

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION
MANPOWER DEVELOPMENT

APOLLO GUIDANCE AND NAVIGATION
SYSTEM FAMILIARIZATION
PART I
INERTIAL AND OPTICS

COURSE NO. 733-GS

NOVEMBER 1968

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DEVELOPED BY:

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COURSE DATA

1. DESCRIPTION OF DESIGN AUDIENCE

This course has been specifically designed for Test Personnel in Bldg. 290 (Downey) whose work involves the proper test and checkout of the installed Primary Guidance Navigation and Control System. Course contents is also directly applicable to, and appropriate for the training of Q&RA inspection personnel.

PREREQUISITES: 734NN Apollo Program Orientation
734XY Checkout Station Orientation

2. GENERAL METHODS OF PRESENTATION

This course is conducted by the discussion method with the instructor acting as discussion leader. Student participation is a planned activity in the course. Instructional methods include discussion of schematics, test procedures and training handout materials, and display and description of wall charts and transparencies. The course includes a written examination.

3. DESCRIPTION OF EQUIPMENT & SPECIAL MATERIALS USED IN PRESENTATION

An overhead projector and chalkboard are required to conduct this course. Transparencies, wall charts, and handout materials are prepared and provided by the responsible instructor.

Abundant 18h

4. COURSE PRESENTATION

The Inertial and Optics section of this course will normally be conducted in two (6) hour sessions. Training sessions should be on successive working days. Presentation frequency is as required to meet Space Division requirements for training Test Engineers, Test Technicians, and Q&RA personnel on the Apollo Guidance and Navigation System. Scheduling is by request rather than by any calendar based interval.

5. COURSE SCOPE

The Inertial and Optics section of this training course is comprised of four major parts: System Introduction, Inertial Subsystem, Optical Subsystem, and an Introduction to related Ground Support Equipment and test procedures.

System principles of operation and basic mechanization are taught from simplified training graphics. A discussion of Ground Support Equipment emphasizes the system functions of GSE items and and input - output interfaces with the spacecraft. Instructions in the operation of major items of GSE are the subject of another series of training courses.

The course includes a written examination, the purpose of which is to measure student achievement with respect to course objectives.

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COURSE OBJECTIVES

At course completion the trainee will have that knowledge of the G&N System, associated Ground Support Equipment, and technical reference documentation required to:

1. Successfully identify, isolate, and report system malfunctions while the system is undergoing test.
2. Initiate system operational modes discussed during course of instruction.
3. Recognize; and understand the purpose of, related Ground Support Equipment.
4. Participate in the Primary Guidance Navigation and Control System Operational Checkout Procedure number MA0705-6504 (OCP 6504).

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COURSE OUTLINE

SECTION I:	Introduction To The PGNCS
1 HOUR	System Requirements
	Interfacing Subsystems
	PGNCS Subsystems
SECTION 2:	Inertial Subsystem
5 HOURS	ISS Equipment
	ISS Functions And Interface
	Axes Relationships
	Stabilization Loop
	Fine Align Electronics
	Accelerometer Loop
	Coupling Data Unit
	ISS Modes Of Operation
	IMU Temperature Control System

SECTION 3:
4 HOURS

Optical Subsystem

OSS Equipment

OSS Functional Blocks

Optical Unit Assembly

Associated Optical Equipment

Optical Loop Mechanization

SECTION 4:
1 HOUR

PGNCS Test, Servicing, and GSE

~~SECTION 5:~~
~~1 HOUR~~

~~Written Examination~~

SYSTEMS DATA



SECTION 2

SUBSECTION 2.2

GUIDANCE AND NAVIGATION SYSTEM (G&N)
(CSM 101-106)

2.2.1 INTRODUCTION.

The primary guidance navigation and control (PGNCS) system measures spacecraft attitude and velocity, determines trajectory, controls spacecraft attitude, controls the thrust vector of the service propulsion engine, and provides abort information and display data. Primary determination of the spacecraft velocity and position, and computation of the trajectory parameters is accomplished by the manned space flight network (MSFN).

The PGNCS system consists of three subsystems as follows:

- Inertial subsystem (ISS)
- Computer subsystem (CSS)
- Optics subsystem (OSS).

The inertial subsystem is composed of an inertial measurement unit (IMU), part of the power and servo assembly (PSA), part of the controls and displays, and three inertial coupling data units (CDUs). The IMU provides an inertial reference with a gimbaled, three-degree-of-freedom, gyro-stabilized stable platform.

The computer subsystem is composed of the command module (CMC) and two display and keyboard panels (DSKYs), which are part of the controls and displays. The CMC is a digital computer which processes and controls information to and from the IMU, the optics, DSKYs, and stores programs and reference data.

The optics subsystem is composed of a scanning telescope (SCT), a sextant (SXT), drive motors for positioning the SCT and SXT, parts of the PSA, part of the controls and displays, and two optics CDUs. The SCT and SXT are used to determine the spacecraft position and attitude with relation to stars and/or landmarks.

The three G&N subsystems are configured such that the CSS and OSS may be operated independently. This allows continued use of the CSS and/or OSS in the event of a malfunction in one of these subsystems, or the ISS. System power requirements and reference signals are provided by the

APOLLO OPERATIONS HANDBOOK

SYSTEMS DATA

power and servo assembly (PSA). Major components of the system are located in the command module lower equipment bay (figure 9). System circuit breakers, caution and warning indicators, and one of the DSKYs are located on the main display console.

2.2.2 FUNCTIONAL DESCRIPTION.

The primary guidance navigation and control system provides capabilities for the following:

- Inertial velocity and position (state vector) computation
- Optical and inertial navigation measurements
- Spacecraft attitude measurement and control
- Generation of guidance commands during CSM-powered flight and CM atmospheric entry.

The PGNCS system is initially activated and aligned during the prelaunch phase. During the ascent phase, the system measures velocity and attitude, computes position, compares the actual spacecraft trajectory with a predetermined trajectory, and displays pertinent data. The flight crew uses the displayed information as an aid for decision to abort or continue the mission.

During periods when onboard velocity and/or attitude change sensing is not required, the IMU is placed in standby operation to conserve electrical power. The CMC is used more extensively than the IMU; however, it will also be placed in standby operation to conserve electrical power. When the guidance and navigation function is to be restored, the IMU and CMC are reactivated, with the CMC using the last computed velocity as the basis for further velocity computations. New positional data must be acquired from optical sightings or MSFN through telemetry or voice communications.

Initial position and attitude information as well as periodic updating of this information is made through use of the optics. This is accomplished by the navigator making two or more landmark and/or star sightings. The sightings are made by acquiring the star-landmark with the SCT and/or SXT. When the viewed object is centered, a mark command is initiated. The CMC reads the optics angles, IMU angles, and time, in conjunction with internal programs to determine the spacecraft position. This position information and the spacecraft velocity are used to compute an estimated trajectory. The actual trajectory is compared with previous trajectory data to generate the trajectory error, if any, for further reference. Optical measurements are also used in aligning the IMU to a specific reference orientation.

GUIDANCE AND NAVIGATION SYSTEM

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SYSTEMS DATA

The IMU (figure 8) contains three inertial rate integrating gyros (IRIGs), and three pulsed-integrating pendulous accelerometers (PIPAs). The IRIGs and PIPAs are mounted on the stable platform which is gimballed to provide three degrees of freedom. The stable platform inertial reference is maintained by the IRIGs in conjunction with electronic stabilization loops. Any displacement of the platform is sensed by the IRIGs, which produce output signals representative of the magnitude and direction of displacement. The IRIG signals are applied to servoamplifiers, which condition the signals to drive gimbal torque motors. The gimbal torque motors then restore the initial platform orientation by driving the gimbals until the IRIG signals are nulled.

The PIPAs are orthogonally mounted and sense changes in spacecraft velocity. An acceleration or deceleration results in output signals which are representative of the magnitude and direction of the velocity change. The output signals are applied to the CMC which uses the information to update spacecraft velocity data. Continual updating of velocity information, with respect to the initial spacecraft position and trajectory, enables the CMC to provide current velocity, position, and trajectory information.

The IMU also provides a space-stabilized reference for spacecraft attitude sensing and control. Attitude change sensing is accomplished by monitoring the spacecraft attitude with reference to the stable platform. Resolvers are mounted at the gimbal axes to provide signals representative of the gimbal angles. Inertial CDUs repeat the platform attitude. Attitude monitoring is afforded by comparing the inertial CDU angles with the CMC desired angles. If the angles differ, error signals are generated. If the attitude error is larger than the selected deadband limits, the CMC fires the appropriate RCS engines. The spacecraft is rotated back to the initial reference attitude and the error signals are nulled (within deadband limits).

The CMC provides automatic execution of computer programs, automatic control of ISS and OSS modes, and, in conjunction with the DSKYs, manual control of ISS and OSS modes, and computer displays. The CMC contains a two-part memory which consists of a large nonerasable section and a smaller erasable section. Nonerasable memory contains mission and system programs, and other predetermined data which are wired in during assembly. Data readout from this section is nondestructive and cannot be changed during operation. The erasable section of memory provides for data storage, retrieval, and operations upon measured data and telemetered information. Data readout from this section is destructive, permitting changes in stored data to be made as desired. Information within the memory may be called up for display on the two DSKYs. The DSKYs enable the flight crew to enter data or instructions into the CMC request display of data from CMC memory, and offer an interrupt control of CMC operation. The CMC timing section provides timing signals of various frequencies for internal use and to other onboard systems which require accurate or synchronized timing. Data within the CMC is

APOLLO OPERATIONS HANDBOOK

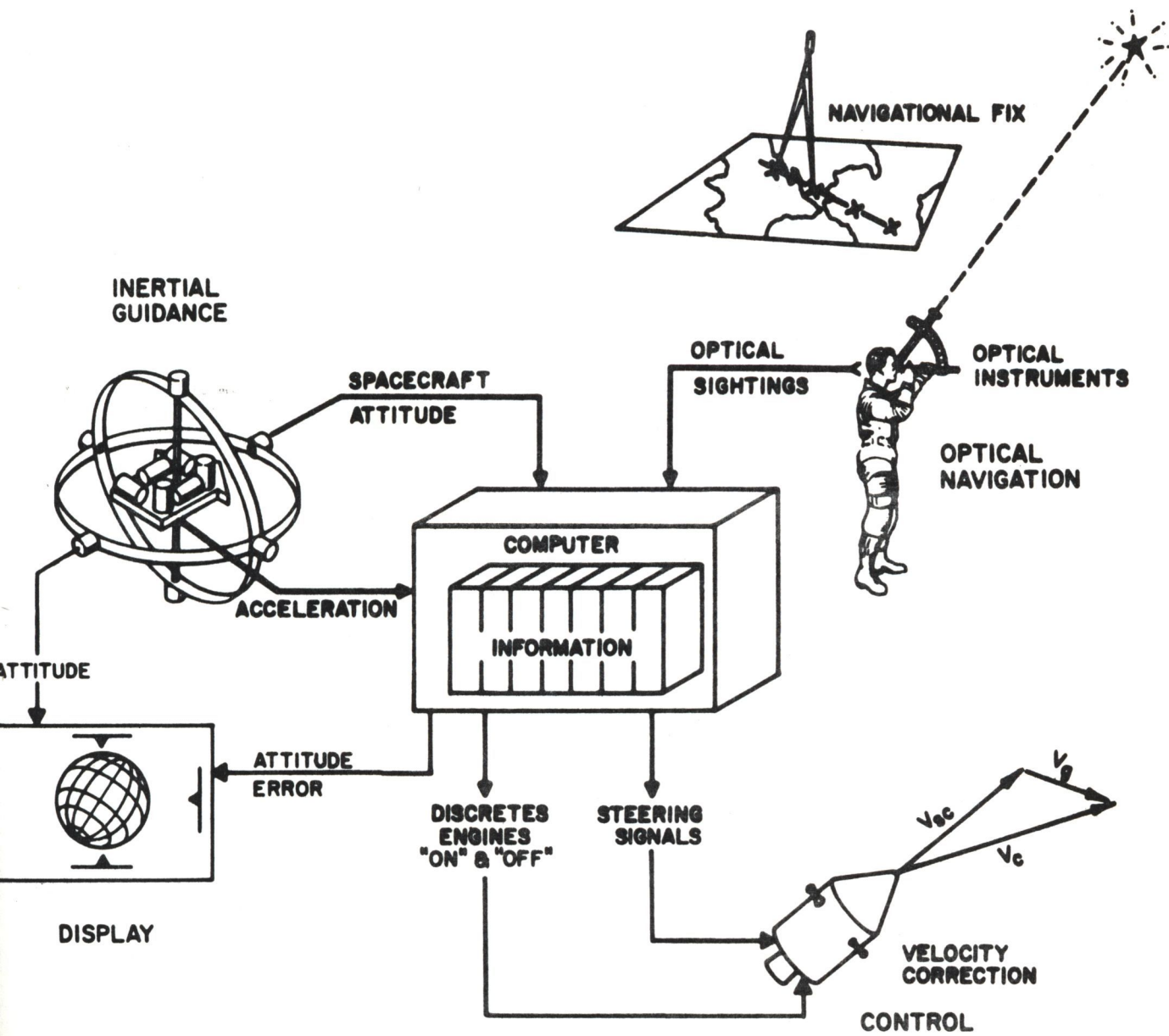
SYSTEMS DATA

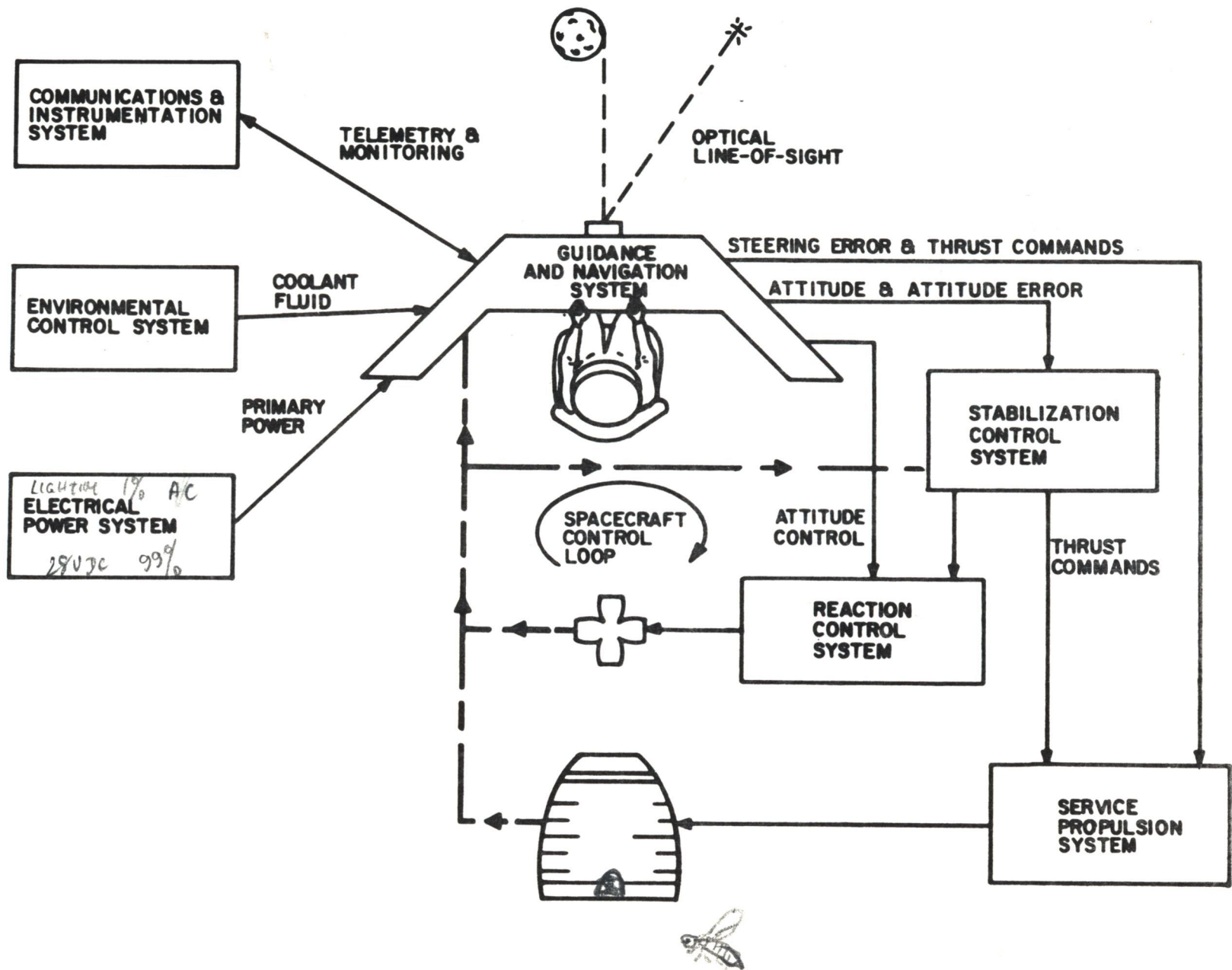


transmitted to MSFN through a "downlink" telemetry function. Telemetered data is transmitted as a function of a CMC program or by request from MSFN. Data within the CMC may be updated through "uplink" telemetry from the MSFN. The CMC performs guidance functions by executing internal programs using predetermined trajectory parameters, attitude angles from the inertial CDUs, velocity changes from the PIPAs, and commands from the DSKYs (crew) to generate control commands. The navigation function is performed by using stored star-landmark data, optics angles from the optics CDUs, and velocity changes from the PIPAs in the execution of navigation programs.

