MIT Instrumentation Lab

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DG MEMO NO. 320

DESCRIPTION OF BLOCK I, SERIES 100

G & N DISPLAYS AND CONTROLS

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Section 1 INTRODUCTION

1-1 INTRODUCTION

The purpose of this document is to provide a description of the displays and controls (D & C) associated with the Apollo Guidance and Navigation (G & N) system in the Command Module.

The information contained herein is primarily concerned with the displays and controls associated with the Block I; Series 100 guidance and navigation systems. However, specific references have been made to AGE 12, the Block I, Series 50 system that will be utilized on the first manned flight. References to AGE 12 have been specifically labelled as such.

The illustrations and photographs in this document represent the latest configuration of the Series 100 systems. For purposes of clarification, the differences between the D & C on the Series 100 systems and those of AGE 12 have been illustrated and described.

1-2 DESCRIPTION

The purpose of the Apollo G & N system is to provide the astronautnavigator with the equipment necessary to navigate from the earth to the moon and return. A second function of the G & N system is to generate the steering signals necessary for course correction. To accomplish the above purposes the G & N system comprises the three major substems essential to astronautical navigation: 1) an inertial subsystem (ISS) to provide measurement of vehicle attitude and acceleration, 2) an optical subsystem for angle measurements to stars and landmarks, and 3) a computer subsystem (AGC) which serves as the central data processor. These subsystems and other supplementary equipment are integrated with the G & N displays and controls for system status monitoring and operation by the astronaut navigator.

The primary location of the G & N displays and controls is at the navigation station where they are arranged in functional groups about a navigation base which incorporates the optics and the IMU (see Figs. 1-1, 1-2 and 1-3). Attitude controls functionally related to the G & N system are also located at the navigation station for use by the navigator in the performance of the navigation tasks. A computer display and control panel and G & N system power controls requiring primary control by the pilot are located on the main display console (MDC). (See Fig. 1-4).

The subsystems and their associated displays and controls are described in functional groups in the following order:

1. Inertial Subsystem

2. Optical Subsystem

3. Apollo Guidance Computer

4. G&N System Power Controls

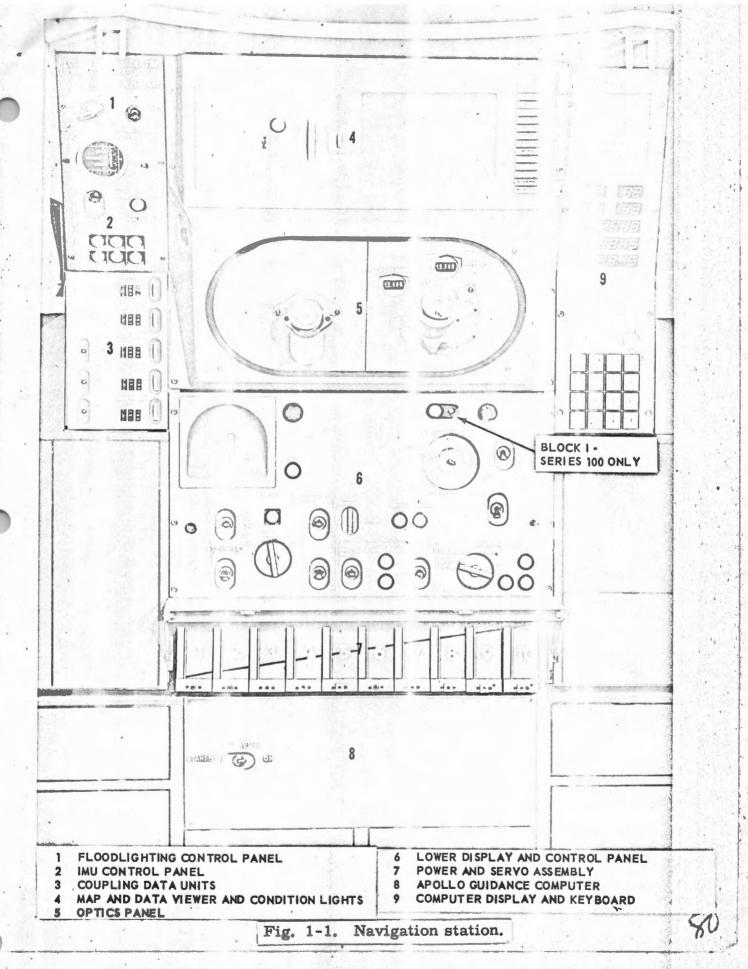
5. G & N Condition Lights

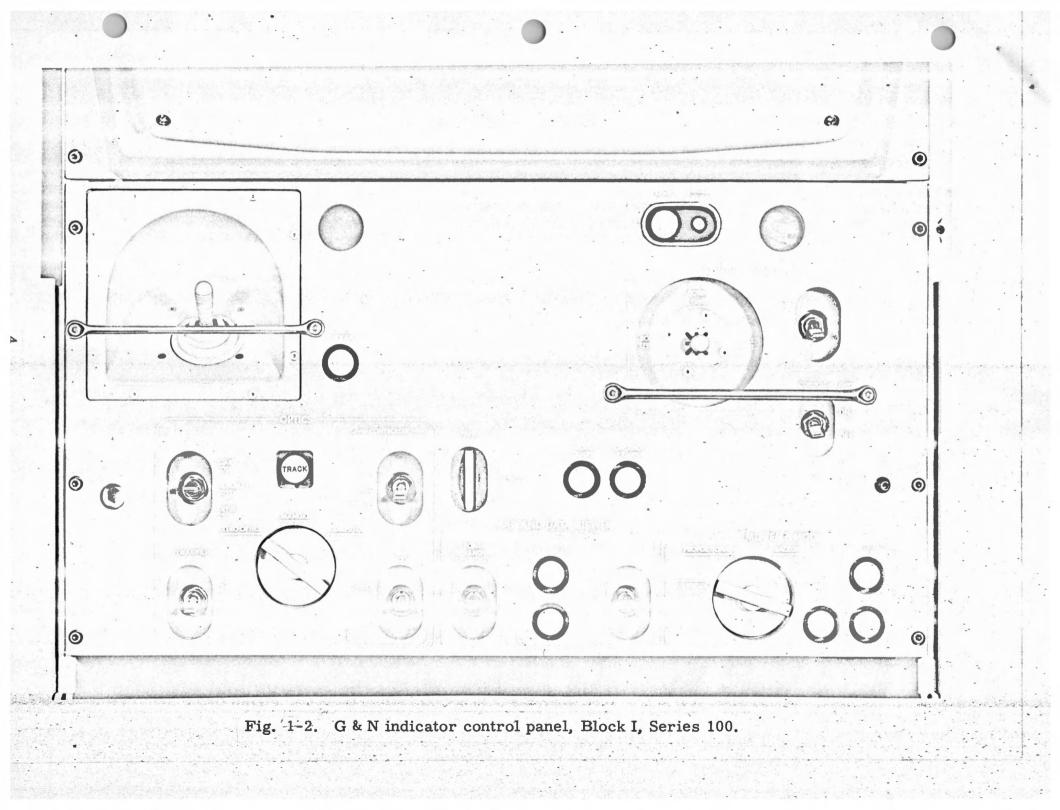
6. Illumination Controls

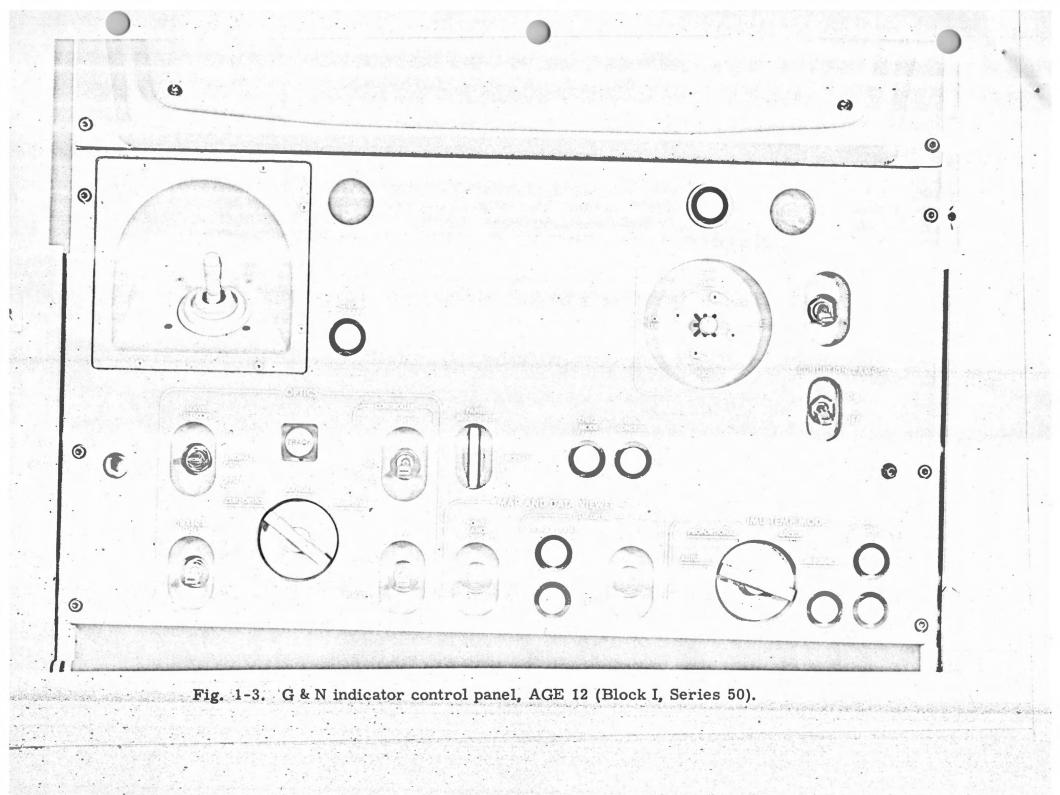
7. Clocks

8. Power and Servo Assembly

9. Attitude Controls







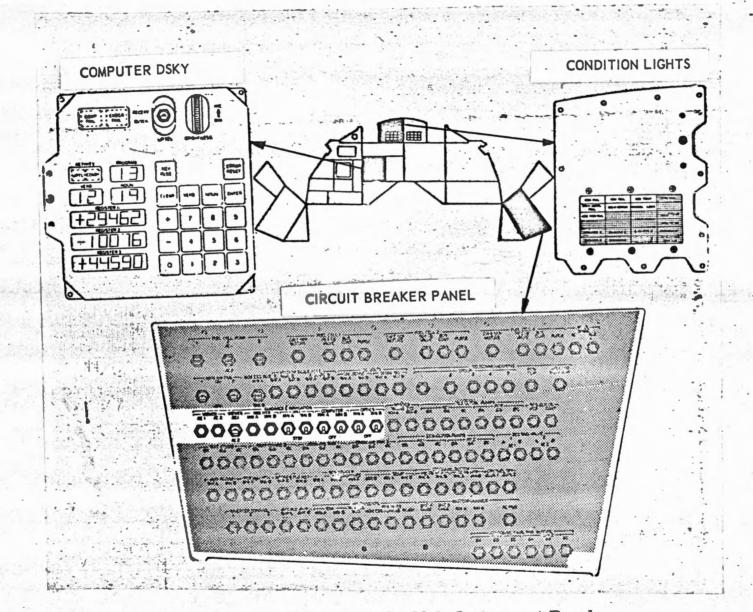


Fig. 1-4. G & N D & C at the Main Instrument Panel.

Section 2 INERTIAL SUBSYSTEM

2-1 INERTIAL SUBSYSTEM

During thrusting phases the inertial subsystem provides attitude references, processes steering commands from the computer to the autopilot, and provides the velocity increment signals which are counted by the computer and used for thrust termination. During nonthrusting phases the inertial subsystem is used to hold or control changes in spacecraft attitude at the direction of the navigator or the computer. Use of the inertial subsystem during nonthrusting phases is optional within the limitations of available electrical energy.

The major components of the inertial subsystem are (1) the inertial measurement unit, (2) three coupling data units, (3) an IMU control panel (4) part of the G&N indicator control panel and part of the power and servo assembly. A description of these components follows.

