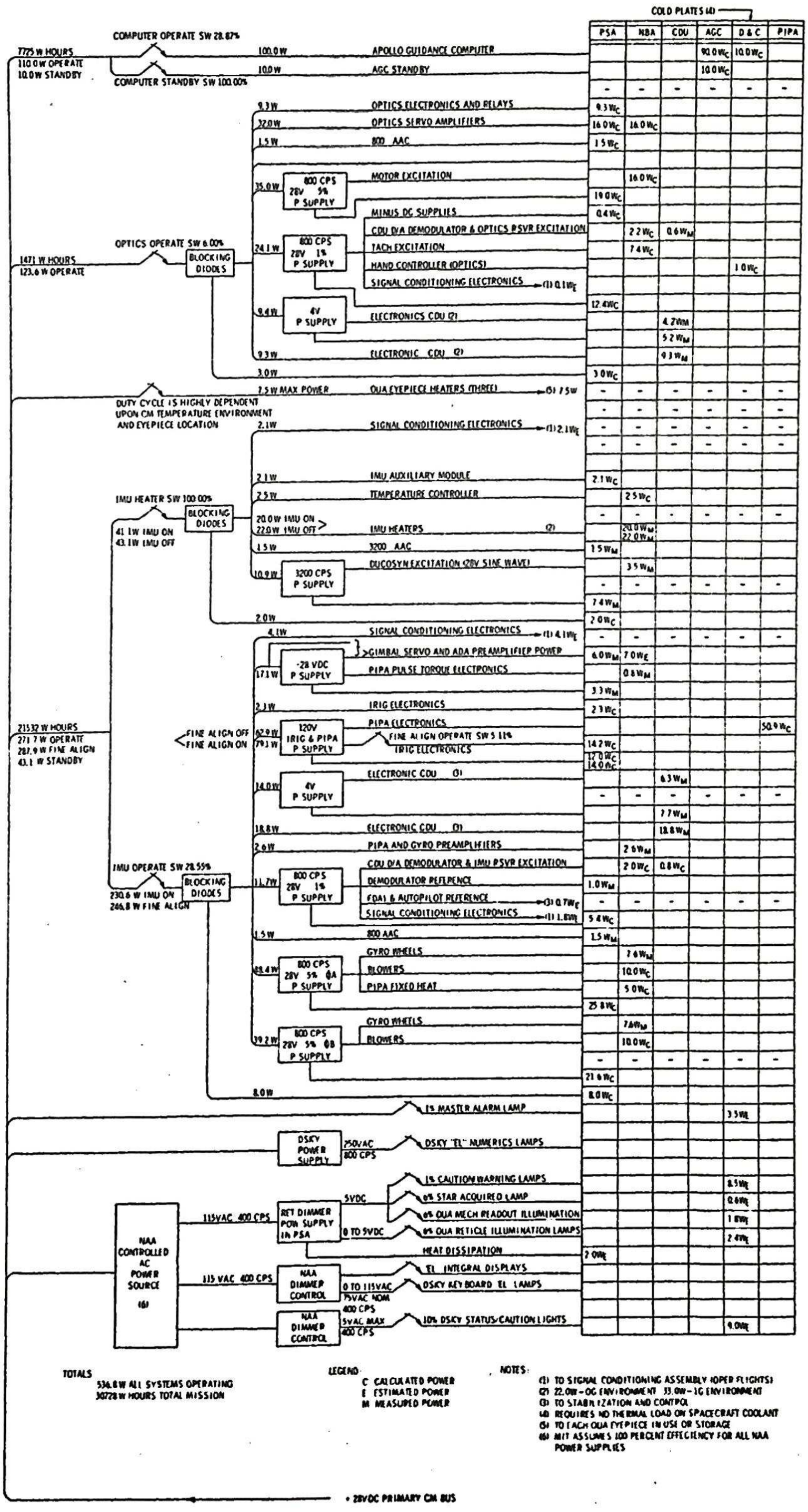
LEGEND: C - CALCULATED POWER
E - ESTIMATED POWER
M - MEASURED POWER

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

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

BASED UPON 195.5 HOUR (8.27 DAY) LUNAR ORBIT MISSION
DESIGN REFERENCE MISSION

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




TOTALS
536.8 W ALL SYSTEMS OPERATING
30728 W HOURS TOTAL MISSION