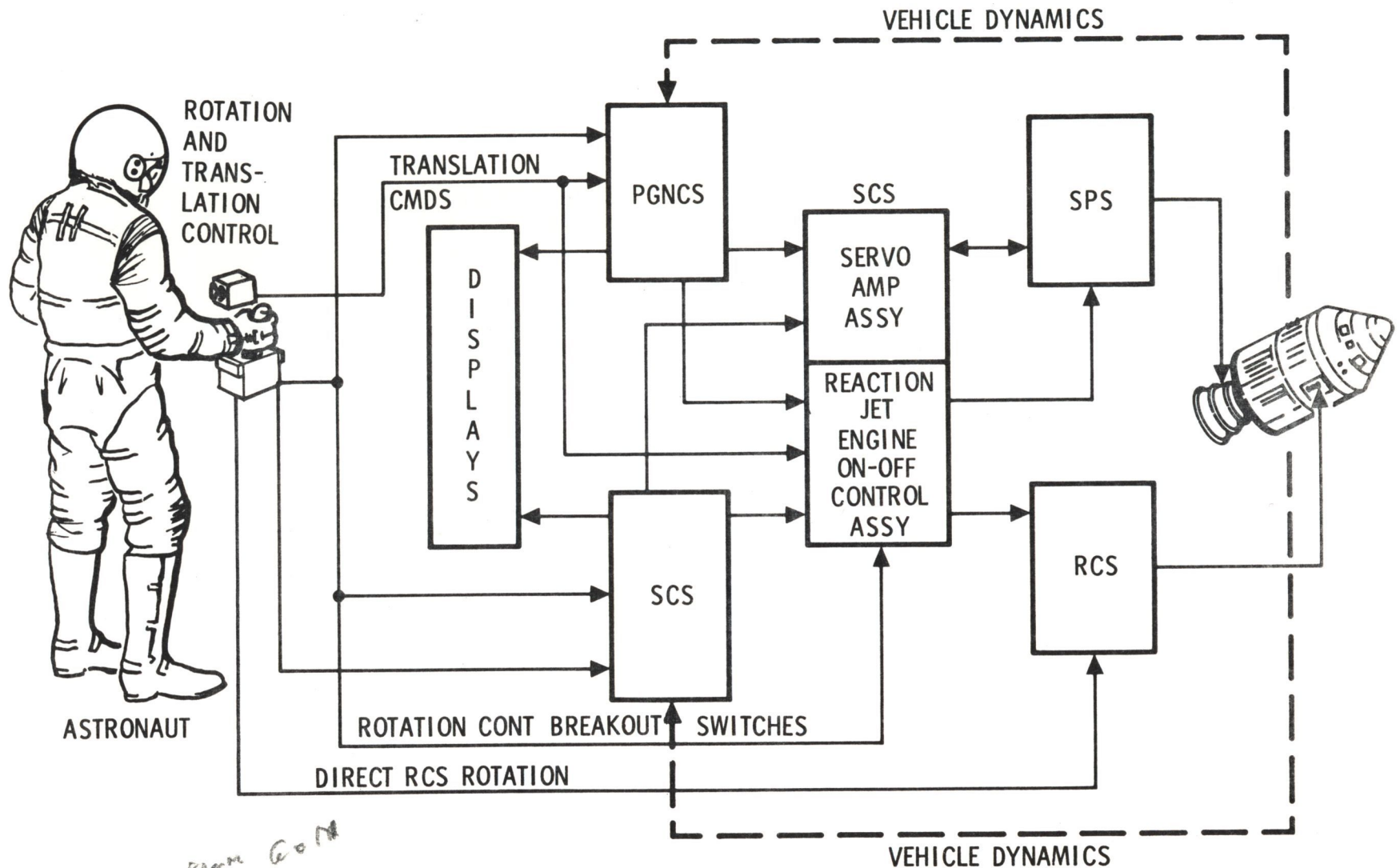
The optics provide accurate star and landmark angular measurements. Sightings are accomplished by the navigator using the SXT and SCT. The optics are positioned by drive motors commanded by the optics hand controller or by the CMC. The shaft axes are parallel. Trunnion axes may be operated in parallel or offset, as desired. The SCT is a unity power instrument providing an approximate 60-degree field of view. It is used to make landmark sightings and to acquire and center stars or landmarks prior to SXT use. The SXT provides 28-power magnification with a 1.8-degree field of view. The SXT has two lines of sight, enabling it to measure the included angle between two objects. This requires two lines of sight which enable the two viewed objects to be superimposed. For a star-landmark sighting, the landmark line of sight is centered along the SXT shaft axis. The star image is moved toward the landmark by rotating the shaft and trunnion axes until the two viewed objects are superimposed. The shaft and trunnion angles are repeated by the optic CDUs. When the navigator is satisfied with image positions, he issues a mark command to the CMC. The CMC reads the optics CDU angles, IMU CDU angles, and time, and computes the position of the spacecraft. The CMC bases the computation on stored star and landmark data which may also be used by the CMC to request specific stars or landmarks for navigational sightings. Two or more sightings, on two or more different stars, must be taken to perform a complete position determination.

GUIDANCE AND NAVIGATION SYSTEM





CSM GUIDANCE & CONTROL

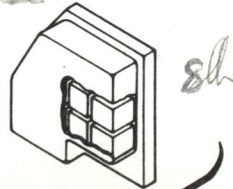


MIN 14P FROM GOM
H1200T 15 min rec.

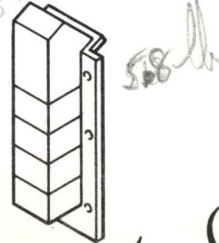
PGNCS EQUIPMENT

PIPA CAM MEASURE UP TO 19.1G
 " SF 5.85 cm/sec Sq per pulse
 each pulse about 6/1000 of our g.

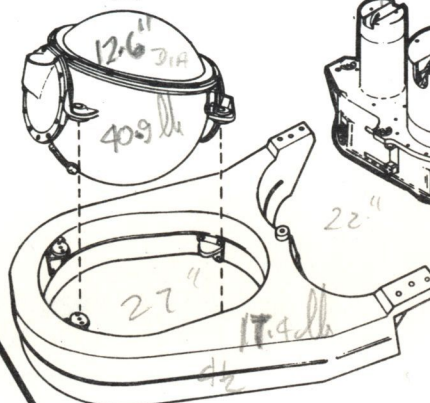
PIPA ELECTRONICS ASSEMBLY



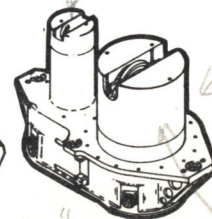
SIGNAL CONDITIONER



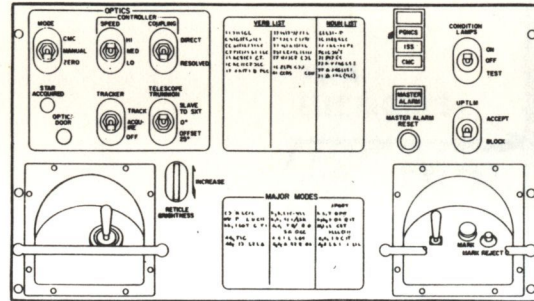
IMU



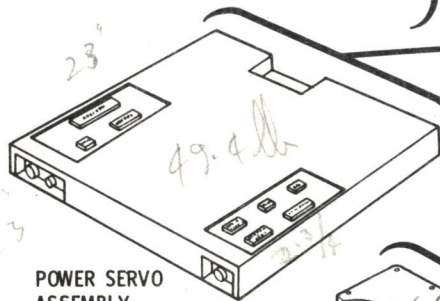
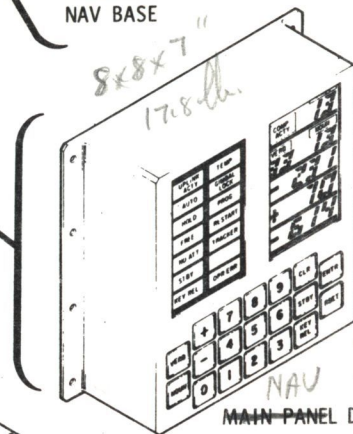
OPTICS ASSEMBLY



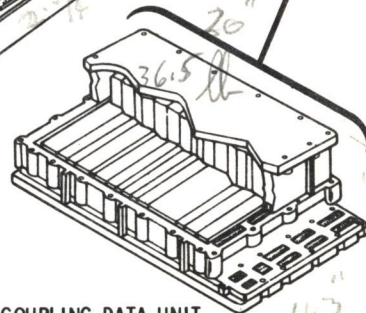
INDICATOR CONTROL PANEL



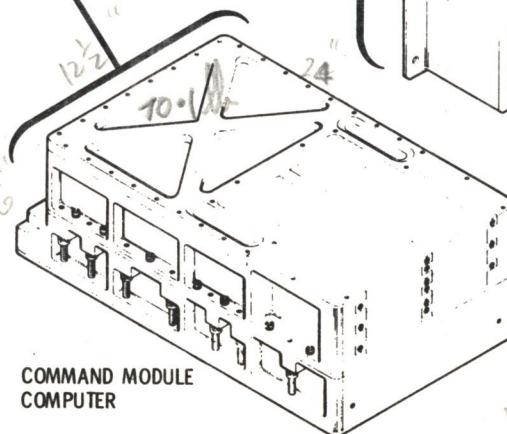
NAV BASE



POWER SERVO ASSEMBLY



COUPLING DATA UNIT



COMMAND MODULE COMPUTER

UNITY Power
 60° FIELD
 123 3/4"
 22 1/2"
 6"
 55.7 lb
 28X
 2 LENSES OF SIGHT
 LOS 95%
 LIGHT LOSS
 SIDE LOS 5%
 65% LIGHT LOSS
 FIELD OF VIEW
 1.8°
 STOPS AT
 ± 270° Shift area
 up 50°
 down 50°

28V.
 Conf - steady 15w
 of pulse 70W

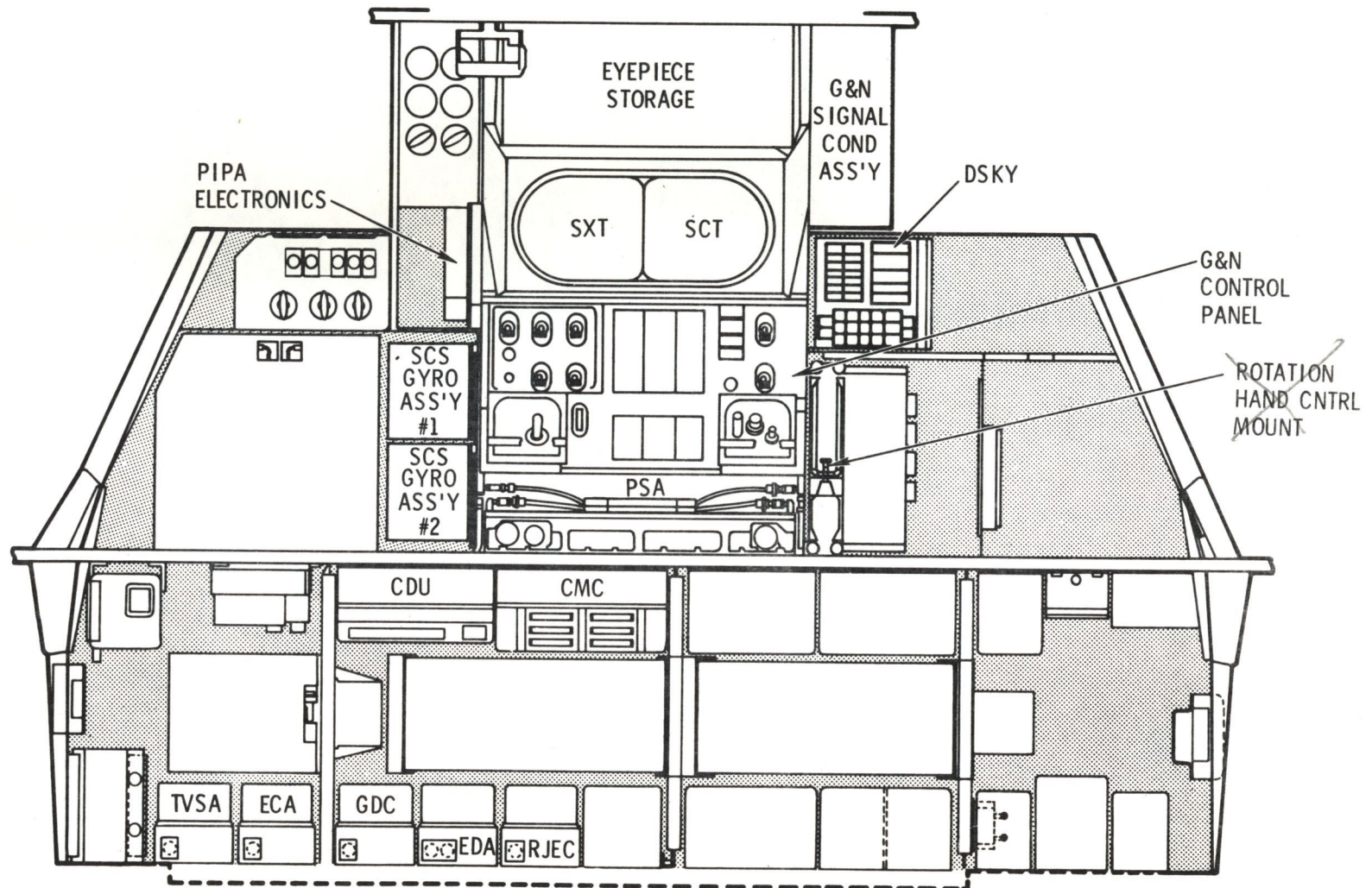
Essential sub-hydr
 {Heath 35 watts
 {Chick 10 watt