2-1.1 INERTIAL MEASUREMENT UNIT. The inertial measurement unit is the primary inertial sensing device of the G & N system. The IMU consists of a three-degree-of-freedom gimbal system containing three pulsed integrating pendulum accelerometers (PIPA) and three inertial reference integrating gyroscopes (IRIG). The inertial components are mounted on the innermost gimbal, or stabilized member, which is held nonrotating with respect to inertial space by the action of error signals from the three gyroscopes. The outer axis of gimbal freedom is mounted parallel to the reentry control wind axis so that the high angular rates, during reentry roll control of lift, are "unwound" by the outer gimbal. This places the outer gimbal axis 33 degrees from the spacecraft symmetry axis. To avoid danger of gimbal lock, the inner gimbal axis is positioned normal to the plane of any planned trajectory or attitude turning maneuver.

The IMU produces two major outputs: 1) vehicle orientation signals from the gimbal angle transducers (or resolvers) mounted on each gimbal axis, and 2) velocity increments from the accelerometers which measure the specific forces applied to the vehicle by aerodynamic forces and thrust. A functional and schematic diagram of the IMU is shown in Fig. 2-1.

2-1.2 IMU DISPLAYS AND CONTROLS. The controls for the IMU are located on the IMU control panel at the upper left of the navigators panel (see Fig. 2-2). The IMU control panel contains the IMU-CDU difference meter, the transfer switch, the manual align button and the six mode control buttons. The controls and their functions are described in the paragraphs that follow.

2-1.2.1 <u>IMU-CDU Difference Indicator</u>. The IMU-CDU DIFFERENCE indicator provides a 3-axis display of the angular difference between the IMU gimbal angles and the angles set on the coupling data units (para. 2-1.3). (See Fig. 2-3). The maximum angular difference displayed is ± 5 degrees.

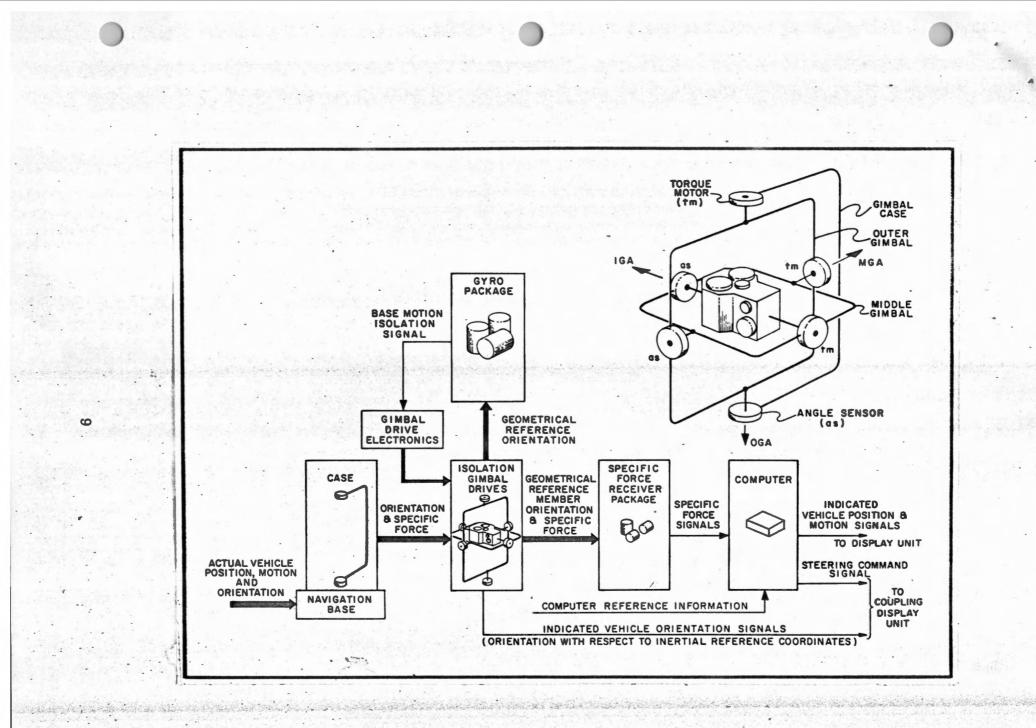
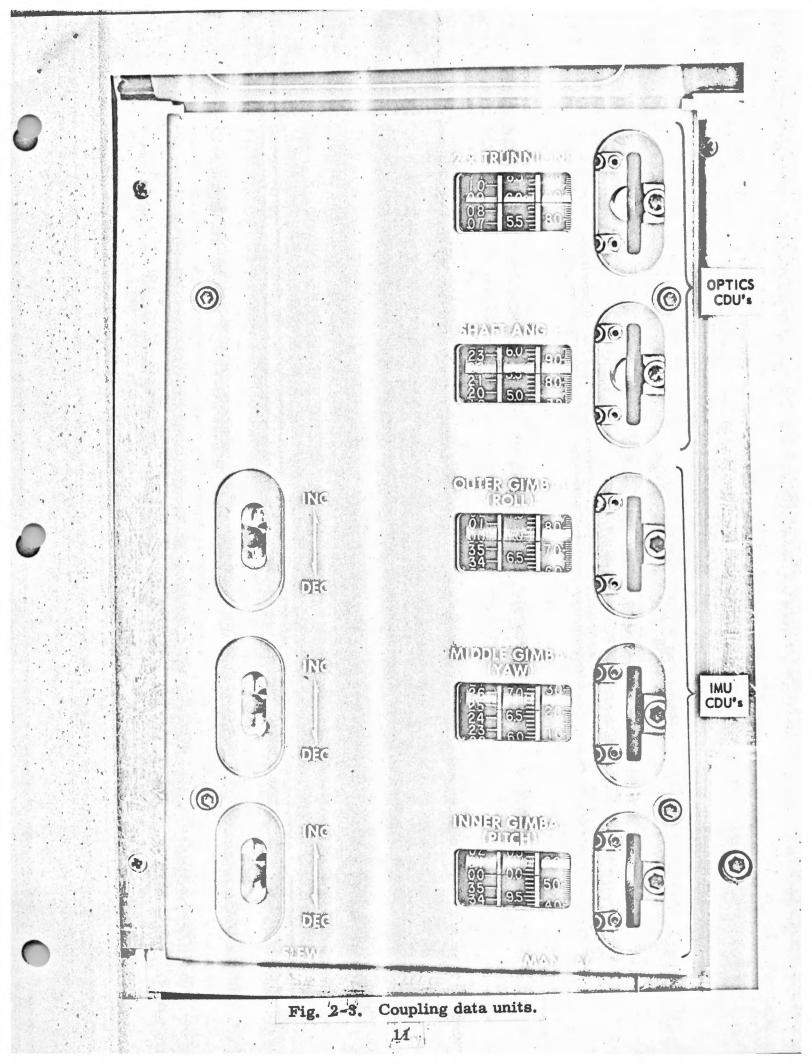


Fig. 2-1. IMU functional and schematic diagram.

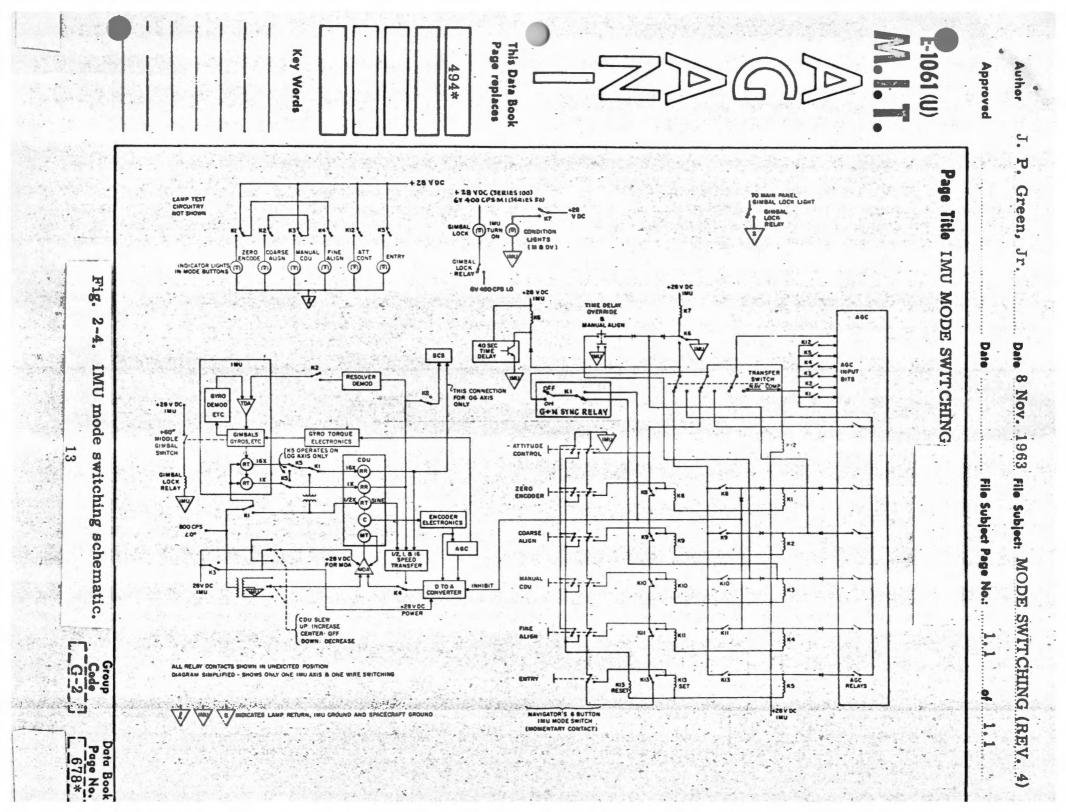




2-1.2.2 <u>Transfer Switch</u>. A two-position (COMPUTER-MANUAL) transfer switch is provided for selecting either manual or computer control of the six IMU modes. In the COMPUTER position, mode selection is accomplished by the AGC using programs. In the MANUAL position, the astronaut selects the operating mode by means of the IMU mode control buttons. 2-1.2.3 <u>Manual Align Button</u>. In the CDU manual mode (para. 2-1.2.4.6) holding in the MANUAL ALIGN button causes the IMU gimbals to be driven into alignment with the CDUs.

2-1.2.4 <u>IMU Mode Control Buttons.</u> The IMU MODE control buttons are momentary contact, internally lighted, pushbutton switches which provide manual selection of the six operational IMU modes. The mode buttons will function after: 1) TRANSFER switch is turned to MANUAL position, 2) IMU switch is turned to OPERATE and 3) the IMU gyros are at operating speed (a 40 second time delay is provided for this purpose after the IMU is turned from STANDBY to OPERATE). Actuation of a mode button will send a discrete signal to the computer to indicate the operating mode. In either MANUAL or COMPUTER operation, the appropriate button will illuminate to indicate the current operating mode. The functions of the mode buttons are as follows (see Fig. 2-4).

2-1.2.4.1 Zero Encoder Button. Acutating the ZERO ENCODER button activates a relay to place a reference voltage on the CDU resolvers which drives the CDU's (and their associated gimbal angle displays) to their electrical zero. Simultaneously, discrete signals are sent to the computer indicating zero encode and fine align. The computer clears the registers



after 30 seconds, thus zeroing the CDU angles stored in the computer. While the encoders are zeroing, the ZERO ENC light remains illuminated. 2-1.2.4.2 Coarse Align Button. The COARSE ALIGN mode is used to set the IMU gimbals to some desired orientation with respect to the navigation base. Normally the computer sets the CDU's to the desired gimbal angles by program instructions. Actuating the COARSE ALIGN button activates a relay which causes error signals, representing the difference between IMU gimbal angles and CDU angles, to drive the gimbals into alignment with the CDU's. The IMU-CDU difference meter will indicate when the gimbals are aligned.

2-1.2.4.3 Fine Align Button. Actuating the FINE ALIGN button causes the CDU's to follow and repeat the IMU gimbal angles. The incremental encoders attached to the CDU motor shafts transmit IMU gimbal angular changes to the computer. In this mode the navigator uses the optics to obtain two star sightings. A simultaneous reading of star direction angles by means of optics CDUs, and IMU gimbal angles, by means of IMU CDU's, is fed into the computer. The computer derives the necessary angular corrections which are then used to torque the IMU gyros until the required IMU orientation is obtained.