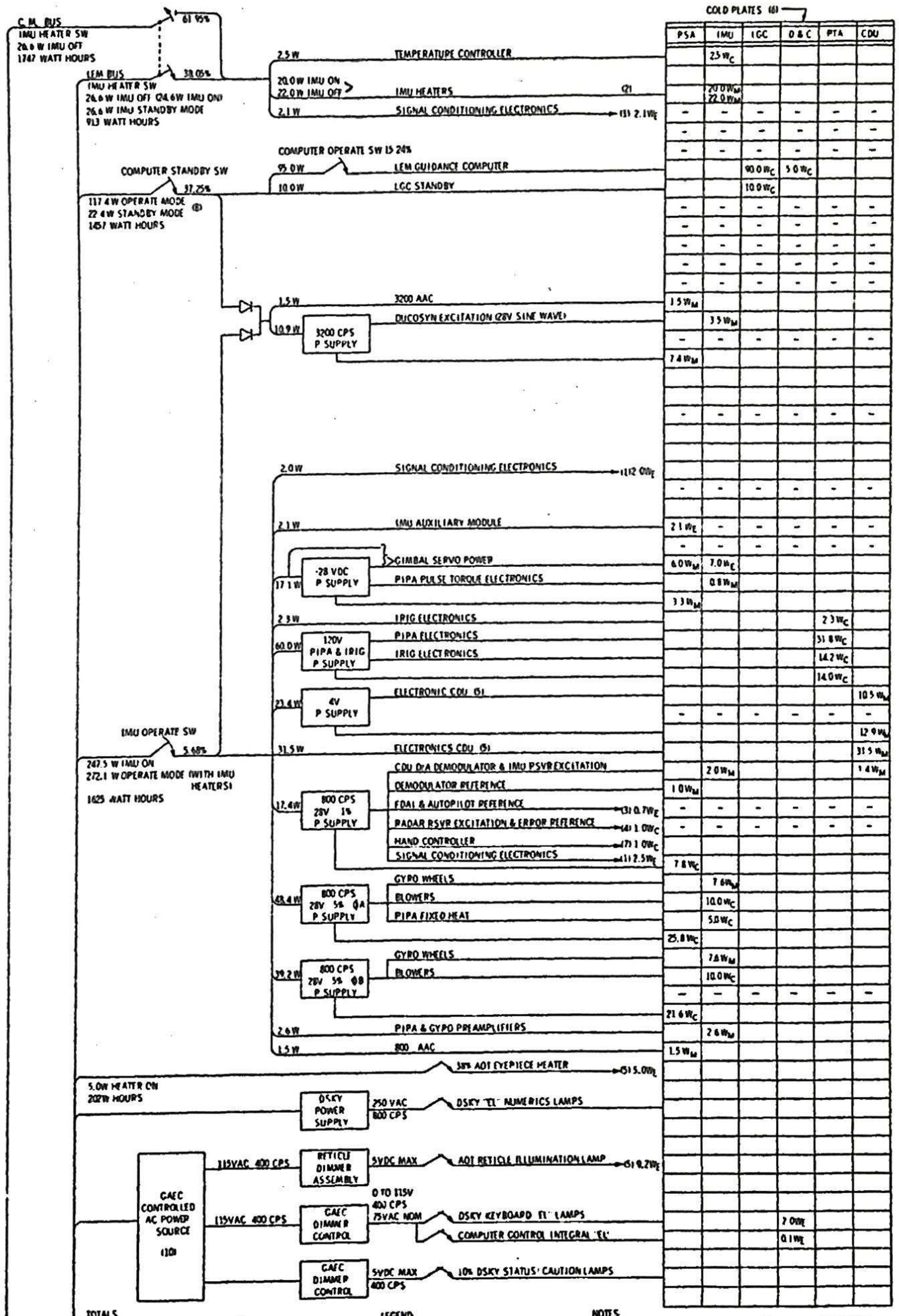
LEGEND
C CALCULATED POWER
E ESTIMATED POWER
M MEASURED POWER

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

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

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

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



## SECTION 6

# GUIDANCE COMPUTER PROGRAMMING

Guidance computer programs fall into three categories: service, test and mission programs.