Normal Intel Load
 218 watts

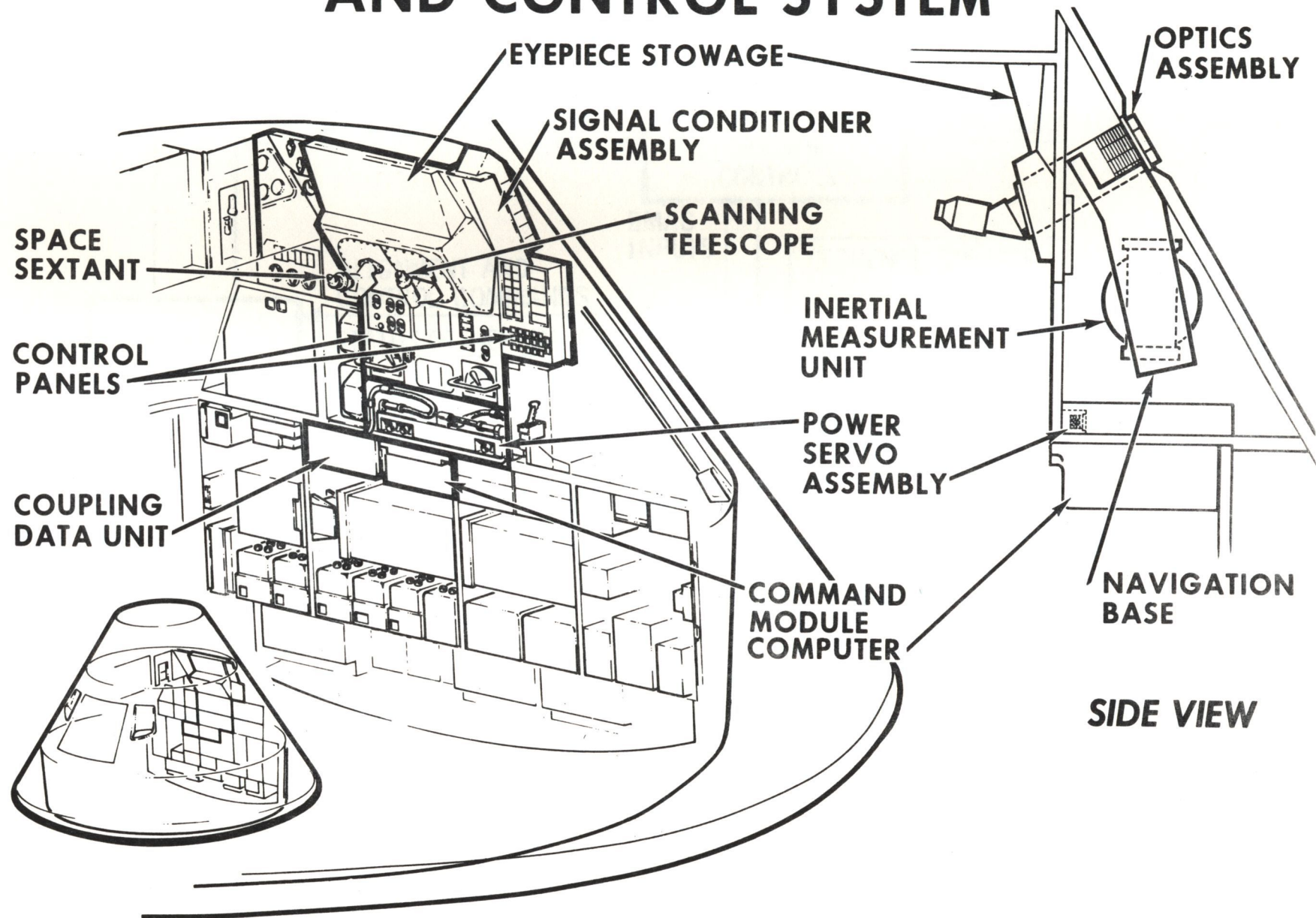
5 cm dig 6 cm dig
 apply to dig combi
 0.55 in pulse 94 1/2 watt

Et. Syst 397 watts
 250 lb Intel

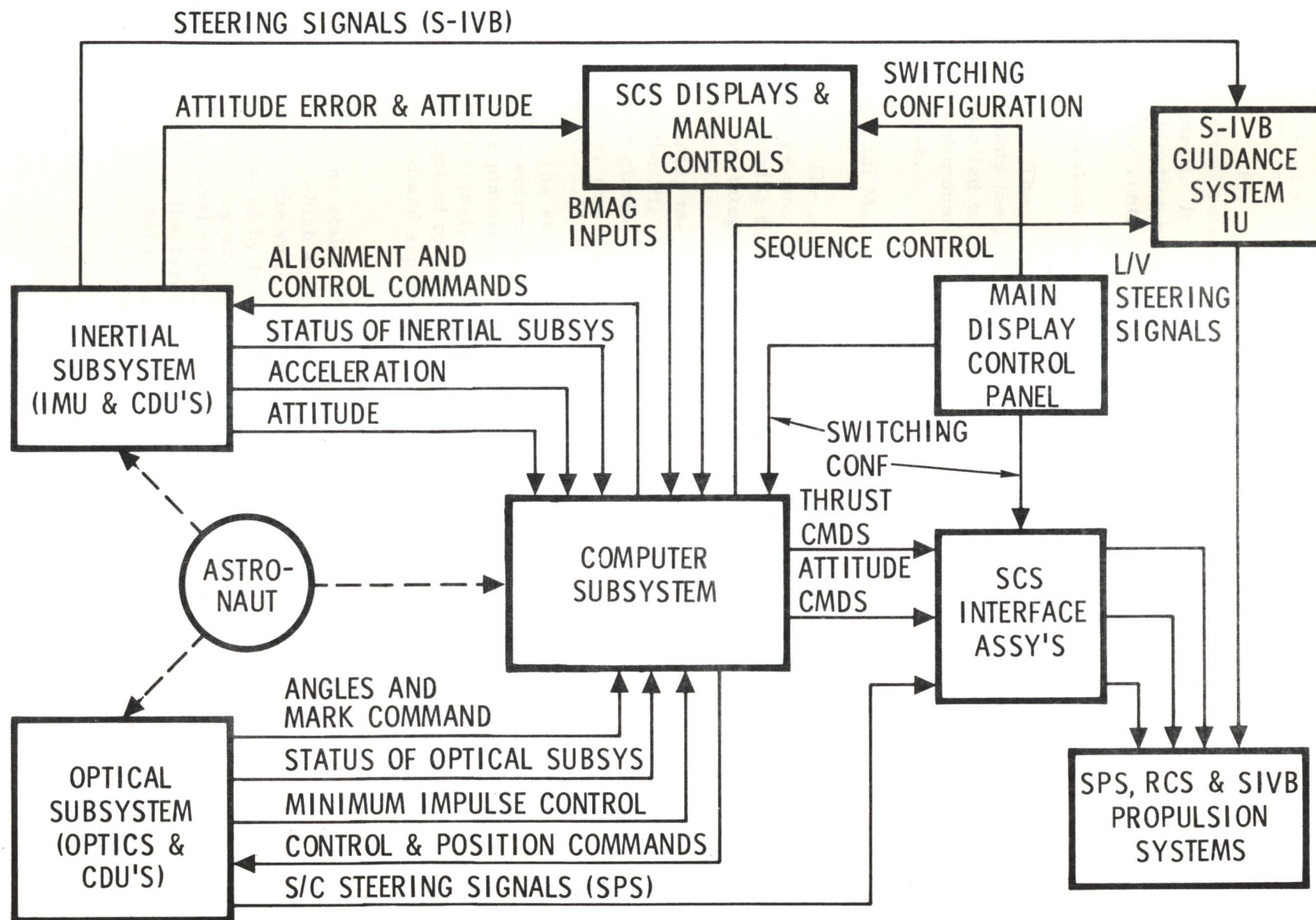
G&C EQUIPMENT LOCATION



GUIDANCE, NAVIGATION, AND CONTROL SYSTEM



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2.2.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.2.3.1 Inertial Subsystem.

The function of the inertial subsystem is to provide a space-stabilized inertial reference from which velocity changes and attitude changes can be sensed. It is composed of the inertial measurement unit (IMU), the navigation base (NB), parts of the power and servo assembly (PSA), parts of the control and display panels, and three coupling data units (CDUs).

2.2.3.1.1 Navigation Base.

The navigation base (NB) is the rigid, supporting structure which mounts the IMU and optical instruments. The NB is manufactured and installed to close tolerances to provide accurate alignment of the equipment mounted on it. It also provides shock mounting for the IMU and optics.

2.2.3.1.2 Inertial Measurement Unit.

The inertial measurement unit (IMU) is the main unit of the inertial subsystem. It is a three-degree-of-freedom stabilized platform assembly, containing three inertial reference integrating gyros (IRIGs), and three pulsed-integrating pendulous accelerometers (PIPAs). The stable member itself is machined from a solid block of beryllium with holes bored for mounting the PIPAs and IRIGs. Figure 16 illustrates how the IRIGs and the PIPAs are mounted relative to each other on the stable member (or inner gimbal). The three gimbal axes, about which each of the gimbals rotate, are also shown.

The stable platform attitude is maintained by the IRIGs, stabilization loop electronics, and gimbal torque motors. Any displacement of the stable platform or gimbal angles is sensed by the IRIGs which generate error signals. IRIG error signals are resolved and amplified at the IMU, and applied to stabilization loop electronics. The resultant signal is conditioned and applied to the gimbal torque motors, which restore the desired attitude.

The stable platform provides a space-referenced mount for three PIPAs, which sense velocity changes. The PIPAs are mounted orthogonally to sense the velocity changes along all three axes. Any translational force experienced by the spacecraft causes an acceleration or deceleration which is sensed by one or more PIPAs. Each PIPA generates an output signal proportional to the magnitude and direction of velocity change. This signal, in the form of a pulse train, is applied to the CMC. The CMC will use the signal to update the velocity information, and also generate signals to torque each PIPA ducosyn back to null.

The temperature control system is a thermostatic system that maintains the IRIG and PIPA temperatures within their required limits during both IMU standby and operate modes. Heat is applied by end-mount heaters on the inertial components, stable member heaters, and a temperature control anticipatory heater. Heat is removed by convection, conduction, and radiation. The natural convection used during IMU standby

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SYSTEMS DATA

modes is changed to blower-controlled, forced convection during IMU operating modes. IMU internal pressure is normally between 3.5 and 15 psia enabling the required forced convection. To aid in removing heat, a water-glycol solution passes through coolant passages in the IMU support gimbal. Therefore, heat flow is from the stable member to the case and coolant. The temperature control system consists of the temperature control circuit, the blower control circuit, and the temperature alarm circuit. A separate external temperature control system is also provided for test configurations but will not be discussed in this manual.

2.2.3.1.3 Coupling Data Unit.

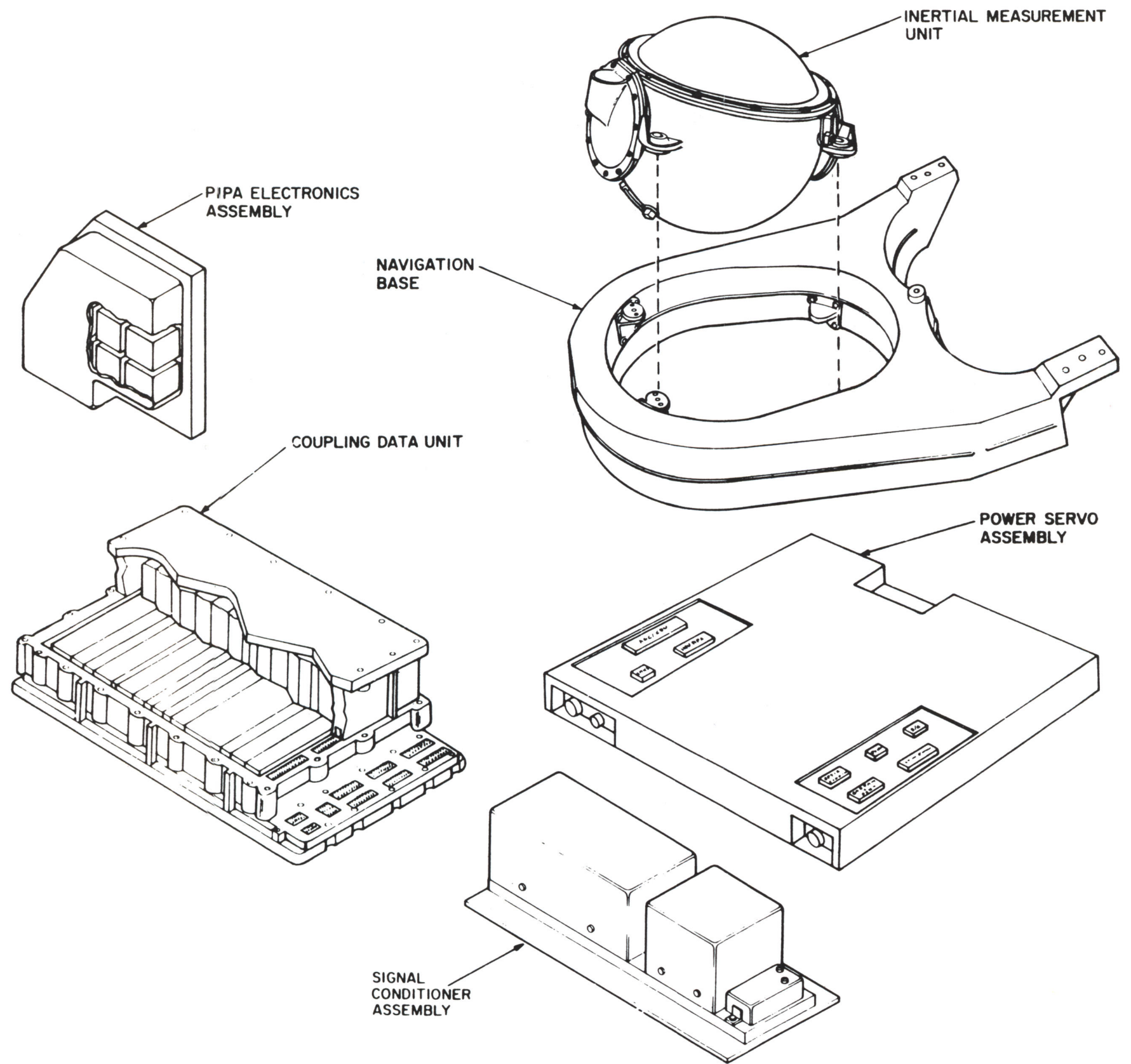
The CDU, an all electronic device, is used as an interface element between the ISS and CSS, the OSS and CSS, and the CSS and various controls and displays. It functions primarily as an analog-to-digital (A/D) or digital-to-analog (D/A) converter. There are five, almost identical, loops; one each for the inner, middle, and outer IMU gimbals, and one each for the shaft and trunnion optical axes. The ISS portion of the CDU performs the following functions:

- a. Converts IMU gimbal angles from analog-to-digital form, and supplies the CMC with this information.
- b. Converts digital signals from the CMC to either 800 cps or direct current signals.
- c. Controls the moding of the ISS through logical manipulation of computer discretes.