2-1.2.4.4 Attitude Control Button. Actuating the ATTITUDE CONTROL button causes the G&N system to provide signals for the SCS system for control of spacecraft orientation. In this mode the computer drives the CDU's to the desired angles with respect to the IMU, and error signals,

representing the difference between IMU gimbal angles and CDU angles, are sent to the SCS system. The error signals operate on the SCS system as steering signals to drive the spacecraft to the desired orientation. 2-1.2.4.5 Entry Button. The ENTRY button permits steering signals to be transmitted to the SCS system for control of spacecraft attitude during entry into the earth's atmosphere. In this mode, the gain of the roll control loop is increased by a factor of 16 to provide increased roll rate capability during entry.

2-1.2.4.6 CDU Manual Button. The CDU manual mode provides a backup capability for the manual alignment of the IMU without the use of the AGC. Actuating the CDU MANUAL button energizes a relay which removes the CDU motor amplifier excitation to lock the CDU's in position. The CDU angles may then be set to any desired value by using the slew switches, which restore the amplifier excitation, or by use of the thumbwheels. The gimbal angles can then be coarse aligned to the CDU angles by holding the MANUAL ALIGN button in until the IMU-CDU difference meter indicates zero $(\pm 1.5^{\circ})$.

2-1.3 IMU COUPLING DATA UNITS (CDU). There are five (5) CDU's three of which are associated with the IMU. The IMU CDUs, one for each gimbal angle of the IMU, are used to transfer angular information

between the IMU, the computer (AGC), the stabilization and control system (SCS) and the astronaut. Each CDU contains a gearbox, motor, resolvers, incremental digital encoders, a drum type angle display, slew switch and thumbwheel. The incremental digital encoders provide a pulse to the computer for each increment of angular change of the CDU.

CDU angles may be set either automatically by the AGC or manually by use of the slew switch and the thumbwheel. A single axis schematic of the IMU-CDU-AGC operation is shown in Fig. 2-5.

2-1.4 CDU CONTROLS. The controls associated with the IMU CDUs are described in the following paragraphs.

2-1.4.1 <u>Slew Switch</u>. The CDU slew switch provides excitation to the CDU motor servo amplifier and supplies in-phase or out-of-phase 800 cps voltage to the CDU servo amplifier to drive the CDU shaft to the desired angle.

2-1.4.2 <u>Thumbwheel</u>. The CDU thumbwheel provides a mechanical drive to the CDU shaft for fine positioning of the CDU shaft.

2-1.4.3 <u>CDU Angle Display</u>. The CDU angle display is a drum type display mechanically connected to the CDU shaft drive. It is calibrated in degrees and decimal parts of a degree on three drums. The first drum displays 360° per revolution in 10° increments; the second drum **displays** 10° per revolution in 0.1° increments; the third drum displays 0.2 degrees per revolution in 0.001 degree increments.

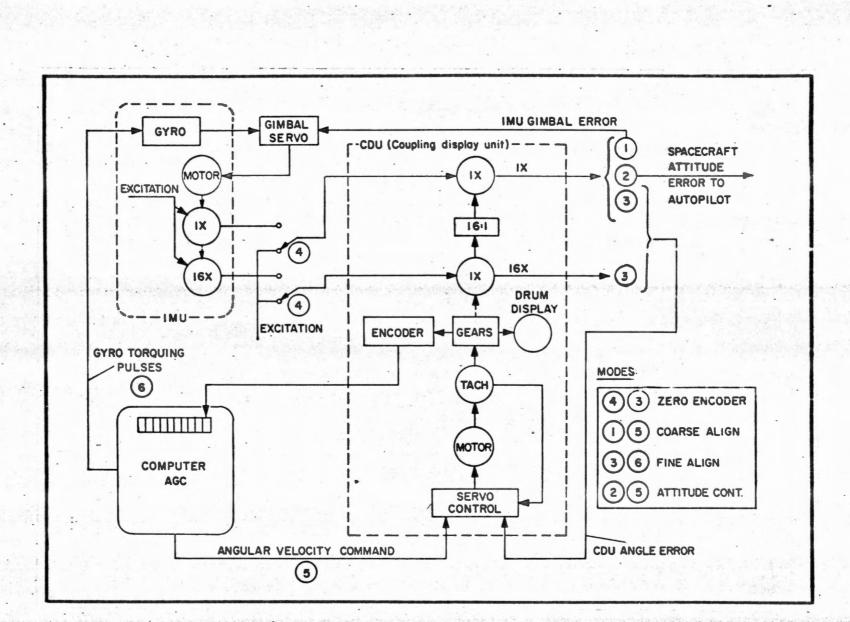


Fig. 2-5. IMU, CDU, AGC single axis schematic.

2-1.5 IMU TEMPERATURE CONTROL SYSTEM. The IRIG's and PIPA's within the IMU are maintained at their normal operating temperatures $(135^{\circ} \pm 1^{\circ}F$ and $130^{\circ} \pm 1^{\circ}F$ respectively) by the IMU temperature control system (see Fig. 2-6). Basically, this system comprises a temperature control circuit, a temperature indicating circuit and associated heaters and blowers. Normally, the temperature control circuit controls the temperature by means of heaters and blowers while the temperature indicating circuit monitors IMU temperature. The indicating circuit has the additional capability of controlling the heaters and blowers in the event of malfunction of the normal temperature control circuit.

The temperature control circuit includes the following elements:

- 1. Two control sensors mounted on each IRIG.
- 2. A temperature control bridge which incorporates all the series connected sensors in one leg of the bridge.
- 3. A temperature control amplifier.

The temperature indicating circuit includes:

- Two temperature sensors mounted in each IRIG and one in each PIPA.
- 2. PIPA and IRIG temperature indicating bridges.
- 3. PIPA and IRIG temperature indicating bridge amplifiers.
- 4. A temperature alarm and backup control amplifier.
- 5. Temperature alarm relays.
- 6. IMU TEMP warning light (in IMU condition light group).

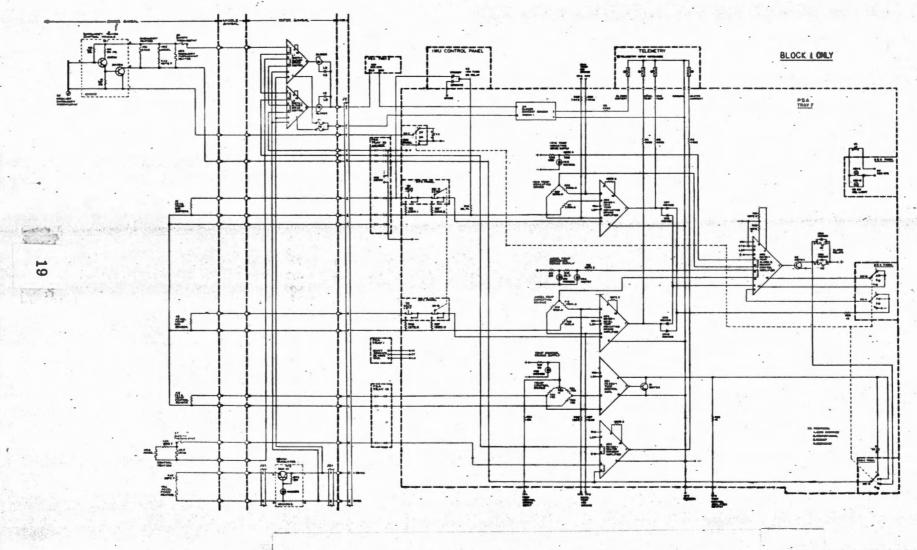


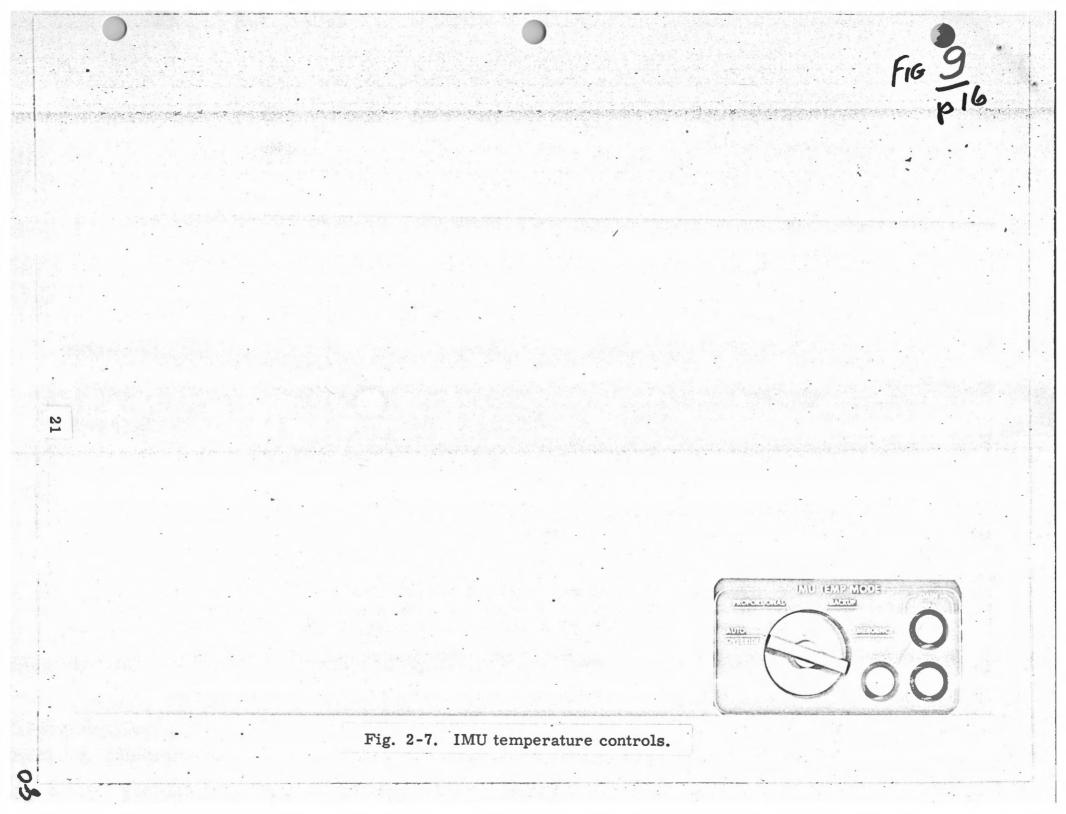
Fig. 2-6. IMU temperature control system schematic.

The system includes the following heaters and blowers:

- Two control heaters and two emergency heaters mounted on each IRIG.
- 2. An emergency heater, a control heater and a fixed heater mounted on each PIPA. The fixed heaters are on whenever the IMU power switch on the main instrument panel is in the OPERATE position.
- 3. Two cooling blowers mounted on the outer gimbal. Blower speed is inversely proportional to control heater and emergency heater current.
- 4. Safety thermostats in the emergency heater circuit and in the heater circuit. These thermostats are set to open at 156°F and close at 144°F.
- Two heaters mounted on the stable member which remain on when the ISS is in STANDBY.

2-1.6 TEMPERATURE CONTROL SYSTEM CONTROLS. To provide maximum reliability, temperature control can be accomplished in four different modes using combinations of the above circuitry. The controls and indicators provided in the temperature control system are: a 4position rotary mode selector, a ZERO button, an IRIG GAIN button, a PI PA GAIN button, and an IMU TEMPERATURE condition light. See Fig. 2-7.

2-1.6.1 Temperature Control Mode Selector. The IMU TEMP MODE selector is a 4-position rotary switch. The four positions and their functions are as follows: (see Fig. 2-8).