1. Service Programs: The service programs may be regarded as the "tools" used to accomplish the mission objectives. These programs are necessary for the general operation of the computer and they are completely insensitive to mission planning.

2. Test Programs: The test programs are used to test the AGC, the G&N System, and other programs.

3. Mission Programs: The mission programs are those AGC programs which directly accomplish the guidance and navigation functions. Certain parts of these are highly sensitive to mission plans, vehicle configuration, ground based activities, etc. Although some portions of these programs are quite general, a complete specification is not possible until the release of the Guidance System Operation Plan for each particular mission.

The memory also contains all mission and vehicle dependent data that is written directly into the memory of AGC. The very limited erasable section is intended primarily for storage of computational variables. Those mission parameters that do not change during flight are consigned to the fixed section of the memory.

## Computer Programming Status

During the next reporting period, MIT/IL will publish a computer programming development plan. The development plan will contain amongst other things, preliminary estimates of fixed memory allocation for the various missions. The next revision of the System Status Report will contain this information.

## FIXED MEMORY ALLOCATION FOR BLOCK I COMMAND MODULE COMPUTER

| COMPUTER PROGRAMS AND ROUTINES | CORONA FLIGHT AS-202 | CORONA FLIGHT AS-501 | CORONA FLIGHT AS-502 | SUNSPOT FLIGHT AS-204 | SUNSPOT FLIGHT AS-205 |
|---|---|---|---|---|---|
| Interrupt Transfer Routines | 39 | | | | |
| Fixed-Fixed Interpreter Section | 941 | | | | |
| Bank 03 Interpreter Section | 822 | | | | |
| Executive | 339 | | | | |
| Waitlist | 221 | | | | |
| Restart Control | 116 | | | | |
| Restart Tables and Routines | 464 | | | | |
| Fresh Start and Restart | 312 | | | | |
| Down-Telemetry Program | 230 | | | | |
| T 4 Rupt Output Control Program | 805 | | | | |
| Mode Switching and Mark Routines | 587 | | | | |
| IMU Compensation Package | 215 | | | | |
| IRIG Pulse-Torquing Routines | 288 | | | | |
| Extended Verbs for Moding | 695 | | | | |
| AGC-Self Check | 984 | | | | |
| Inter-bank Communication | 74 | | | | |
| Alarm and Display Procedures | 59 | | | | |
| Orbital Integration Program | 840 | | | | |
| Midcourse Navigation Game | 808 | | | | |
| Latitude-Longitude Subroutines | 279 | | | | |
| Midcourse Initialization | 159 | | | | |
| Orbital Integration | 170 | | | | |
| Measurement Incorporation | 168 | | | | |
| B Vector Routine | 535 | | | | |
| Prelaunch Alignment Program | 900 | | | | |
| Inflight Alignment Program | 235 | | | | |
| RTB OP Codes | 348 | | | | |
| IMU Performance Tests 1 | 1009 | | | | |
| IMU Performance Tests 2 | 1017 | | | | |
| Inflight Alignment Subroutines | 410 | | | | |
| Keyrupt, Uprupt, Fresh Start | 98 | | | | |
| Pinball Game Buttons and Lights (DSKY) | 2259 | | | | |
| Mission Control Program | 2015 | | | | |
| Powered Flight Subroutines | 1867 | | | | |
| Dummy Initialization | 32 | | | | |
| Re-Entry Control | 1349 | | | | |
| Average G Integrator | 153 | | | | |
| Verification Assistance Programs | 99 | | | | |
| Sum Check End of Record Marks | 24 | | | | |
| TOTAL FIXED MEMORY WORDS | 21,965 | | | | |

FIXED MEMORY ALLOCATION - FOR BLOCK II CM COMPUTER - FOR BLOCK II LEM COMPUTER

| COMPUTER PROGRAMS AND ROUTINES | SUNDIAL FLIGHT AS-278 | SUNDIAL FLIGHT AS-503 | SUNDIAL FLIGHT AS-504 | AURORA FLIGHT AS-206 | AURORA FLIGHT AS-278 | AURORA FLIGHT AS-503 | AURORA FLIGHT AS-504 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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