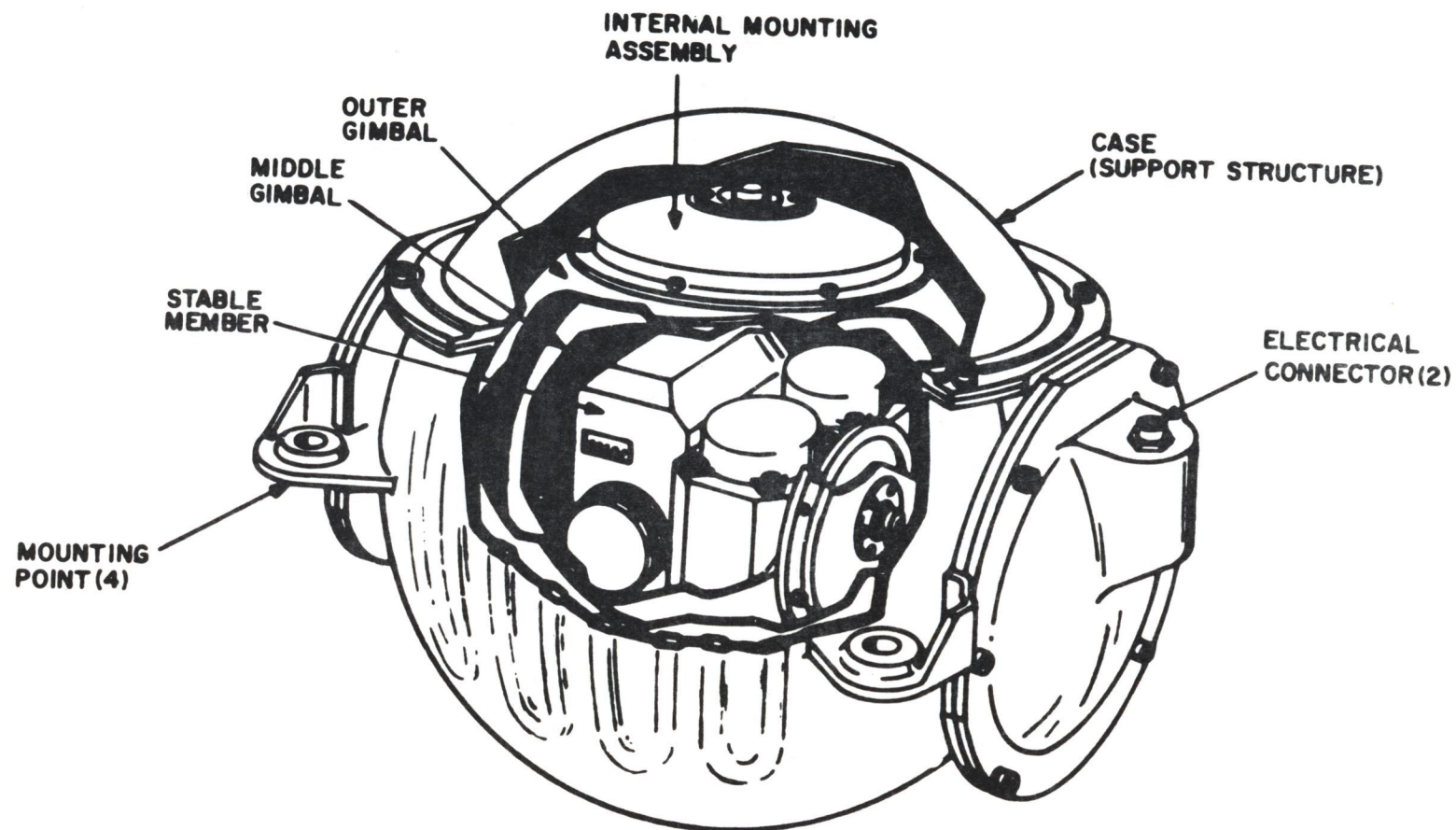
2.2.3.1.4 Power and Servo Assembly.

The purpose of the power and servo assembly (PSA) is to provide a central mounting point for the majority of the G&N system power supplies, amplifiers, and other modular electronic components.

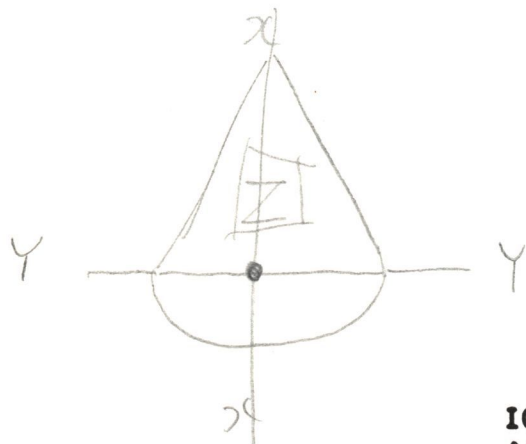
The PSA is located on the lower D&C panel rack directly below the IMU. It consists of 42 modules mounted to a header assembly. Connectors and harnessing are integral to the construction of the header assembly, and G&N harness branches are brought out from the PSA header. A thin cover plate is mounted on the PSA, providing a hermetic seal for the interior. During flight this permits pressurization of the PSA to remain at 15 psi. Connectors are available at the PSA for measuring signals at various system test points.



ISS Equipment

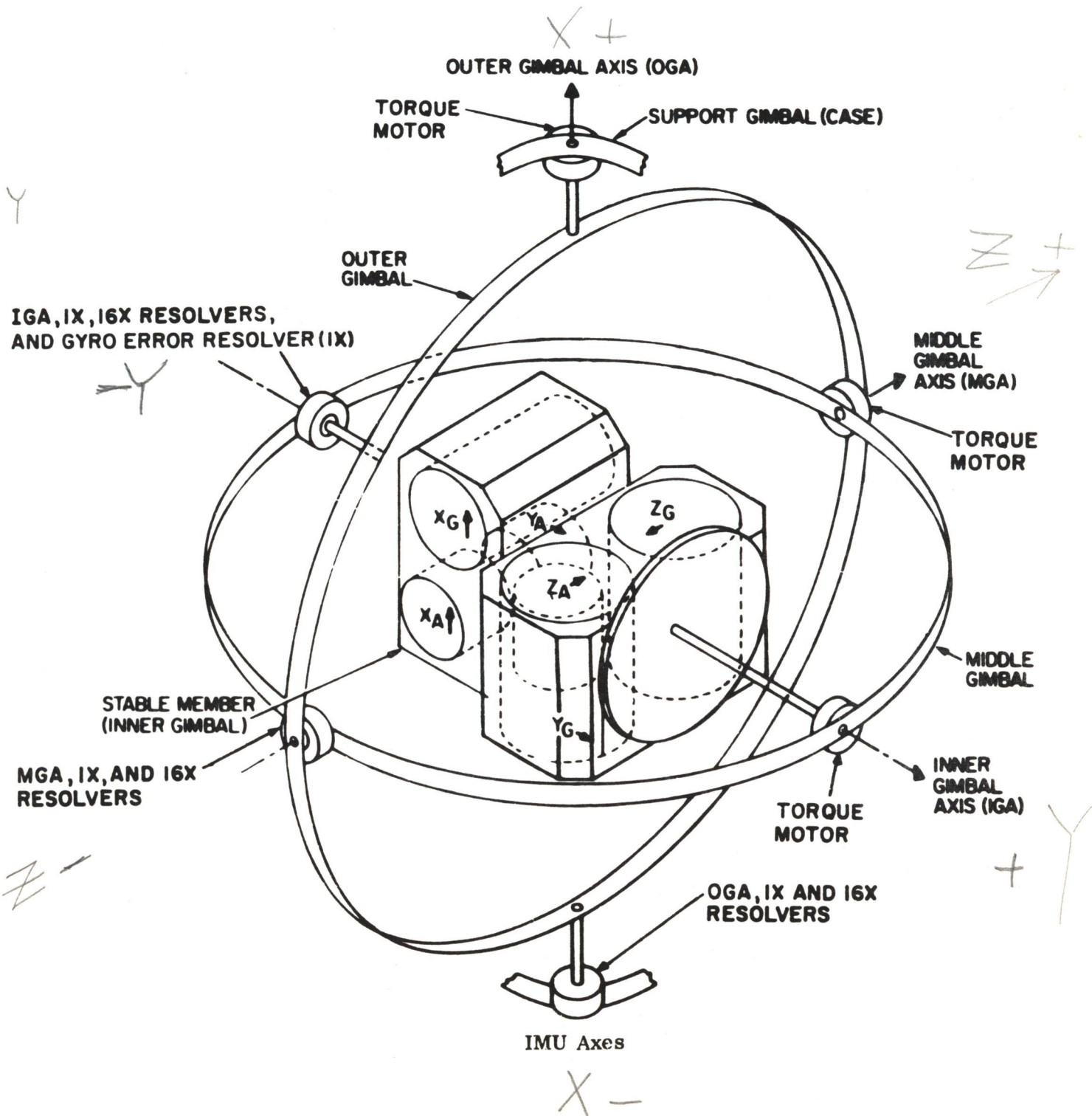


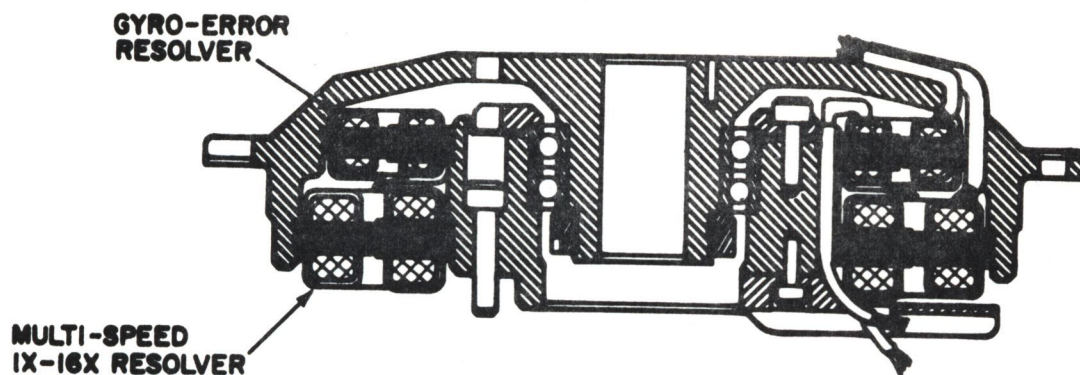
Block II Inertial Measurement Unit



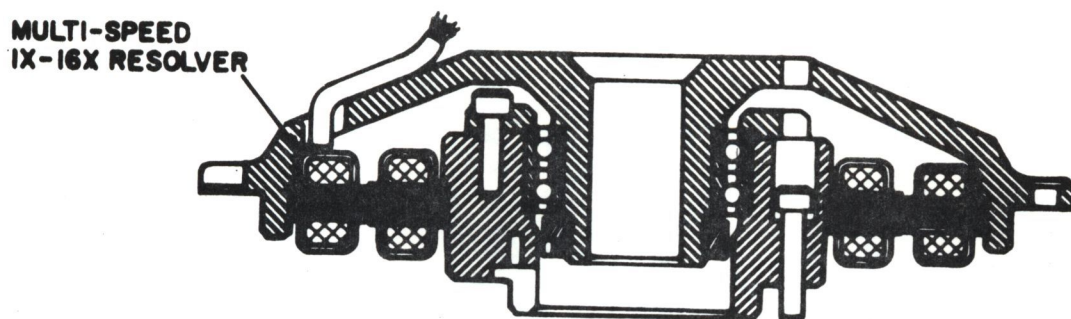
can detect angular changes
 as small as 20 arc sec
 1/80 deg of angle
 Ball pointed by 1X magn
 only.