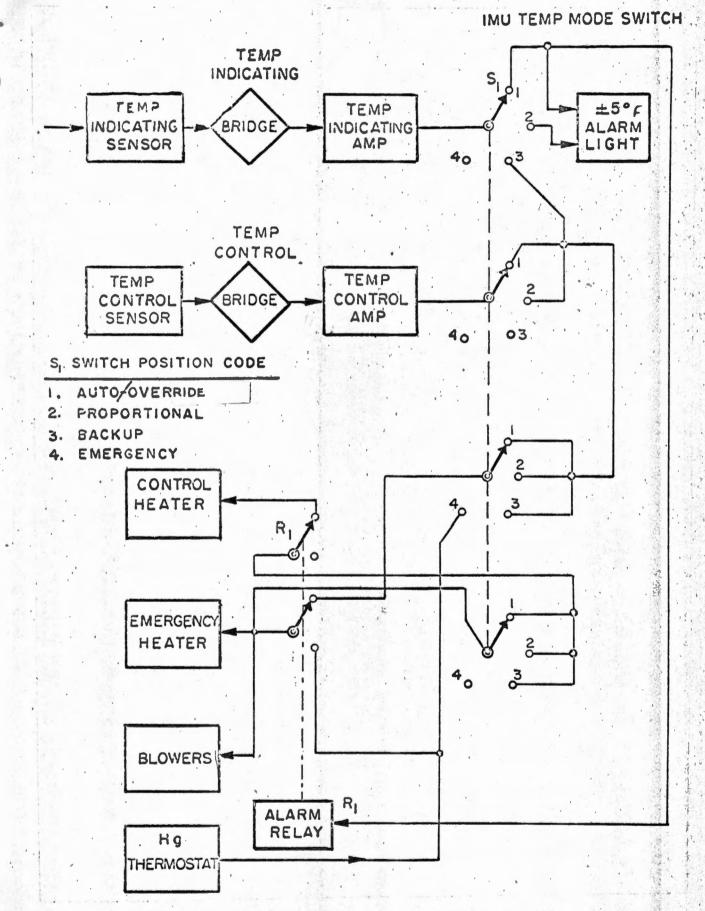


Fig. 2-8. IMU temperature control functional diagram.

2-1.6.1.1 Auto/Override. The AUTO/OVERRIDE switch position is the normal operating position. In this mode, both the temperature control circuit and temperature indicating circuit are utilized. Temperature control is furnished by the temperature control amplifier using the IRIG temperature control sensors.

Normally, heating is accomplished by the control heaters and emergency heaters operating in parallel. If the IMU exceeds normal temperature tolerances (\pm 5°F), the system will automatically switch to the emergency mode and the IMU TEMP light will illuminate. When this occurs, the temperature alarm relays turn off the control heaters. The emergency heaters continue to operate under the control of an emergency mercury thermostat. When the temperature returns to within \pm 1°F of normal, the IMU TEMP temperature light will be extinguished and the system will switch back to the normal control mode. The system will continue to cycle between auto override and emergency modes with an attendent cycling of the IMU TEMP light as long as the malfunction exists and the selector switch remains in the AUTO/OVERRIDE position. In this event, the navigator should select another mode. The mode selected will depend on whether the malfunction exists in the control circuit or indicating circuit as determined by ground telemetry.

2-1.6.1.2 Proportional. The PROPORTIONAL mode is used if a malfunction occurs in the temperature indicating circuit causing cycling to

the EMERGENCY mode. In the proportional mode, temperature control is furnished by the same heater control circuitry used in the auto/override mode. The temperature indicating circuitry is not used. Abnormal temperature will cause the IMU TEMP light to illuminate, but will not switch the system to the emergency mode.

2-1.6.1.3 Backup. The BACKUP mode is used if a malfunction occurs in the normal control circuit. Temperature control is then furnished by the temperature indicating circuits. In this mode, the IMU TEMP light will illuminate when the heaters are off and will extinguish when the heaters are on. The navigator must monitor the IMU temperature and manually switch to the emergency mode if the temperature becomes excessive.

2-1.6.1.4 Emergency. In the EMERGENCY switch position, IRIG temperature is controlled to approximately $135^{\circ} \pm 3^{\circ}F$ by means of an emergency mercury thermostat and the emergency heaters. A safety thermostat provides overheat protection for the IMU by opening the emergency heater circuit when the stable member temperature exceeds 156°F. When this temperature drops below 144°F the thermostat closes the circuit to reactivate the heaters.

2-1.6.2 <u>Zero Button</u>. The ZERO pushbutton is a momentary contact pushbutton used for checking the calibration of the temperature monitoring devices. Depressing this button replaces the IRIG and PIPA temperature indicating sensors in the bridge with standard resistances equal to the resistance of the indicating sensors at their normal operating temperature, thus providing a calibration point for the condition of normal temperature. When the ZERO button is pressed, the IMU TEMP light should not illuminate.

2-1.6.3 <u>IRIG Gain Button</u>. The IRIG GAIN pushbutton is similar in function to the ZERO button. Depressing the IRIG button replaces the IRIG temperature indicating sensor in the bridge with a standard resistance equal to the resistance of the temperature indicating sensor when it is operating at 5°F below normal. Depressing the IRIG button also tests the temperature alarm circuit and will light the IMU TEMP light.

2-1.6.4 <u>PIPA Gain Button</u>. The PIPA GAIN pushbutton performs the same function as the IRIG GAIN button with the exception that the resist-ance used is equivalent to PIPA indicating sensors operating at 5°F above normal.

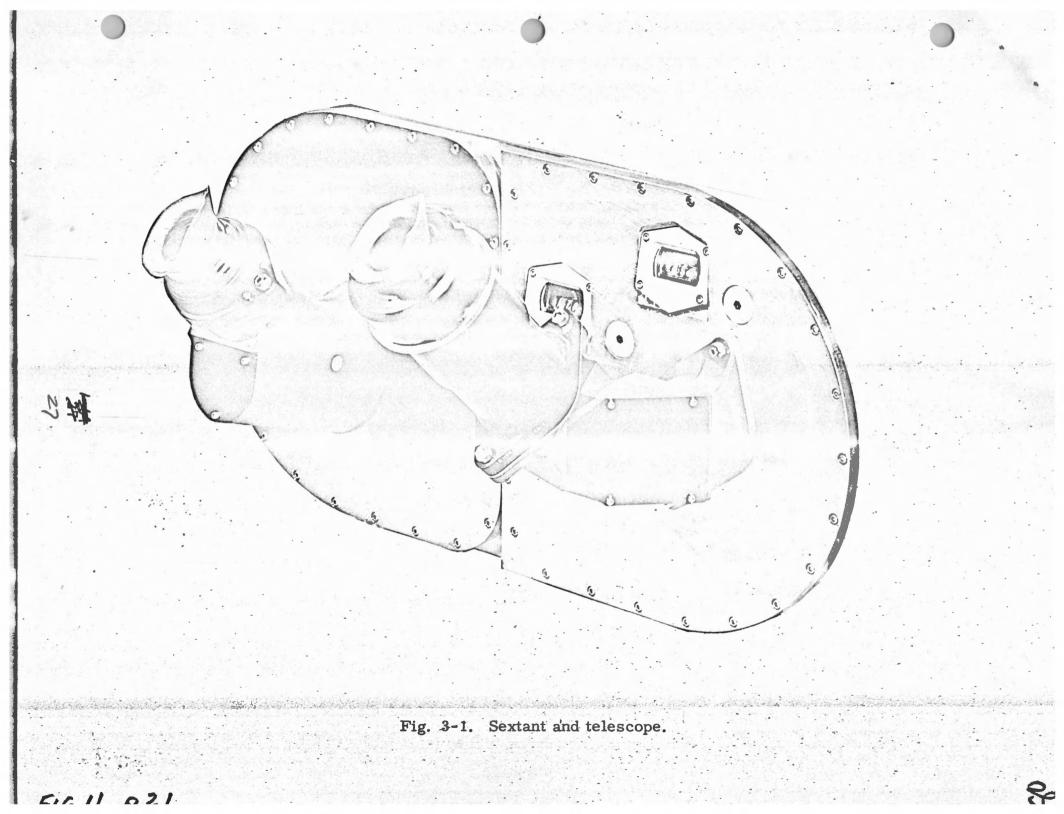
Section 3 OPTICAL SUBSYSTEM

3-1 OPTICAL SUBSYSTEM

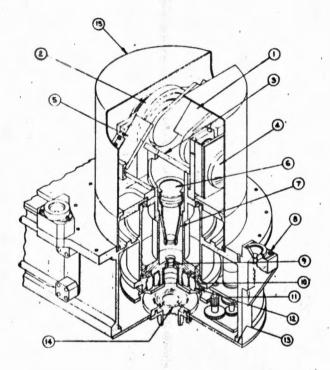
The optical subsystem comprises two optical instruments: a scanning telescope which is used for general viewing and orbital measurements and a sextant which is used for mid-course navigation measurements and IMU alignment. See Fig. 3-1. The optical instruments and the IMU are mounted on a common navigation base so that angle data measured by them can be referenced to one rigid structure. Figure 3-2 shows a cutaway view of the two sighting instruments.

Normally, the navigator will not be helmeted while using the optics. In this condition, he places his eye directly against the eyepieces when sighting. Under pressurized conditions he must wear his helmet with the faceplate closed, necessitating a large gap between his eye and the optics. Two long eye relief eyepieces have been provided which the navigator may substitute for the normal eyepieces. These enable him to sight through the optics while helmeted. However, this advantage is gained at a sacrifice in magnification. When the long eye relief eyepieces are installed, optics magnification is approximately halved.

Two of the five CDU's are associated with the optics. The two optics CDU's, one for the sextant trunnion axis and one for the sextant shaft axis, are used to transfer angle information between the sextant and the other major G&N subsystems. See Fig. 2-3.



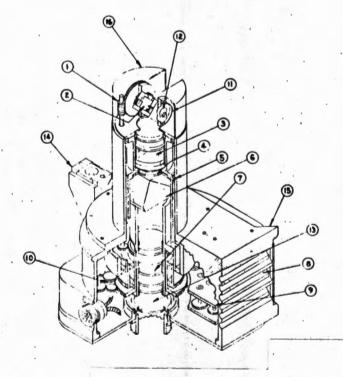
SEXTANT CUTAWAY



DESCRIPTION

1- ROTATING MIRROR 2- TRUNNION ARIS RESOLVER 2- TRUMNON ARIS HESOLVEN 3- BEAM-SPLITTER 4- TRUNNION DRIVE GEAR SOR 5- FIXED MARRORS 6- OBJECTIVE LEMBES 7- INTERMEDIATE LEMBES 8- MOUNTING PAD 8- MOUNTING PAD 9- RETICLE Marticle LAMP 11- Shaft Drive Gear Bor 12- Shaft Aris Resolver 13- Panel M- Evergee Socket (Seal 5- Cover

TELESCOPE CUTAWAY



- I TRUNNION DRIVE WORMSHAFT 2- PRISMAND MOUNT ASSEMBLY 9- OBJECTIVE LENS ASSEMBLY
- 4-RETICLE B-RETICLE RLUMINATION 6-PECHAN PRISM 7-RELAY LENS ASSEMBLY 6-HEAT EXCHANGER

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- 8-MEAT EXCHANGER 9-SHAFT DRIVE GEAR BOX 10-TRIANION DRIVE GEAR BOX 11-SPRING AND CAM FOLLOWER ASSEMBLY (ANTIBACKLASM) 12-CAM 13-WINDOW 4-MOUNTRIG PAD 16-OPTICAL BASE 16-OPTICAL BASE 16-OPTICAL BASE

2

81.1.4

At the navigator's discretion a protective cover is fastened to the optics shroud to protect the alignment between the optics assembly and the navigation base.

3-1.1 SCANNING TELESCOPE. The scanning telescope is a single-line. of-sight, low power, 60° field of view instrument used for making navigation measurements in earth or lunar orbit, or for general use such as acquisition of landmarks and stars for sextant sightings. The telescope has two degrees of mechanical freedom to deflect the line-of-sight with respect to the navigation base: 1) a shaft axis, normal to the local conical surface of the spacecraft, permitting unlimited rotation of the optics assembly, and 2) a trunnion axis perpendicular to the shaft axis permitting unlimited rotation of the line of sight away from the shaft axis. Due to interference between the line of sight and the optics well, the useful rotation about the trunnion axis is limited to less than 70°. The telescope shaft axis is electrically coupled to the sextant shaft axis. Figure 3-3 shows the relation of the optics axes system to the spacecraft axes system. The telescope line of sight may be directed as follows: 1) fixed along the shaft axis, 2) fixed at 25° trunnion angle with shaft axis slaved to the sextant, or 3) slaved to the sextant star line of sight, in which case it is controlled by the hand controller, the AGC, or the tracker.

A back-up mechanical control for each axis is provided by means of a gearbox which is driven by the universal tool.

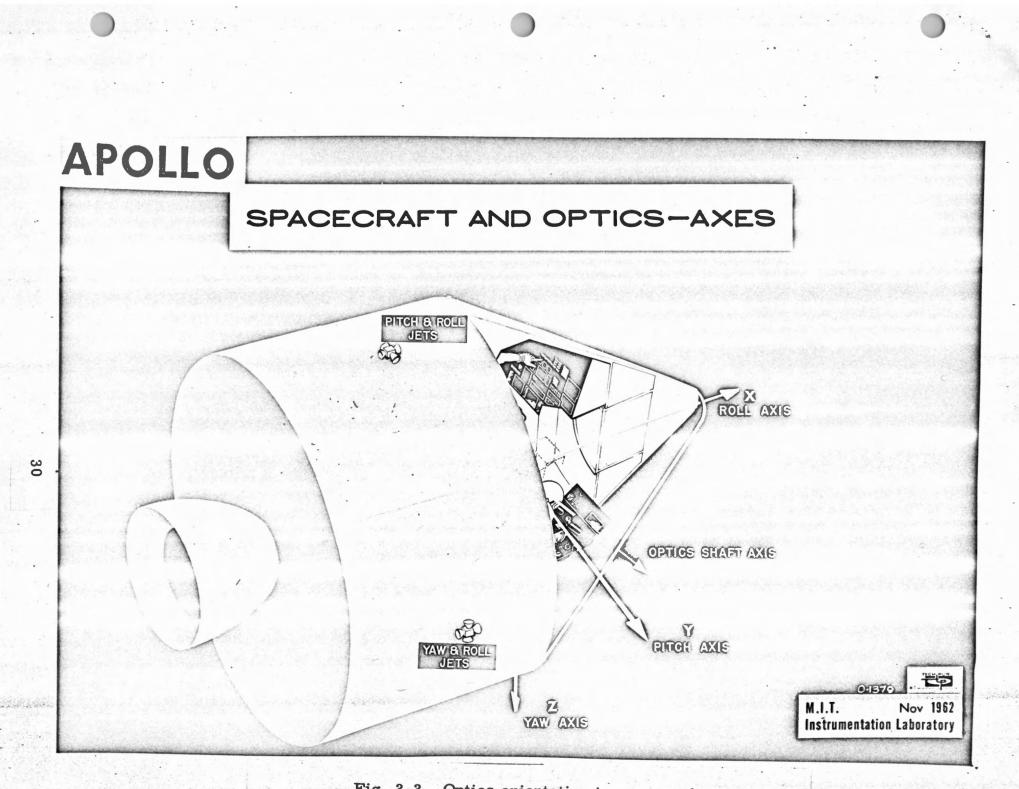


Fig. 3-3. Optics orientation in spacecraft

Telescope line-of-sight angles with respect to the navigation base are read on mechanical counters through viewing windows on the telescope base. The telescope shaft angle is normally repeated on the sextant shaft axis CDU. When the telescope is slaved to the sextant star line of sight the telescope trunnion angle may also be read on the sextant trunnion axis CDU.

3-1.2 SEXTANT. The sextant is a precision, two-line-of-sight, highpower instrument used to make star-to-planet angle measurements for navigation purposes and to make star direction measurements for orienting the IMU and the spacecraft in inertial space.

This instrument is a 28 power, 1.8 degree field of view telescope containing a beamsplitter, redirection mirror elements, and an articulating mirror all outboard of the objective element of the telescope. The beamsplitter divides the entering light to the telescope and directs approximately 20 percent along the focal axis of the instrument and 80 percent of the light is reflected by the articulating mirror. These two light paths constitute the landmark and star lines of sight respectively. Measurement of the angle the reflecting mirror element makes with respect to the head of the instrument and navigation base when the star is coincident with the landmark in the field of view constitutes the navigational sighting desired.

The sextant, like the telescope, has two degrees of mechanical freedom to deflect the line of sight with respect to the navigation base: 1) a shaft axis which permits $\pm 270^{\circ}$ rotation of the optics assembly and 2) a trunnion axis perpendicular to the shaft axis which permits rotation of the

line of sight from -10° to +90° of useful rotation. However, actual navigational sightings are limited to 58° between landmark and star as vignetting of the star line of sight occurs beyond this angle.

The sextant star line of sight may be controlled by the AGC or manually controlled by use of the optics hand controller. Star line of sight angles with respect to the navigation base can be read on the sextant CDU's. The sextant shaft angle CDU is read directly; the sextant trunnion angle CDU displays twice the actual trunnion angle (para. 3-1.3). The sextant shaft angle is also displayed on the telescope mechanical counter since the shaft axes are electrically coupled. The star line of sight trunnion angle is also displayed on the telescope counter if the telescope is slaved to the star line of sight. In normal operation the CDU should be read in lieu of the mechanical counter due to greater accuracy of the CDU.

A horizon photometer and star tracker are mounted on the sextant head for use in automatic tracking of a star and for determining the true horizon in navigation measurements. AGE 12 does not incorporate a photometer-tracker.

3-1.2.1 <u>Photometer-Tracker</u>. The horizon photometer and star tracker enable the navigator to measure the angle subtended between a target star and a point of relative illumination on the earth's horizon. This capability is necessary to supplement star-landmark sightings or to substitute for star-landmark sightings when landmarks are not available or are obscured.

The photometer and tracker are mounted on the sextant head and operate in conjunction with the appropriate computer program. Both the tracker and photometer rotate with the sextant shaft.

The photometer is a fixed-line-of-sight, light-sensing instrument which detects and measures the variable light intensity of the earth's horizon. The photometer line of sight is fixed in trunnion at -5.625°.

The star tracker is a narrow-field-of-view $(1/2^{\circ} \times 1/2^{\circ})$ instrument which detects and tracks a preselected star. Tracking is initiated by centering the target star in the telescope and pressing the TRACK button. The star tracker line of sight uses the sextant mirror for trunnion motion.

As the star is tracked, the navigator pitches the craft so that the sextant, and thus the photometer, scans through the earth's horizon in a plane normal to the horizon. This plane should be along an imaginary radius line from the center of the earth to the target star. The amount of light entering the sextant is sensed by the photometer and, at a predetermined illumination level, an automatic mark signal is sent to the computer. The computer then records the angle between the target and the horizon level sensed by the photometer.

3-1.2.2 <u>Track Button</u>. When the photometer/tracker is used and a star has been acquired and centered in the telescope, pressing the TRACK button initiates tracking of the star by the sextant.

3-1.3 OPTICS COUPLING DATA UNITS. The optics coupling data units couple information from the sextant to the computer and the astronaut. When the sextant is driven by the hand controller through the integrator loops, the CDU's follow and repeat the sextant shaft and trunnion positions. A drum-type display (para. 2-1.4.3) provides a visual presentation of shaft and trunnion angles to the astronaut. The incremental encoders within the CDU's send incremental angular changes to the AGC. To achieve the

proper encoder granularity, the trunnion CDU encoder shaft is driven at 1/4 the speed of the sextant shaft. Due to mirror gain this factor is doubled to 1/2. As a result, the trunnion angle displayed is twice the actual trunnion angle. Any readings from the $2\times$ trunnion CDU must be halved to obtain the actual trunnion angle.

3-1.4 OPTICS COUPLING DATA UNITS (AGE 12). In AGE 12 the optics CDU's provide control and display of the sextant shaft and trunnion angles. Normally, in the manual mode, the CDU's are controlled by the optics hand controller. Thumbwheels adjacent to the CDU displays provide backup control over the sextant, if required.

Since the CDU's were originally designed for use with the IMU, it was necessary to adapt them for use with the optics in such a manner that interchangeability would not be affected. The necessity for the 2× trunnion angle display is a result of the mechanics of CDU gearing of the optics drives as described below.

Displacing the optics hand controller in trunnion activates the 2× trunnion CDU drive motor. The drive motor in turn simultaneously drives the display drums and a position command resolver. The position command resolver is driven through a 4:1 gear pass which positions the resolver shaft to an angle of 1/4 that displayed on the CDU. The sextant mirror is electrically slaved to the command resolver shaft and is driven to the same angle as the resolver shaft. Since the sextant line of sight is reflected from the mirror at an angle of twice the mirror angle, the 4:1 ratio between the CDU display and the mirror angle is halved. Thus the CDU displays two times the actual trunnion angle.

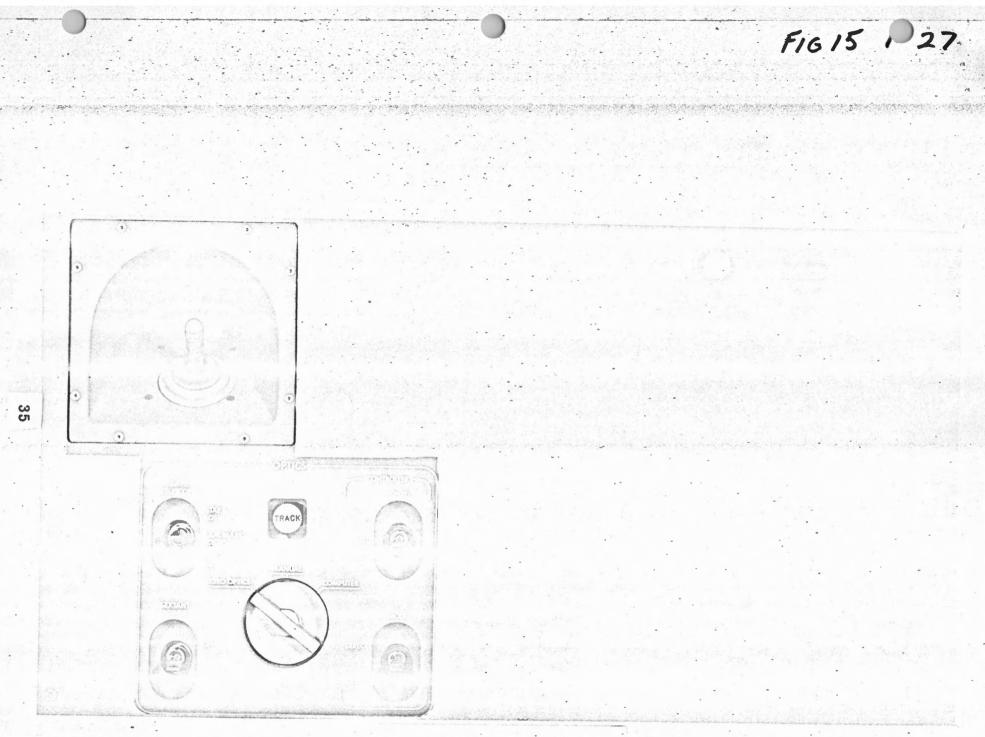


Fig. 3-4. Optics controls.

3-1.5 OPTICS CONTROLS. All the optics controls with the exception of the optics power switch and the focus and attenuation controls are located on the G&N indicator control panel at the navigation station. (See Fig. 3-4). A brief description of each control and its function follows.

3-1.5.1 Optics Power Switch. Two optics power switches are located on the main instrument panel right-hand circuit breaker panel. (See Fig. 1-4). The switches are labelled A and B. Each switch controls power from a separate 28 VDC bus. Placing either or both switches in the ON position provides the power to operate the optics.

3-1.5.2 Focus Control. Focus control is provided for the sectant only. Focusing of the reticle is accomplished by rotating the knurled portion of the sextant eyepiece until the desired focus is obtained.

3-1.5.3 <u>Attenuation Control.</u> Variable attenuation of the landmark line of sight is accomplished by means of a polarizer which may be installed at the discretion of the navigator. The polarizer is inserted in a slot provided in the sextant eyepiece and is rotated to obtain the light balance desired. When not in use, the polarizer is stored in a slot provided on the side of the eyepiece housing.

3-1.5.4 Optics Door Control. The optics door cover, which protects the optics on the outside of the command module, is operated manually with the universal tool. The engagement socket is located to the left of the optics control panel.