9/

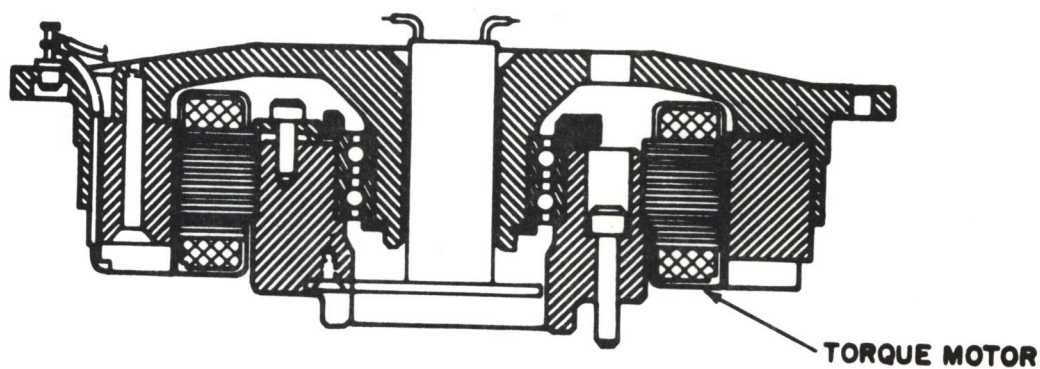




INNER GIMBAL AXIS ASSEMBLY SHOWING
MULTI-SPEED RESOLVER & GYRO ERROR RESOLVER

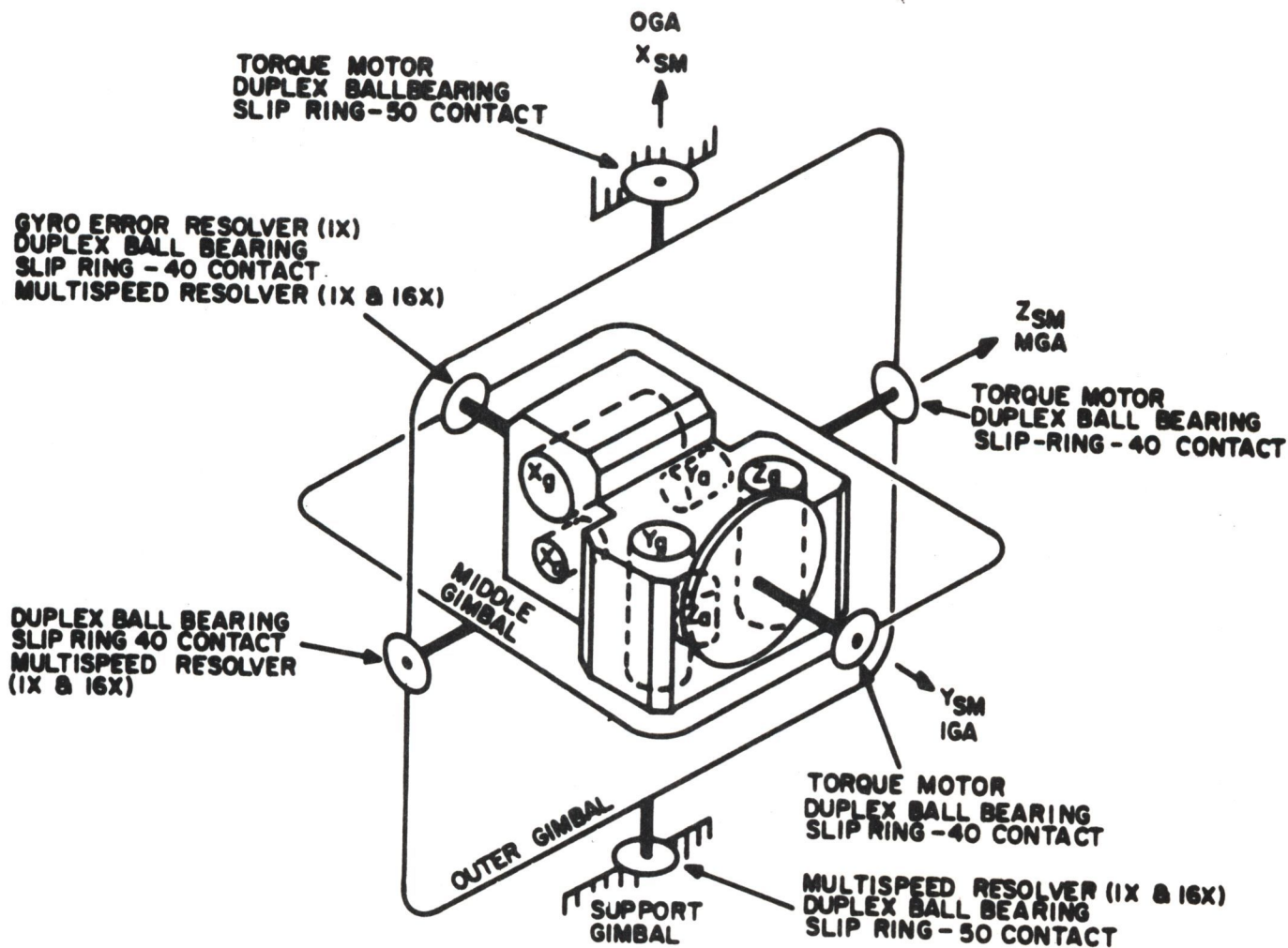


MIDDLE GIMBAL ASSEMBLY SHOWING
MULTI-SPEED RESOLVER

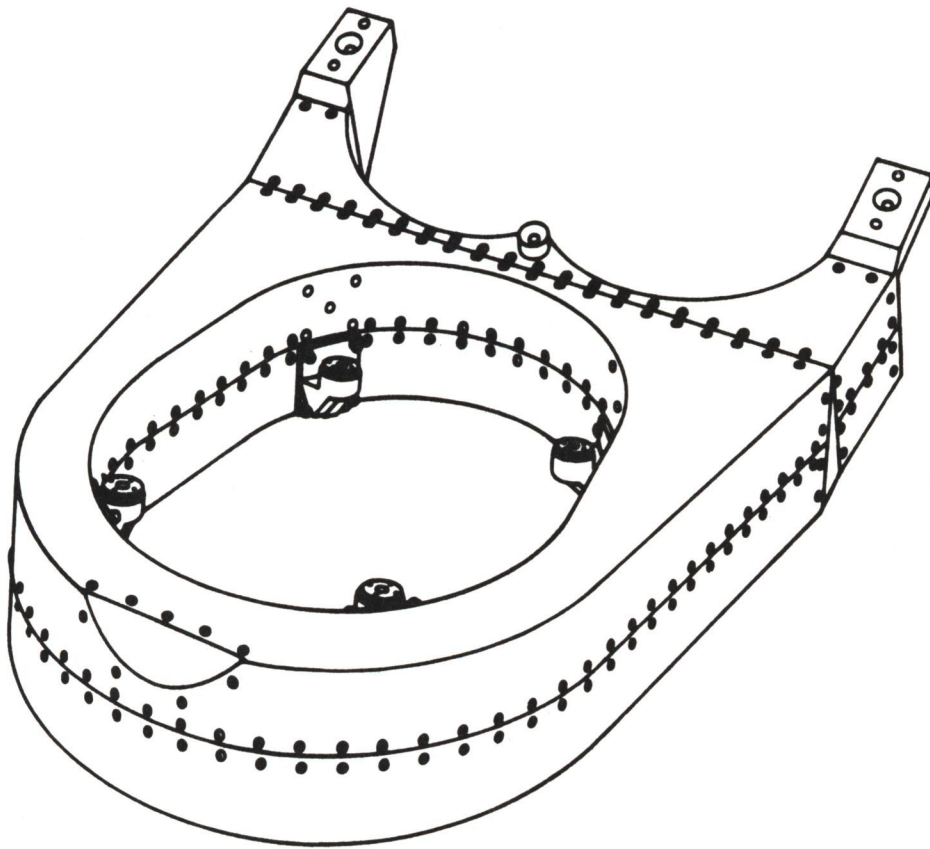


OUTER GIMBAL ASSEMBLY SHOWING
TORQUE MOTOR

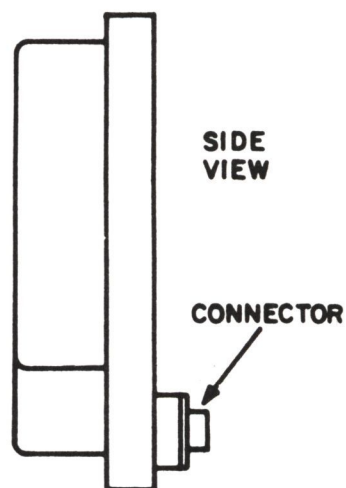
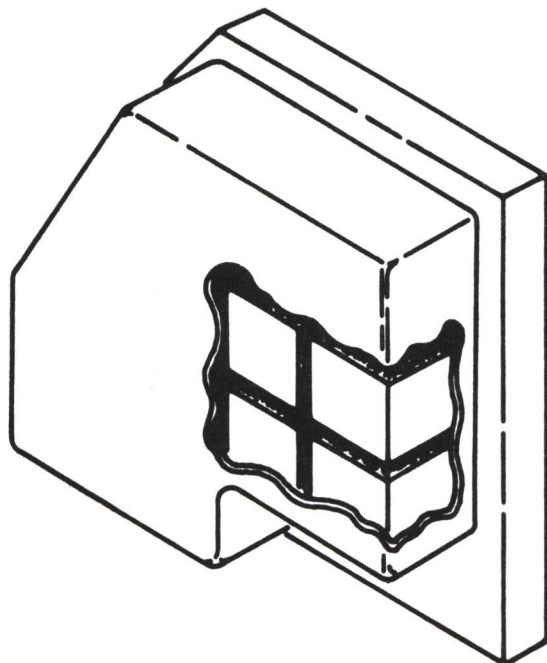
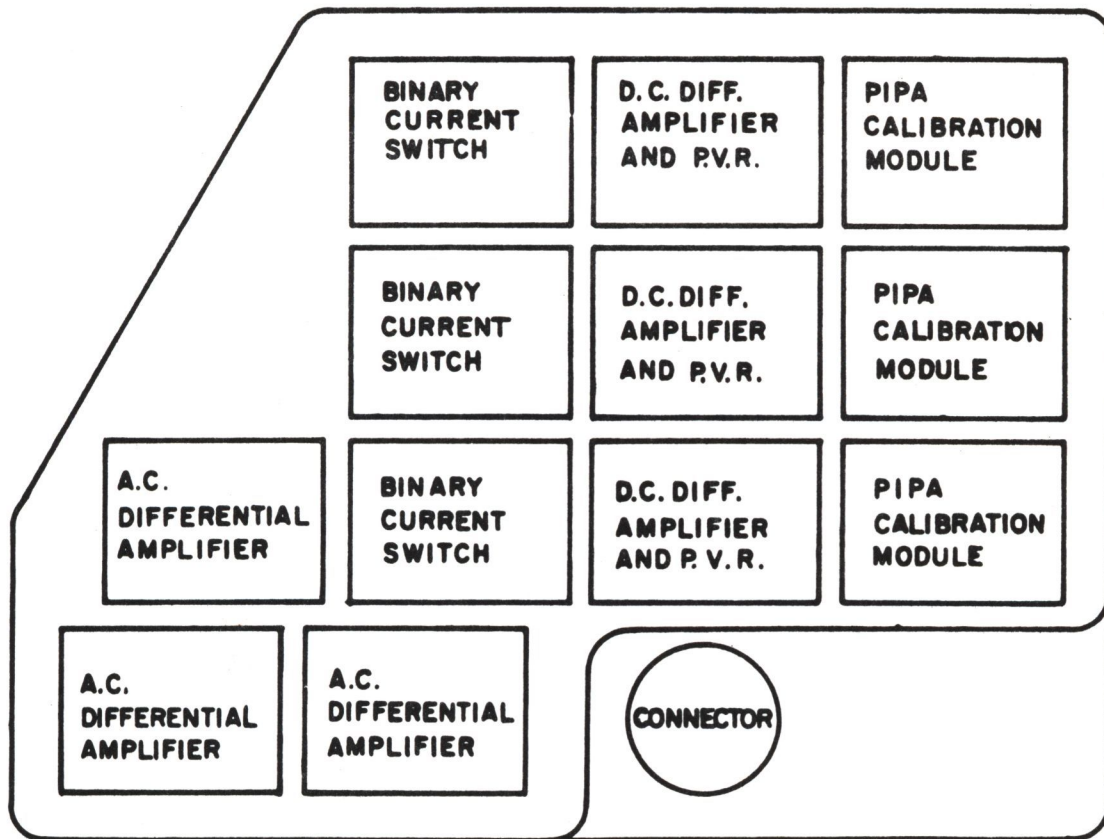
Inter-gimbal Assembly