3-1.5.5 Optics Hand Controller. The optics hand controller is a twodegree-of-freedom control stick which is used to control the sextant shaft and trunnion angles. The angular rate of travel of the line-of-sight is proportional to the stick displacement. Refer to Para. 3-1.5.10 for a description of the controls associated with the optics hand controller 3-1.5.6 Optics Mode Control Selector. The optics mode control selector is a three position rotary switch which provides the following modes of operations:

3-1.5.6.1 Zero Optics. In the ZERO OPTICS mode, fixed reference excitation is applied to the sextant resolvers. The servo loop drives the sextant to zero and the CDU's follow. A discrete is supplied to the AGC to clear the registers.

3-1.5.6.2 Zero Optics (AGE 12). In the ZERO OPTICS mode, excitation is applied to the CDU resolvers to close the CDU resolver feedback loop and drive the CDU resolvers and optics to zero. The optics follow to a mechanical zero within the accuracy of the coarse resolver loop. A discrete is supplied to the AGC to clear the registers.

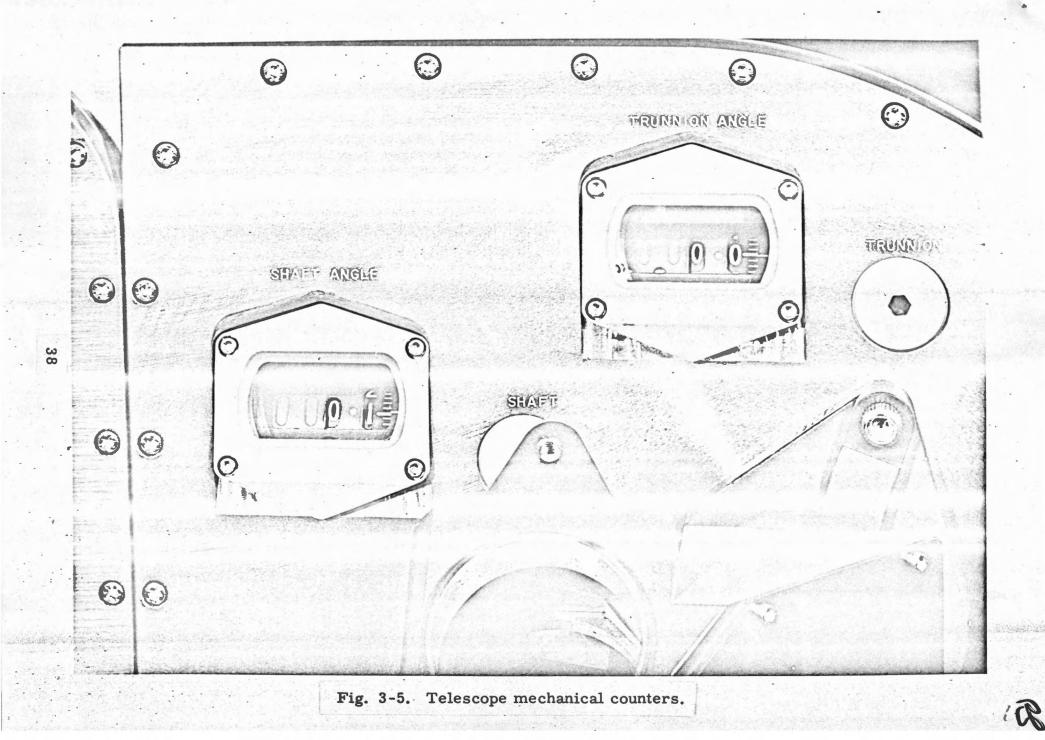
3-1.5.6.3 Manual. The MANUAL mode is the normal operating position in which the sextant and telescope are controlled by the optics hand controller. 3-1.5.6.4 Computer. In the COMPUTER mode the sextant and telescope are positioned by signals from the AGC.

3-1.5.7 <u>Telescope Manual Drive.</u> If necessary, the telescope can be manually driven by means of the universal tool and two drive sockets. The sockets are located adjacent to the telescope mechanical counters and are labelled SHAFT and TRUNNION. See Fig. 3-5.

Before mechanically operating the telescope, the optics power switch on the main instrument panel must be turned off and telescope eyepieces removed.

3-1.5.8 <u>Telescope Mechanical Counters</u>. Two mechanical counters on the base of the telescope (see Fig. 3-5) display the telescope shaft and trunnion angles with respect to the navigation base. Normally, the SHAFT ANGLE

Fig 16 p 31



displayed is the same as that displayed on the sextant shaft angle CDU due to the electrical coupling of the telescope and sextant shaft axes.

The TRUNNION ANGLE displayed is the telescope trunnion angle only, except when the telescope is slaved to the sextant star line of sight. In this condition, the telescope and sextant trunnion angles are identical. However, the telescope trunnion angle displayed is the actual trunnion angle and will therefore read one-half of the angle displayed on the sextant 2X TRUNNION CDU.

The mechanical counters are drum-type indicators which present a digital display in four windows. The first three windows indicate degrees of arc; the fourth window indicates tenths of a degree in 0.02 degree increments.

3-1.5.9 <u>Slave Telescope Switch.</u> The SLAVE TELESCOPE switch is a three-position toggle switch which affects the telescope trunnion angle control. It provides the following functions:

3-1.5.9.1 Landmark LOS 0°. In the LANDMARK LOS 0° switch position the telescope trunnion is positioned at zero and the line of sight is along the shaft axis. A landmark is acquired by sighting through the telescope while controlling spacecraft attitude with the rotational hand controller. When the landmark has been positioned in the center of the telescope field of view. the switch should be placed in the STAR LOS position.

3-5.9.2 Offset 25°. If, in the STAR LOS position, the target star is not in the telescope field of view, the OFFSET 25° position should be selected. In this position the telescope trunnion drive is offset 25 degrees from the shaft axis. A 360° rotation of the shaft axis will then permit acquisition of all targets within a 110° cone. In this

mode the landmark is held in the 1.8° reticle circle by the 1/2° deadband control of the SCS or by the navigator using the impulse controller. The shaft axis is rotated until the target star appears on the reticle line. The STAR LOS position is then selected.

3-1.5.9.3 Star LOS. In this position, the telescope trunnion axis is slaved to the sextant star line of sight. In this mode, the navigator sights through the telescope and uses the optics hand controller to center the star in the field of view. He then sights through the sextant and uses the optics hand controller to superimpose the star on the landmark or position both images parallel to an M (reticle) line.

3-1.5.10 <u>Hand Controller Switches</u>. The following optics control switches are associated with the optics hand controller.

3-1.5.10.1 Optics Speed Switch. The optics SPEED switch is a three position toggle switch which selects three different ranges of speed control (LOW, MED, HI) for the optics hand controller. The maximum control rate for each speed is 0.1, 1.0, and 8.6 deg/sec respectively. In the resolved mode, shaft speeds up to 17.2 deg/sec are obtainable.

3-1. 5. 10. 2 Mode Switch. The MODE switch is a two-position (DIRECT-RESOLVED) toggle switch. In the DIRECT mode the shaft and trunnion axis servos are commanded directly by the control stick motion. Rightleft stick motion commands clockwise-counterclockwise shaft rotation respectively and fore-aft stick motion commands increase-decrease of trunnion angle respectively. In the RESOLVED mode the rate inputs to the command servos are resolved such that right-left fore-aft stick motion results in left-right down up motion of the reticle.

Impulse Controller + Rotational Controller: Rt stick -> Left reticle (for + trunnion) Fore, stick -> Down reticle Rt. twist -> Right reticle 3-1. 5. 11 <u>Tracker Power Switch</u>. The TRACKER POWER switch is an ON-OFF toggle switch which controls 28 VDC power to the photometer-tracker electronics.

3-1. 5. 12 Optics Hold Switch (Age 12). The OPTICS HOLD switch is an ON-OFF toggle switch. In the ON position this switch removes power from the CDU drive motors to prevent the optics from creeping.

3-1.5.13 <u>Mark Button</u>. The MARK button is a momentary contact pushbutton switch which supplies an interrupt signal to the AGC to note optics angles, time of measurement, and, if the IMU is operating, the IMU gimbal angles. It is actuated, for example when star-landmark superimposition is achieved.

On AGE 12, the operator must indicate the completion of a successful mark by entering Verb 52 (Mark Accept) into the computer. He may make several MARK's to achieve a successful one before he enters mark accept. It is not necessary to depress the ENTER button after entering Verb 52.

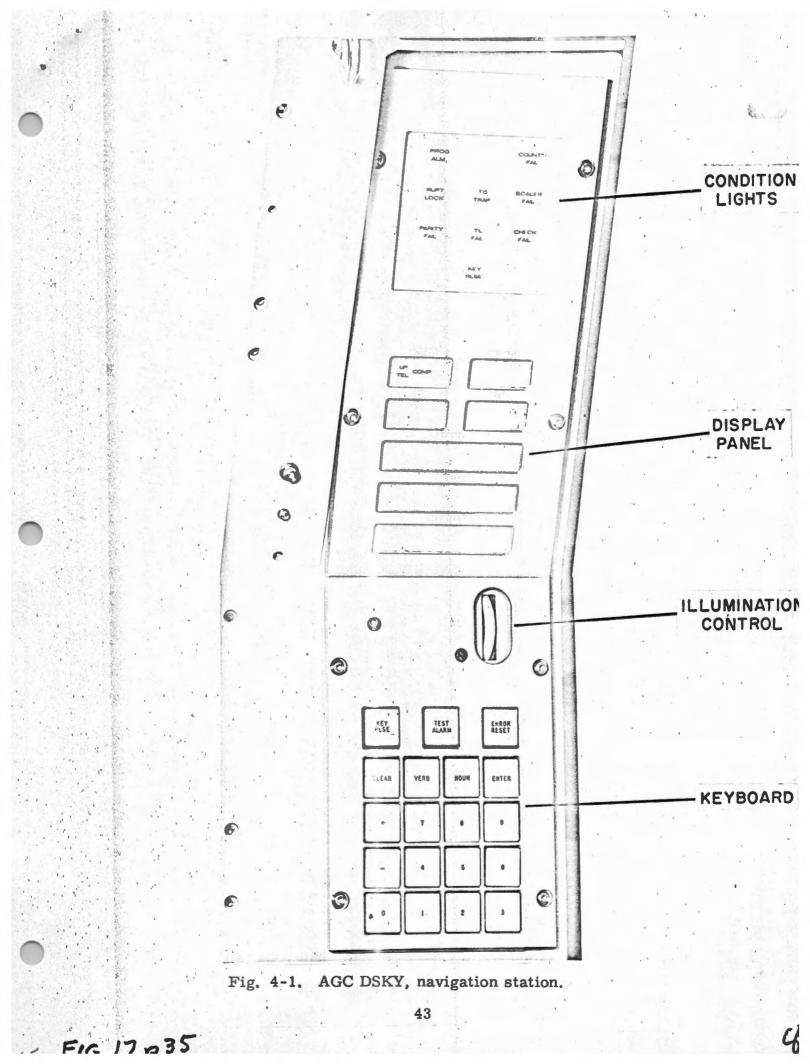
3-1.5.14 <u>Mark Reject Button</u>. The MARK REJECT button allows the navigator to reject an unsatisfactory mark. When a mark is rejected, it is not entered into the computer. The MARK REJECT button is located adjacent to the MARK button on the indicator control panel. There is no mark reject button on the AGE 12 system.