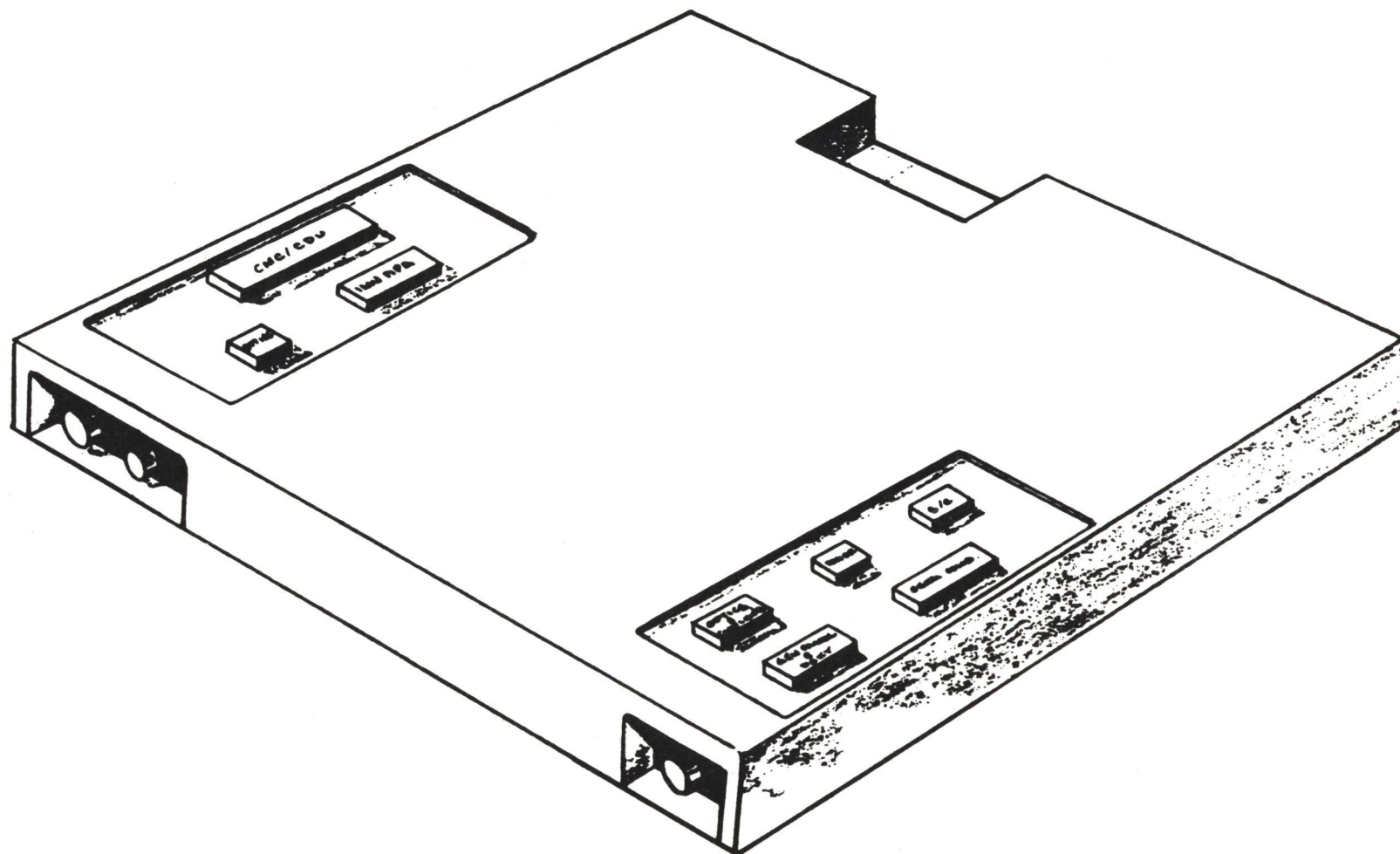
IMU Gimbal Assembly and Gimbal Axes



Navigation Base



PIP Electronics Assembly



Block II Power and Servo Assembly

PSA Modules

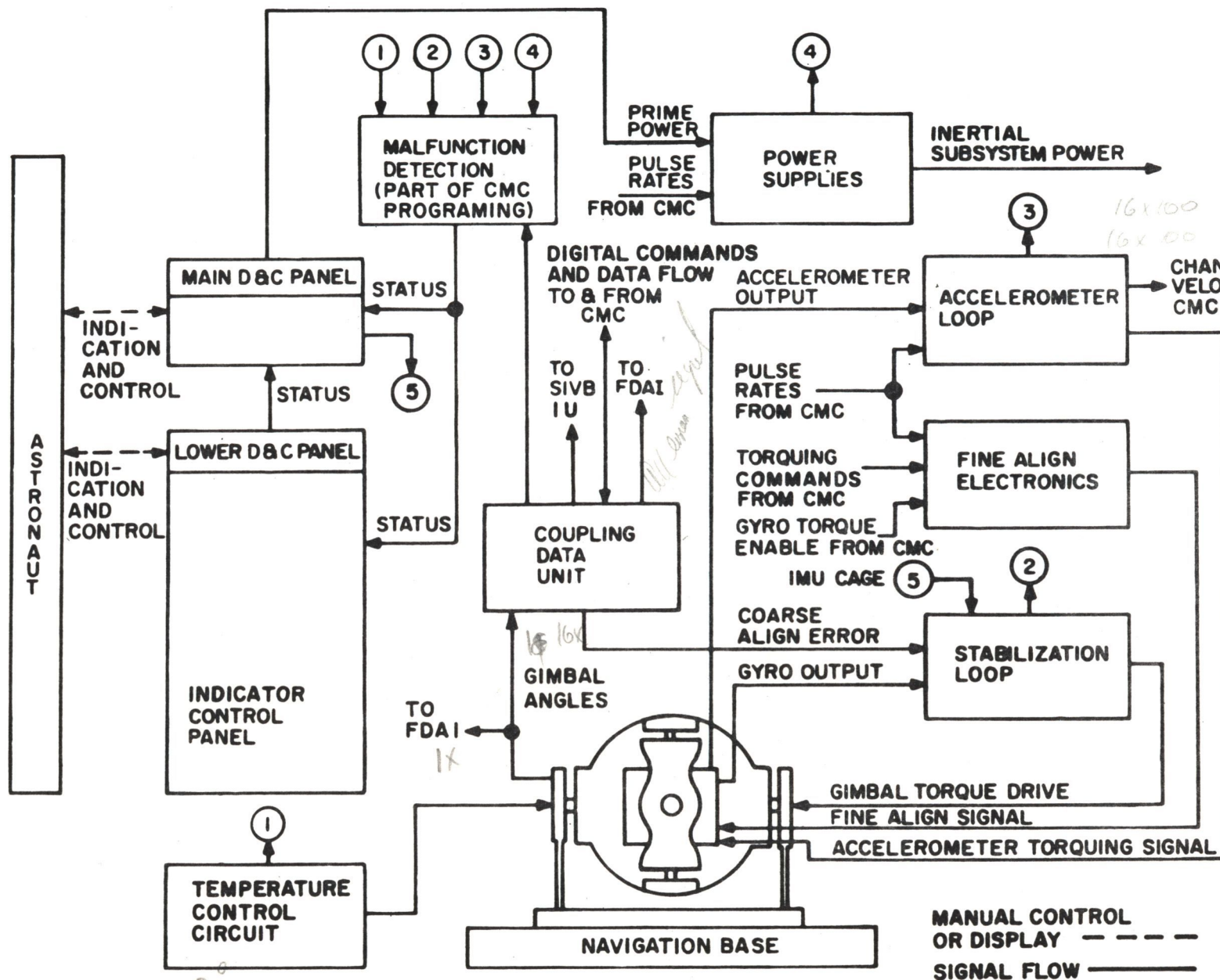
Figure 2-9 Callout Number	Module Name	Module Function
1	Relay Module	Provides relay switching for IMU control.
2	Gyro Calibration Module	Applies plus or minus torque pulses to IRIG's as directed by CMC.
3	DC Differential Amplifier and PVR Module	Supplies precision reference voltage for IRIG pulse torquing current control.
4	Binary Current Switch Module	Switches current pulses to one of the IRIG torque generators to control gimbal position.
5	Pulse Torque Power Supply Module	Supplies +120 vdc to PIPA loops and to fine align electronics. Also supplies +28 vdc, +20 vdc, and -20 vdc to PIPA loops.
6, 7, and 8	Gimbal Servo Amplifier Modules (X, Y and Z)	Amplifies outer (X), middle (Z), and inner (Y) gimbal error and supplies correction signals to the gimbal torque motors.
9	800 cps 5% Amplifier Module	Supplies 28 volts 800 cps for IMU blowers and PIP heaters. Also supplies 28 volts 800 cps ϕ B IRIG wheel power.
10	800 cps 5% Amplifier Module	Supplies 28 volts 800 cps for IMU blowers and PIP heaters and 28 volts 800 cps ϕ A IRIG wheel power.
11	-28 vdc Power Supply Module	Supplies power to the three gimbal servo amplifiers in the stabilization loop and the pulse torque power supply to generate -20 vdc for the accelerometer loop.
12	3,200 cps AAC Filter and Multivibrator Module	Regulates operation of the 3200 cps 1% amplifier.
13	IMU Load Compensation Module	Provides power factor correction for the 800 cps 1% and 5% power supplies.
14	3200 cps 1% Amplifier Module	Supplies 3200 cps ducosyn excitation and magnetic suspension voltage. Also used as a reference for gimbal servo amplifier demodulator in all modes of operation except the coarse align mode.
15	800 cps 1% Amplifier Module	Provides IMU resolver excitation and a reference to the FDAI and the 800 cps 5% amplifier.
16	800 cps 5% Amplifier Module	Supplies excitation for trunnion and shaft drive motors in the SXT and SCT.

PSA Modules

Figure 2-9 Callout Number	Module Name	Module Function
17	800 cps AAC Filter and Multivibrator Module	Supplies and regulates 800 cps voltage to the ISS 1% power amplifier.
18	800 cps AAC Filter and Multivibrator Module	Supplies and regulates 800 cps voltage to the OSS 1% power amplifier.
19	Optics Load Compensation Module	Provides power factor correction for 800 cps 1% and 5% power supplies.
20	800 cps 1% Amplifier Module	Provides resolver and tachometer excitation and a reference for the 800 cps 5% amplifier in the OSS.
21	G&N Subsystem Supply Filter	Filters the 0, 27.5, and 28 vdc power supplies for ISS standby power.
22 23 24	Relay Modules (3)	Provides OSS relay switching control.
25	Two Speed Switch Module	Provides signal selection for switching null seeking servo loops from coarse to fine resolver error detection in the OSS.
26	IMU Auxiliary Module	Indicates out of tolerance conditions on 28 vrms, 3200 cps, 28 vrms, 800 cps, the resolved IRIG pre-amplifier outputs and IMU temperature. Also provides the IMU turn-on moding discrete.
27	Anti-creep Electronics Module	Removes B+ from OSS motor drive amplifiers when the optics hand controller output drops below certain limits and thus prevents the optics from drifting.
28	Motor Drive Amplifier Module	Drives the SXT shaft motor.
29	Cosecant Generator Module	Maintains constant optics shaft image drive rate regardless of the trunnion angle in the manual resolved OSS mode.
30	Motor Drive Amplifier Module	Drives the SCT shaft motor.
31	Motor Drive Amplifier Module	Drives the SXT trunnion motor.
32	Optics Automatic Operate Relay Module	Provides relays for computer control of optics.

PSA Modules

Figure 2-9 Callout Number	Module Name	Module Function
33	G&N Subsystem Supply Filter Module	Filters 0, 27.5, and 28 vdc power for ISS operate power.
34	G&N Subsystem Supply Filter Module	Filters 0, 27.5 and 28 vdc power for OSS operate power.
35	Motor Drive Amplifier Module	Drives SCT trunnion motor.
36	SCT Moding Module	Provides SCT trunnion control.
37	Reticle Light Dimmer Module	Provides circuitry for controlling the brightness of the SXT and SCT reticle lamps.

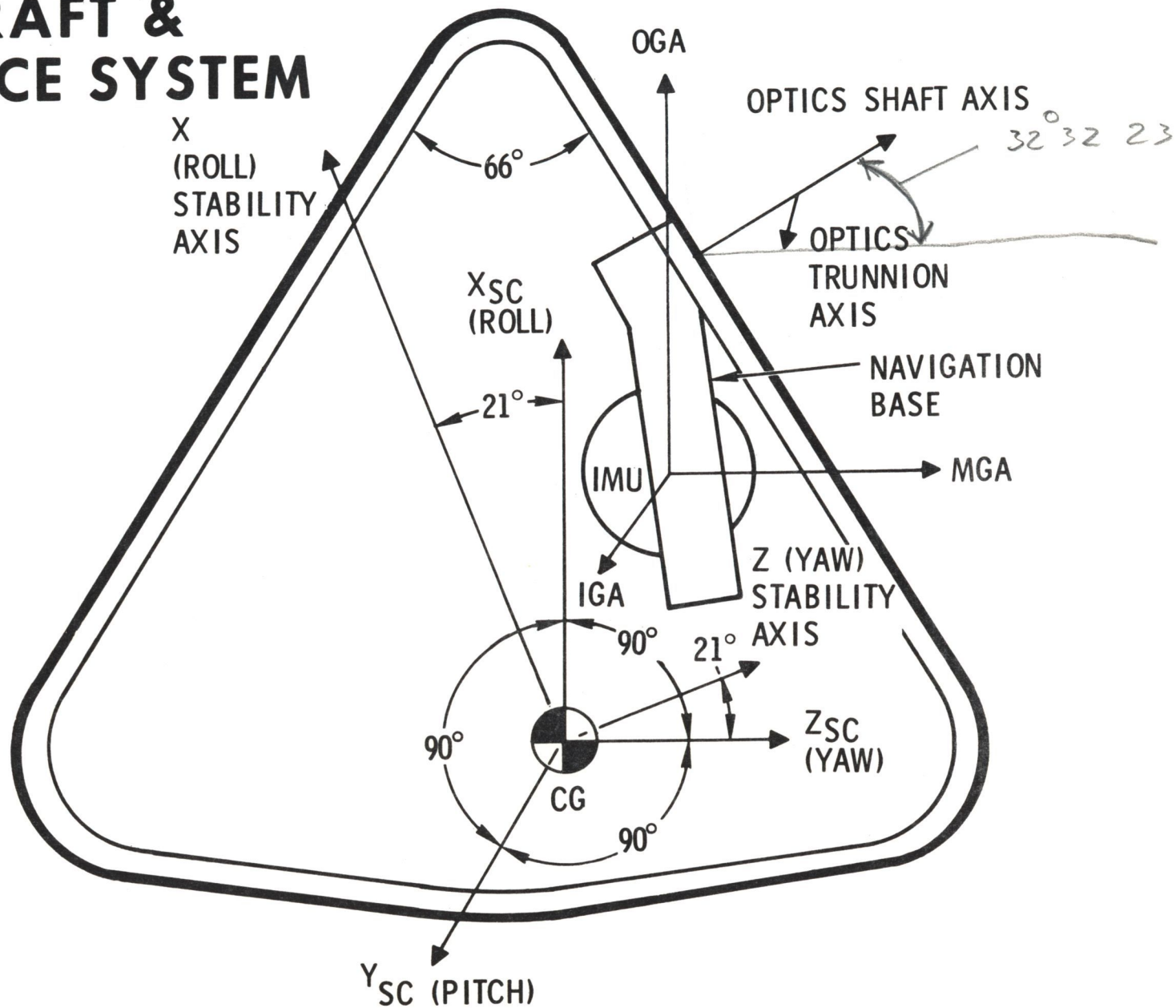


126-30
134-30

16x100 help
16x100 antenna change velocity

Inertial Subsystem Interface

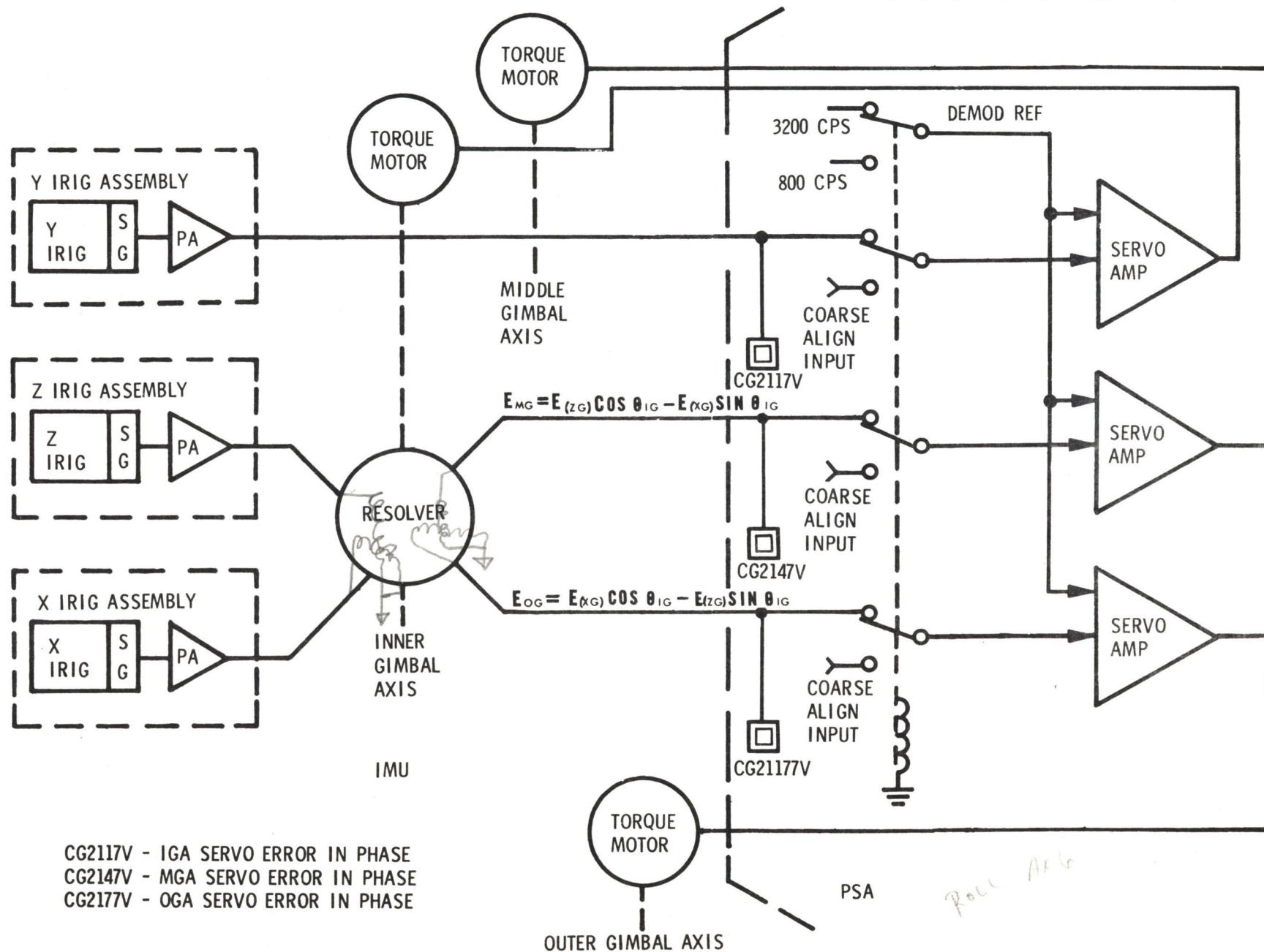
SPACECRAFT & GUIDANCE SYSTEM AXES



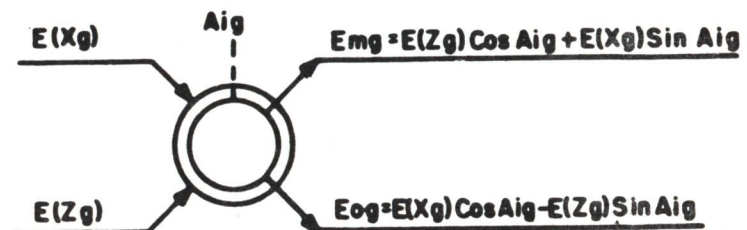
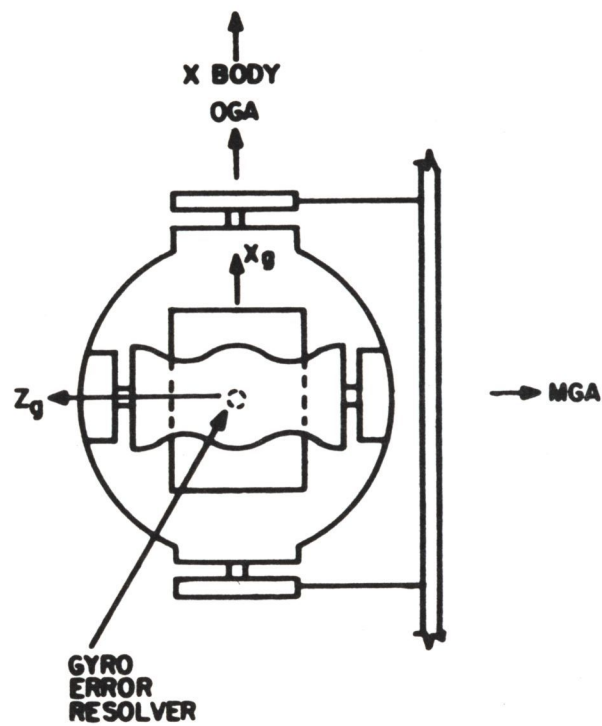
*Roll to Yaw
Corrections
? -05g*

REQUEST Co-ALIGN
V41 N20

BLOCK II STABILIZATION LOOPS



CG2117V - IGA SERVO ERROR IN PHASE
CG2147V - MGA SERVO ERROR IN PHASE
CG2177V - OGA SERVO ERROR IN PHASE



Gyro Error Resolver

Mechanical rest f.

0.5°

1.0°

Coarse Align with 15°

24,000 RPM

Hand bias drift
Less than 15 mrad

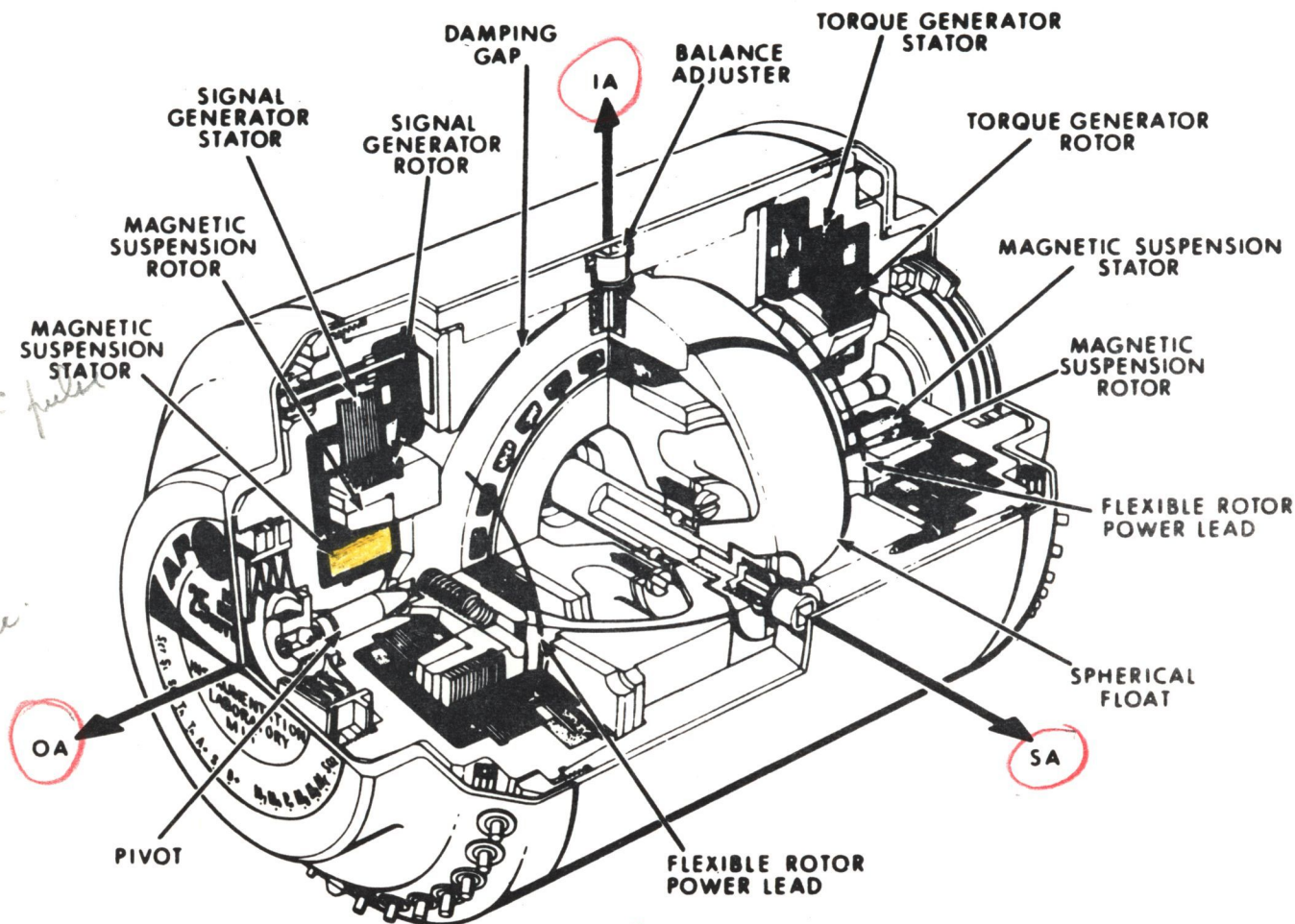
Jagun • 617981 One sec / core pulse

3200 Hz sec

0.617981 x 3200

= 1977.5392 One sec / pulse

Both in 1/2 sec



↑ VIEW FOR RHB

Apollo II IRIG (Generalized Pictorial Schematic)

4V 3200 ~

0V AC

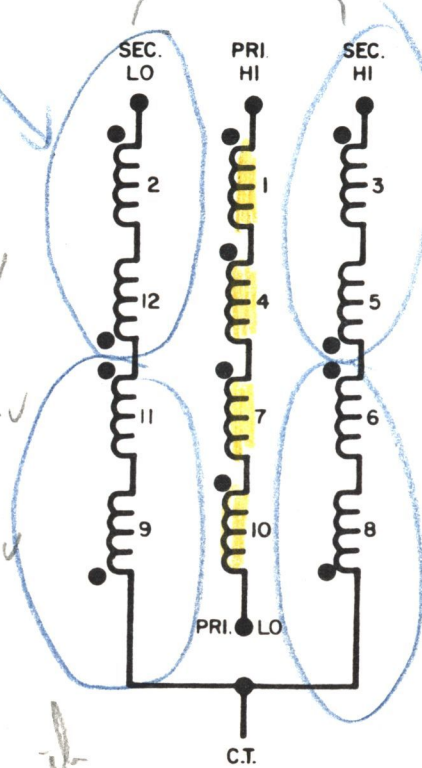
SERIES
OHMS

0.4V

0.4V

0.4V

0.4V

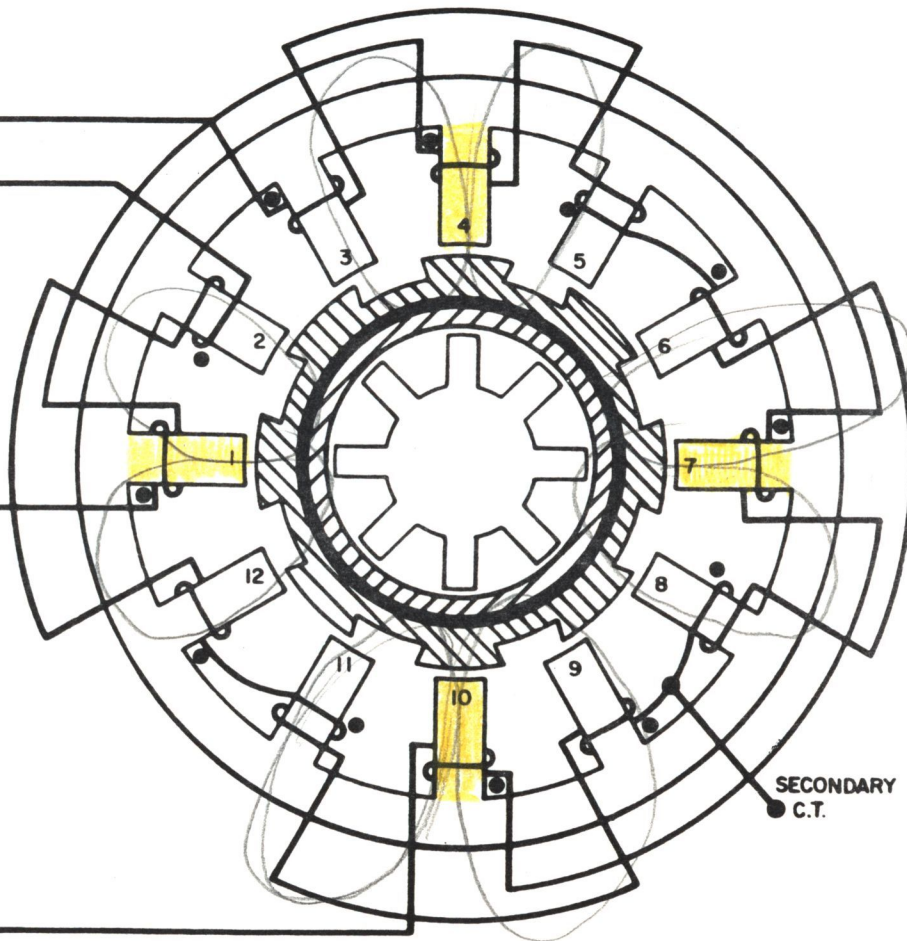


SECONDARY
HIGH
SECONDARY
LO

PRIMARY
EXCITATION
HIGH

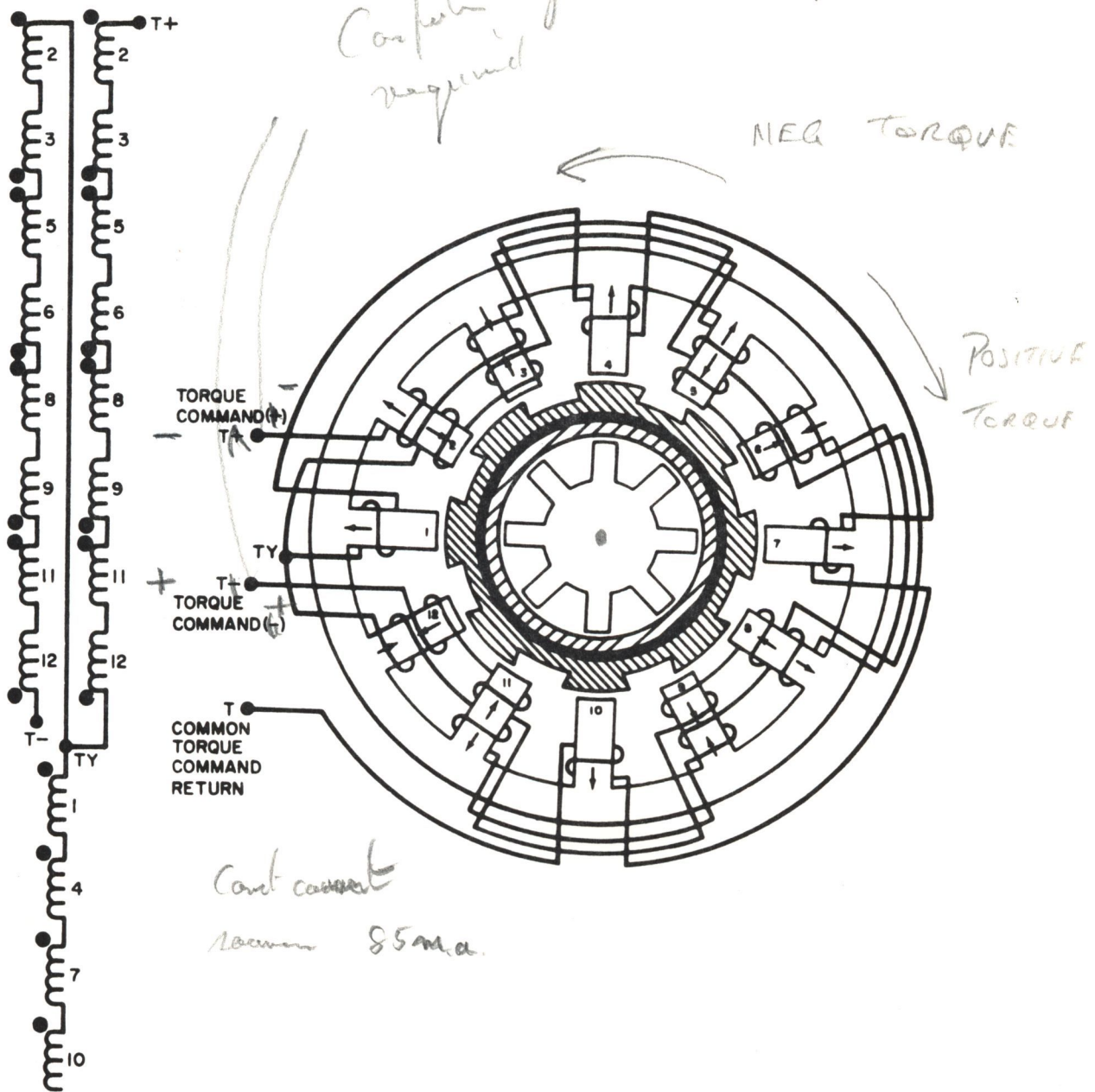
PRIMARY
LO

SECONDARY
C.T.

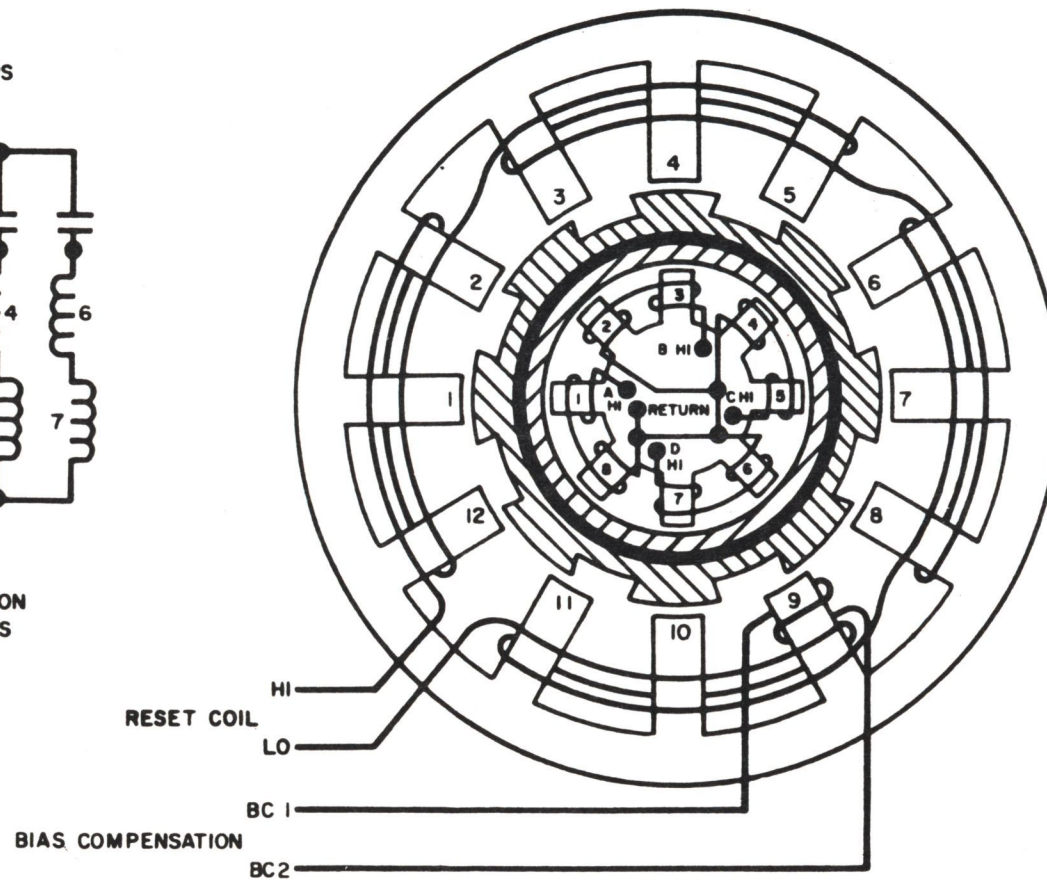
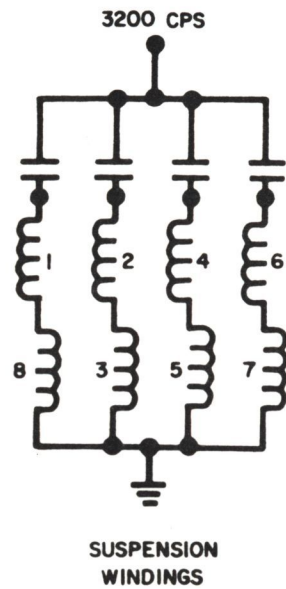


As water moves in
flow slowly will change
and peak output will
vary.