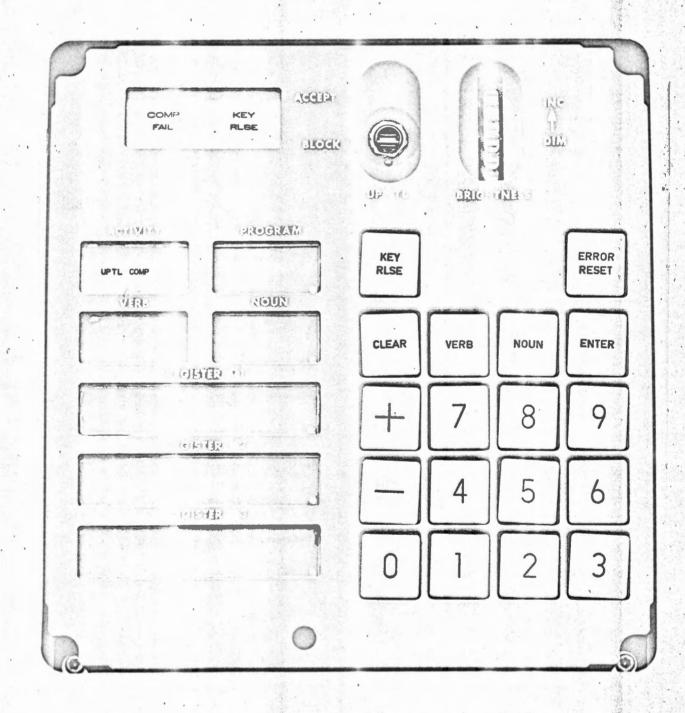
Section 4 COMPUTER SUBSYSTEM

4-1 APOLLO GUIDANCE COMPUTER (AGC)

The Apollo guidance computer is the central data processing system. The AGC is a core memory, variable speed digital computer with two types of memory: fixed and erasable. The fixed memory permanently stores navigation tables, trajectory parameters, programs and constants. The erasable memory stores intermediate information.

The AGC receives inputs from the inertial and optical subsystems and the navigator, processes the information, and furnishes an output in the form of command signals and/or a data display on the computer control panels. The computer also supplies timing signals to synchronize and control the operation of components in the inertial and optical subsystems. The computer display and control panel (DSKY) provides the interface between the navigator and the AGC and contains the displays and controls necessary for selecting programs and inserting or callingup data (see Fig. 4-1). A slightly modified version operating in parallel with this panel is located on the main instrument panel between the center and left astronauts see Fig. 1-4. The main panel DSKY and navigation station DSKY are electrically similar and essentially operate in parallel. While one computer is operating, an input signal will be accepted from the second DSKY. This will result in a false input which may produce an erroneous readout. Thus, during DSKY operation close communication between the pilot and navigator is necessary.





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Fig. 4-2. AGC DSKY, main panel.

Any change in computer display is reflected on the numerical display on both DSKY's. Simultaneously, telemetry up-dates the display on a ground-based DSKY. Information may be transmitted from the ground to the airborne computer by means of UPLINK telemetry (Para, 4-1.1.4).

4-1.1 AGC DISPLAYS AND CONTROLS. The following paragraphs describe the displays and controls associated with the AGC.

AGC

STANDO'-

4-1.1.1 <u>Computer Power Switches.</u> Two COMPUTER power switches are located on the main instrument panel right-hand circuit breaker panel (See Fig. 1-4). The switches are labelled A and B. Each switch controls power from a separate bus. Placing either or both switches in the ON position applies 28 vdc power to the computer.

4-1.1.2 <u>Computer Keyboard</u>. The computer keyboard is used to manually insert or call up data from the computer. The keyboard consists of 10 digital pushbuttons, 2 algebraic sign bushbuttons, and 4 instruction pushbuttons. Code numbers for inserting or calling up data are stored in the map and data viewer or on a placard.

4-1.1.3 <u>Numerical Display</u>. A numerical display is associated with the computer keyboard for display of called-up data and verification of inserted data. Three 2-digit decimal readouts identify the current program (PROGRAM) being processed by the computer and variables (NOUN-VERB) being displayed or entered into the computer. Three rows of data, (REGIS-TER 1, 2 and 3) each with five digits and an algebraic sign are displayed. 4-1.1.4 Computer Activity and Uplink Indicator. Two ACTIVITY lights on the computer control panel illuminate to indicate either COMPUTER activity or UPLINK activity. The COMPUTER activity light is on whenever the AGC is solving a meaningful program. The UPLINK activity light indicates to the operator when computer data is being transmitted to the AGC by the telemetry UPLINK.

4-1.1.5 <u>Computer Alarm Lights</u>. The computer alarm lights at the top of the navigation station DSKY are the primary AGC failure indicators. Each light is labelled with the condition it represents and will illuminate if that conditon occurs. The main panel DSKY (Fig.4-2) has only two alarm lights which indicate a computer malfunction. The specific alarm condition is displayed on the navigation station DSKY. All computer alarm lights are telemetered to ground stations. The alarm lights and their functions are described in Table 4-L

ALARM	FUNCTION
A. Program Word Error	s:
PROG ALM	Indicates that the computer
	program on operation has failed
	to pass a check point test
PARITY FAIL	Ensures that a number stored in
	the memory is read out correctly

Table 4-I. AGC Alarm Lights

Table 4-I. AGC Alarm Lights (Cont)

ALARM	FUNCTION
CHECK FAIL	Indicates an illegal DSKY Opera- tion. (Usually caused by opera- tion error)
B. Logic Failures:	
RUPT LOCK	Indicates that the AGC is in an
(Interrupt Lock)	interrupted state longer than 20
	milliseconds. Indicates that the interrupt priority or counter in-
	crementing circuits have mal-
	functioned. Detects a failure
	of the computer to interrupt a
	program within 40 microseconds.
TC TRAP	Indicates that the computer is
(Transfer Control Trap)	"hung" in an endless loop of
	instructions. (May also be con-
	sidered a type of Program error,)
SCALER FAIL	Indicates some failure of the
	computer timing circuitry. Dir
	ectly monitors operation of the

Table 4-I. AGC Alarm Lights (Cont)

ALARM	FUNCTION
	100 pulse per second source.
COUNTER FAIL	Lights when there is a failure in
	the normal sequence of input pulse
	counting (either the interrupt or
	the circuitry itself).

Although not an alarm, the alarm matrix also contains:

KEY RELEASE

Used to tell the operator that an internal program wishes to display information on the DSKY, but has found the keyboard in use by the operator.

The main panel DSKY displays the following indications:

COMPFAIL

Computer fail indicates the occurrence of any of the following failures;

PROG ALM, PARITY FAIL, CHECK FAIL, RUPT LOCK, TC TRAP, SCALERFAIL,

COUNTER FAIL.

KEY RELEASE

Used to tell the operator that an internal program wishes to display information on the DSKY, but has found the keyboard in use by the operator. 4-1.1.6 <u>Test Alarm Button</u>. The TEST ALARM button tests the computer alarm lights circuit on the top of the computer control panel.

4-1.1.7 <u>Error Reset Button</u>. The ERROR RESET button resets any computer alarm light that may have illuminated.

4-1.1.8 <u>Key Release Button.</u> When an internal computer program has attempted to use the noun-verb subroutine and has found the DSKY busy, depressing the KEY RELEASE button frees the DSKY for use by the internal program.

Section 5 G&N SYSTEM POWER CONTROLS

5-1 G&N SYSTEM POWER CONTROLS

The following G&N circuit breaker switches are located on the righthand circuit breaker panel of the main instrument panel (See Fig. 1-4). These switches provide power, protection and isolation to the G&N equipment.

5-1.1 IMU POWER SWITCHES. Two two-position (STANDBY-OPERATE) IMU power switches are located on the right-hand side console of the main instrument panel. Placing either or both switches in the OPERATE position supplies 28 vdc to the inertial subsystem. When both switches are in the STANDBY position, power is supplied to the IMU heaters only.

5-1.2 COMPUTER POWER SWITCHES. There are two, two-position (ON-OFF) COMPUTER power switches. They are labelled A and B. Each switch controls 28 vdc power from a separate bus. Placing either or both switches in the ON position supplies power to the computer.

5-1.3 AGC MODE SWITCH. The AGC MODE switch is a two-position (STANDBY-ON) toggle switch located on the front of the computer. See Figs. 1-1 and 9-1. Normally, the switch remains in the ON position. In the STANDBY position part of the AGC power supply loads are deenergized and some circuits deactivated. Before STANDBY is selected, the AGC must be prepared through the keyboard.

5-1.4 OPTICS POWER SWITCHES. There are two, two-position (ON-OFF) OPTICS power switches. They are labelled A and B. Each switch controls 28 vdc power from a separate bus. Placing either or both switches in the ON position supplies power to the optics.

Section 6 CONDITION LIGHTS

6-1 CONDITION LIGHTS

G&N condition lights, located on the CONDITION ANNUNCIATOR assembly (see Fig. 6-1), are provided to inform the navigator of subsystem status and detected subsystem errors. Error detectors at critical points throughout the equipment monitor error signals which are combined by logical "or" into groups of master error detection signals. See Fig. 6-2.

The G&N condition lights include eight yellow warning lights (including 1 spare) which indicate a condition requiring caution, and two white lights which indicate a normal time delay period.

The condition lights provide two types of failures indications "hard wire" indications (IMU TEMP, GIMBAL LOCK, G&N ERROR COMP PWR FAIL) and those processed by the computer (CDU FAIL, ACCEL FAIL, IMU FAIL, G&N FAIL).

Also located with the G&N condition light group are a master caution and a master warning light which are associated with the spacecraft Master Caution and Warning System.

6-1.1 G&N ERROR ALARM LIGHT. The G&N ERROR lamp will light if an error is detected by any of the G&N error monitors.

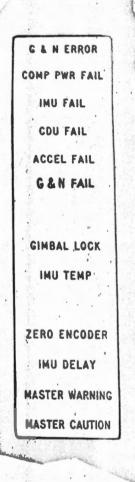


Fig. 6-1. G & N Condition lights.

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THIS SCHEMATIC TO BE PROVIDED WHEN AVAILABLE

Figure 6-2 Condition Lights Schematic

6-1.2 COMPUTER POWER FAILURE ALARM LIGHT. The COMP PWR FAIL lamp will light if there is a failure in the +3, +13 or 28 v power supply within the computer.

6-1.3 IMU FAILURE ALARM LIGHT. The IMU FAIL lamp will light by computer program. Inputs to the program are from the IMU fail gate (see Fig. 6-2) and the inertial subsystem mode status. Inputs to the IMU fail gate are an abnormal IMU gimbal servo error, microsyn power supply loss or gyro wheel power supply loss. This mechanization permits the AGC to filter the transient conditions generated through normal system operation. This light gives positive indication of gimbal lock.

6-1.4 CDU FAILURE ALARM LIGHT. The CDU FAIL lamp will light by computer program. Inputs to the program are from the CDU fail gate (see Fig. 6-2) and the inertial subsystem mode status. Inputs to the CDU fail gate are digital encoder excitation power supply loss, CDU motor power excitation supply loss or a CDU servo error. This mechanization permits the AGC to filter the transient conditions generated through normal system operation.

6-1.5 ACCELEROMETER FAILURE ALARM LIGHT. The ACCEL FAIL lamp will light by computer program. Inputs to the program are from the accelerometer fail gate and the inertial subsystem mode status. Inputs to the accelerometer fail gate are abnormal accelerometer errors. This mechanization permits the AGC to filter the transient conditions generated through normal system operation.

6-1.6 GIMBAL LOCK CAUTION LIGHT. The GIMBAL LOCK lamp will light when the middle gimbal angle becomes greater than $\pm 60^{\circ}$ with respect to the outer gimbal thus indicating a potential gimbal lock.

6-1.7 IMU TEMPERATURE CAUTION LIGHT. The IMU TEMP lamp will light when the IMU temperature deviates greater than $\pm 5^{\circ}$ from normal.

6-1.8 ZERO ENCODER CAUTION LIGHT. The ZERO ENCODER lamp illuminates to indicate that the system is in the process of synchronizing the computer counters to the CDU shaft positions.

6-1.9 IMU DELAY LIGHT. The white IMU DELAY light illuminates for 40 seconds following IMU turn-on. During the time delay period the IMU gyros are attaining operating speed. During this time the IMU cannot be commanded manually or by the computer since 28 vdc power is not supplied to the TRANSFER switch until the time-delay relay closes. 6-1.10 MASTER CAUTION AND WARNING LIGHTS. The MASTER CAUTION and MASTER WARNING lights are associated with the spacecraft master caution system. These lights are duplicated on the main instrument panel. A tone generator activated in conjunction with these lights provides an audible alert over the intercom system.

6-1.11 G & N FAIL LIGHT. The G & N FAIL LIGHT is a master failure indicator which will light by computer program. Inputs to the program are from the three fail gates (IMU, CDU and accelerometer) and a computer failure itself. This mechanization permits the AGC to filter the transient conditions generated through normal system operation.

Section 7

ILLUMINATION CONTROLS

7-1 ILLUMINATION CONTROLS

Illumination controls are provided at the navigation station for control of display illumination and testing of condition lamps for the G&N equipment. See Fig. 1-2.

7-1.1 PANEL BRIGHTNESS. A PANEL BRIGHTNESS thumbwheel controls the illumination intensity of the following:

Optical reticles

IMU-CDU difference indicator

Six IMU mode buttons

Five CDU displays

Track button

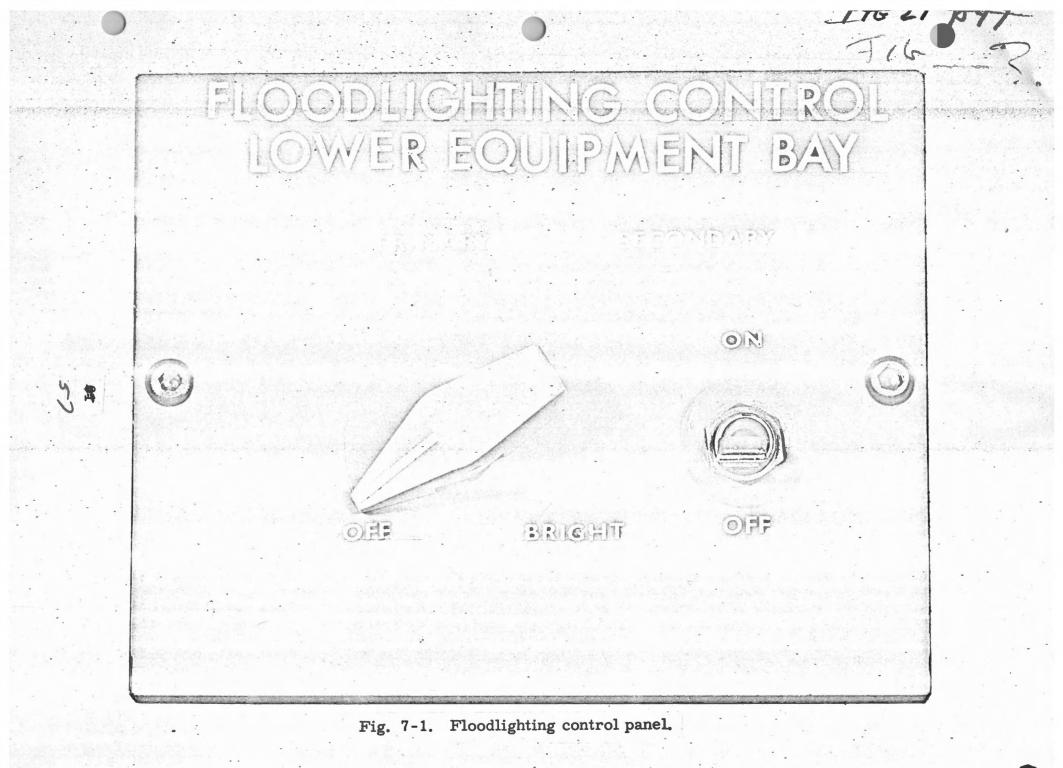
Telescope mechanical readouts

7-1.2 CHECK MODE LAMPS SWITCH. A CHECK MODE LAMPS pushbutton switch is provided to test the lamps in the six CDU MODE buttons and the tracker button.

7-1.3 CHECK COOLANT SWITCH. The CHECK COOLANT SWITCH is a momentary contact pushbutton switch which applies power to the flood lamps located behind the panel to illuminate the IMU quick disconnect couplings. The couplings are viewed through two windows provided in the G&N control panel. 7-1.4 CHECK CONDITION LAMPS SWITCH. A CHECK CONDITION LAMPS SWITCH is provided to test the IMU condition lights on the map and data viewer panel.

7-1.5 PANEL FLOODLIGHT CONTROLS. The navigation station floodlight controls are located on the FLOODLIGHTING CONTROL panel. See Fig. 7-1. A PRIMARY rheostat and a SECONDARY toggle switch control the two floodlights which illuminate the navigation station displays. The rheostat permits the navigator to vary the intensity of one of the floodlights as desired. The rheostat also controls illumination of the clocks. The SECONDARY toggle switch controls the second floodlight. Placing the switch in the ON position turns the floodlight on at full intensity.

7-1.6 CONDITION LAMPS SWITCH. The CONDITION LAMPS switch is a two-position (ON-OFF) toggle switch which normally remains in the ON position. When placed in the OFF position, this switch turns off any condition light which has illuminated with the exception of the MASTER CAUTION and MASTER WARNING lights. This switch permits the navigator to extinguish the light while he is sighting through the optics to prevent it from impairing his dark-adapted vision.



Section 8

CLOCK GROUP

8-1 CLOCK GROUP.

The clock group comprises three mechanical clocks: A Greenwich Meridian Time clock, a Time-To-Event clock, and a Time-From-Event clock. See Fig. 8-1.

8-1.1 GREENWICH MERIDIAN TIME (GMT) CLOCK. The GMT clock is an eight-day mechanical clock with a conventional round dial and an hour, minute, and sweep second hand. This clock displays time-of-day on a 24 hour face.

8-1.2 TIME-TO-EVENT (TTE) CLOCK. The TTE clock displays the time to an event which has been manually set into the clock by the navigator. The clock counts down to zero. It can display up to 10 hours in one second increments.

8-1.3 TIME-FROM-EVENT (TFE) CLOCK. The TFE clock is identical to the TTE clock except that it displays total elaspsed time from a major event up to 100 hours.

Fig. 8-1. Clock group. (suppled when available)

State.

Section 9

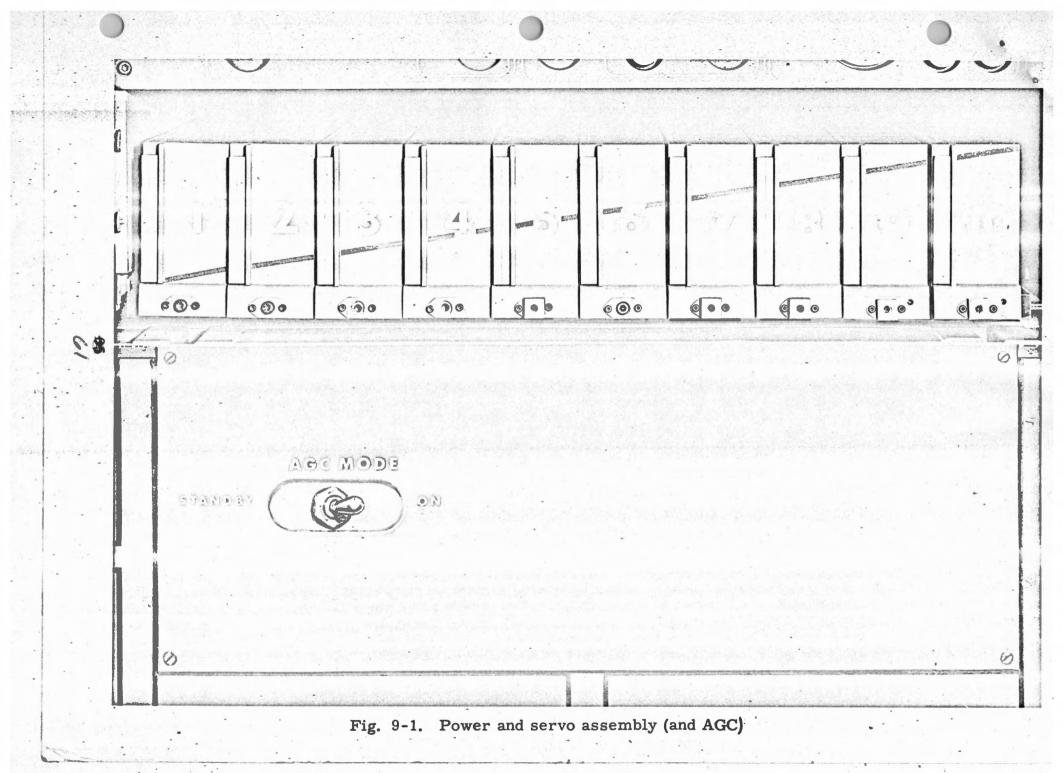
POWER AND SERVO ASSEMBLY

9-1 POWER AND SERVO ASSEMBLY

The power supplies required to operate the G&N subsystems are contained in the power and servo assembly (PSA) located at the base of the navigation station. See Fig. 9-1. The PSA provides various types of DC and AC power to the rest of the G&N system and also serves as the location of various other support electronics such as the servo control amplifiers for the IMU and optics drives. The PSA consists of ten slide-in blocks of electronics which are numbered and mounted on a cold plate and interconnected by a junction box. Each block is identified by a number. The general contents of each block is listed in the table below.

Tray	Contents
1 1	Gimbal Servo Electronics Assy.
2	Power Supply Electronics Assy.
3	Gyro-Accel. Electronics Assy.
4	Gyro-Accel. Electronics Assy.
5	CDU & Gyro-Accel. Electronics Assy.
6	CDU & Power Supply Elect. Assy.
7.	Miscellaneous Electronics Assy.
. 8	Optical Electronics Assy.
. 9	Optical Electronics Assy.
10	Power Diodes & Signal Conditioning Electronics Assy.

Table 9-I. PSA Trays



Section 10

ATTITUDE CONTROLS

10-1 ATTITUDE CONTROLS

The spacecraft attitude controls, located at the navigation station, include a spacecraft rotational hand controller, an attitude impulse controller and an attitude impulse enable switch. Other controls, used for coupling the G&N system to the SCS system for spacecraft attitude control, are located on the SCS control panel on the main instrument panel. The G&N system may be selected to control vehicle attitude during nonaccelerated phases of the mission as well as to control thrust magnitude and direction (or lift forces during re-entry) to achieve a desired trajectory.

10-1.1 ROTATIONAL HAND CONTROLLER. The rotational hand controller is a 3 degree-of-freedom controller normally mounted on the right arm rest of the center couch. For use at the navigation station it is removed from the center couch and fastened to a panel on the right side of the navigation station. The controller is operational for manual attitude maneuvers whenever the controller mechanical lock is in the ARMED position. A DIRECT-ENABLE switch on the main panel provides for direct operation of engine solenoids by the hand controller in event of SCS electronics failure.

If the controller is to be used to maneuver to and hold a new attitude when in the G&N attitude control mode, the pilot must also place the G&N SYNC switch in the ON position. A detent switch in series with the SYNC

switch is incorporated in the rotational hand controller and is closed when the controller is operated. The SYNC switch is used to cause the CDU's to follow manually commanded spacecraft attitude changes and then to establish the attitude hold condition on termination of the manual commands. The controller inputs are sent to the SCS system to provide spacecraft attitude rates proportional to stick displacement. Maximum control rates are $\pm 0.5^{\circ}$ /sec except in the entry mode when maximum roll rate is increased to $\pm 17^{\circ}$ /sec and maximum pitch and yaw rate increased to $\pm 5^{\circ}$ /sec. 10-1.2 ATTITUDE IMPULSE CONTROLLER. The attitude impulse controller is a 3 degree-of-freedom stick controller used to apply small impulses to the spacecraft by means of the service module (SM) reaction jets. This controller has the same sensing as the rotational hand controller. It can be used to apply individual or any combination of roll, yaw, or pitch impulses to give spacecraft attitude rates of 1.2 minutes of arc per second or less. Impulse control gives the navigator a manual vernier control of spacecraft attitude and aids him in reducing drift rates to a minimum while making precision optical measurements. See Fig. 10-1.

10-1.3 ATTITUDE IMPULSE ENABLE SWITCH. The attitude impulse ENABLE switch is a two-position (ON-OFF) switch. In the ON position, it disables the SCS and G&N attitude control and activates the attitude impulse controller. The enable switch is spring loaded to the OFF position but, when turned on, is held in the ON position by a solenoid. The switch turns off automatically when any SCS CONTROL MODE button other than G&N ATT CONT or SCS ATT CONT is selected, or it may be turned off manually. See Fig.10-1.

Fig. 10-1. Attitude impulse controls.

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FIG 23 p.S.

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ATTINDE IMPUISE

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