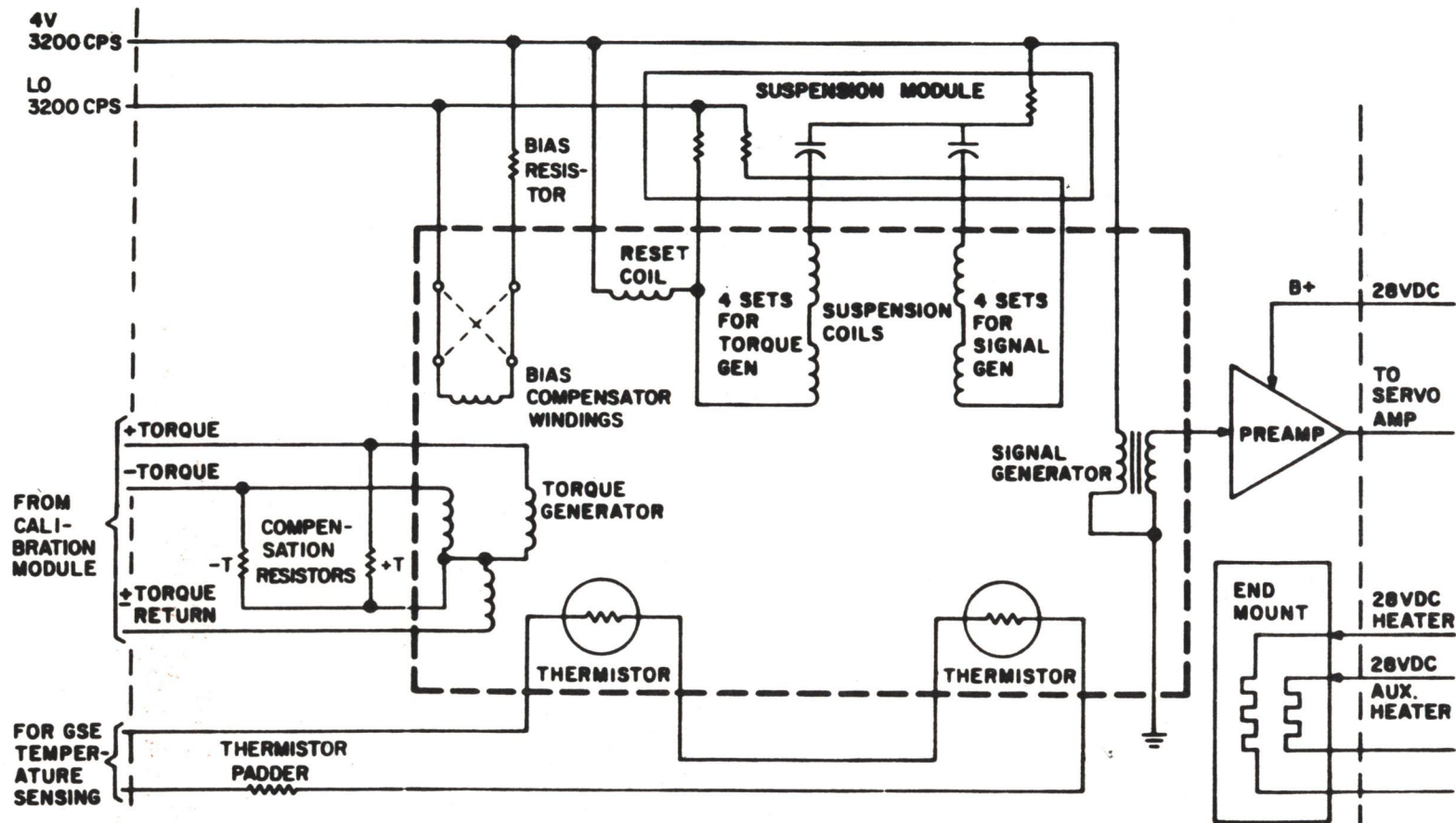
Signal Generator (SG Ducosyn)



Ducosyn Torque Generator

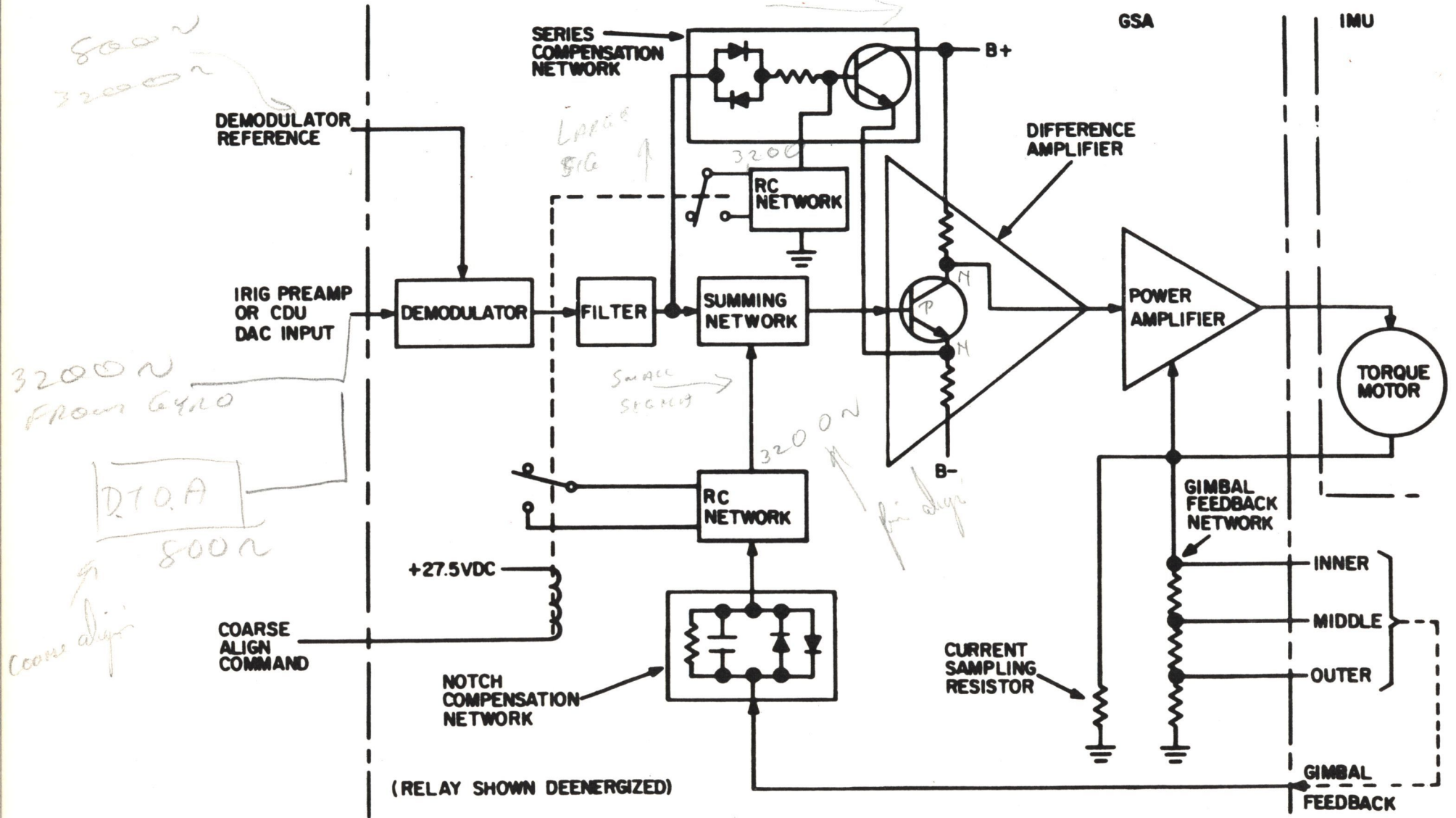


Reset, Bias and Suspension Windings (TG Ducosyn)



Apollo II IRIG Normalizing Assembly

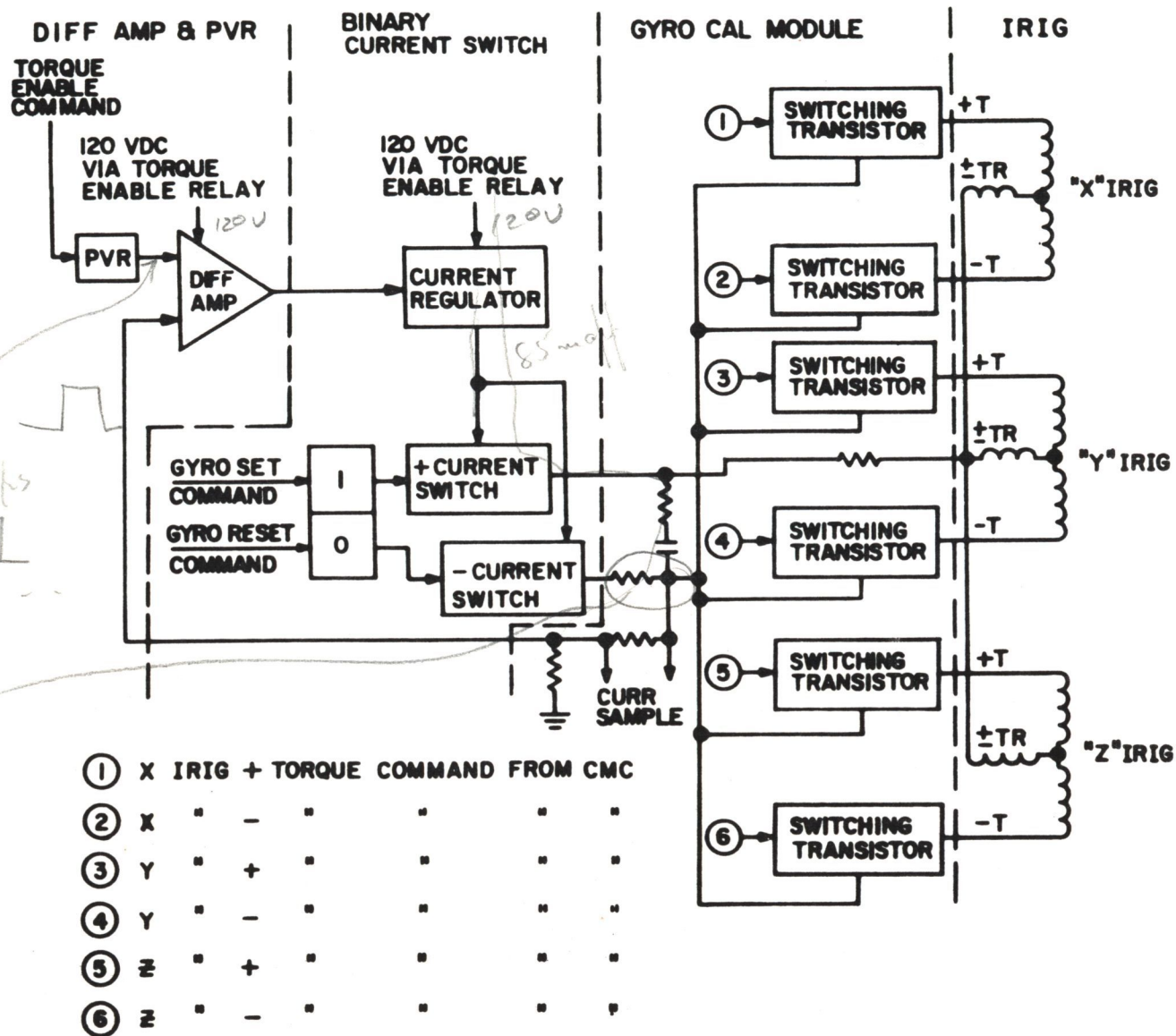
Limit as gain control



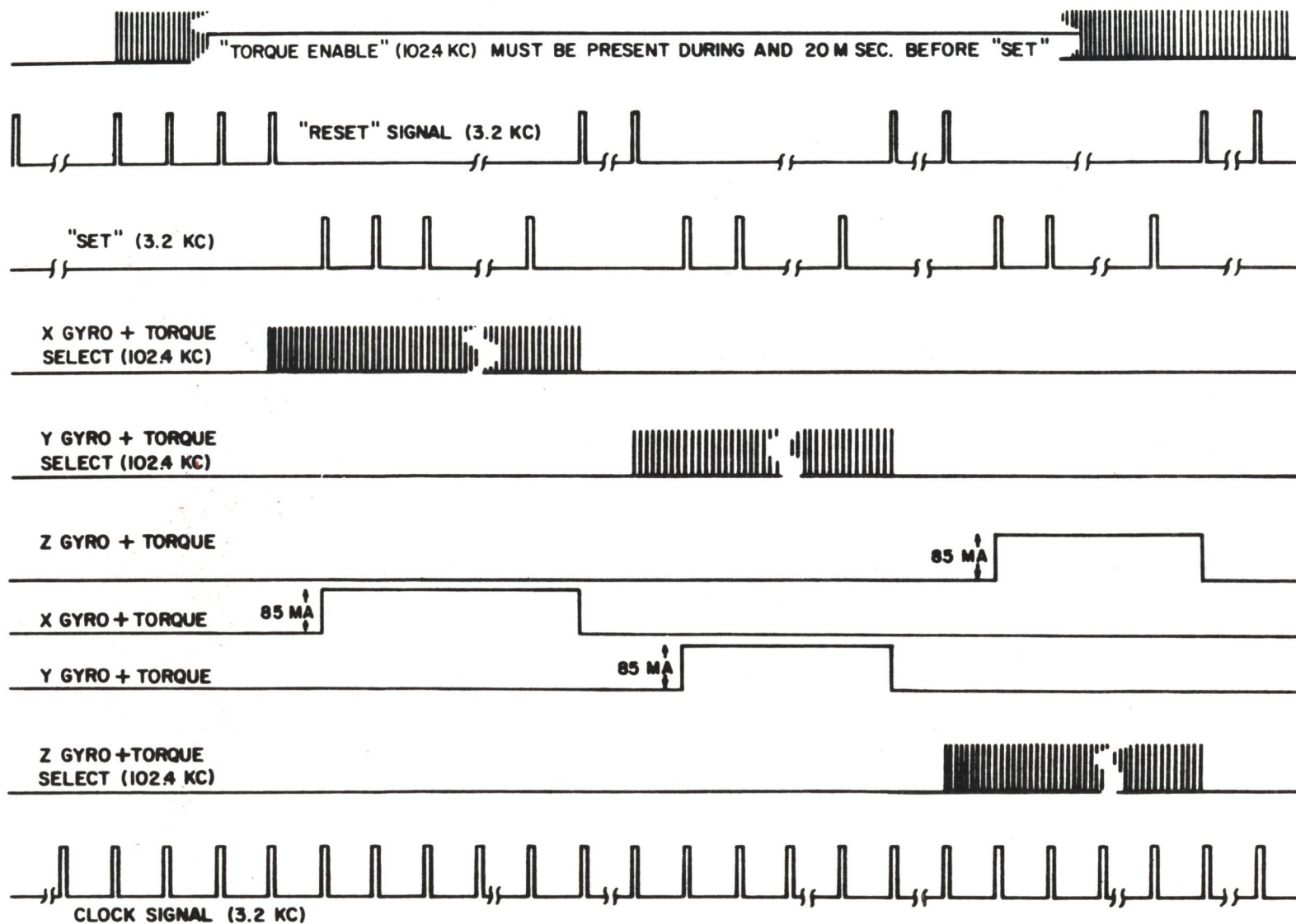
Block II Gimbal Servo Amplifier

FINE PLUGS REQUIRED A VERB 42 E

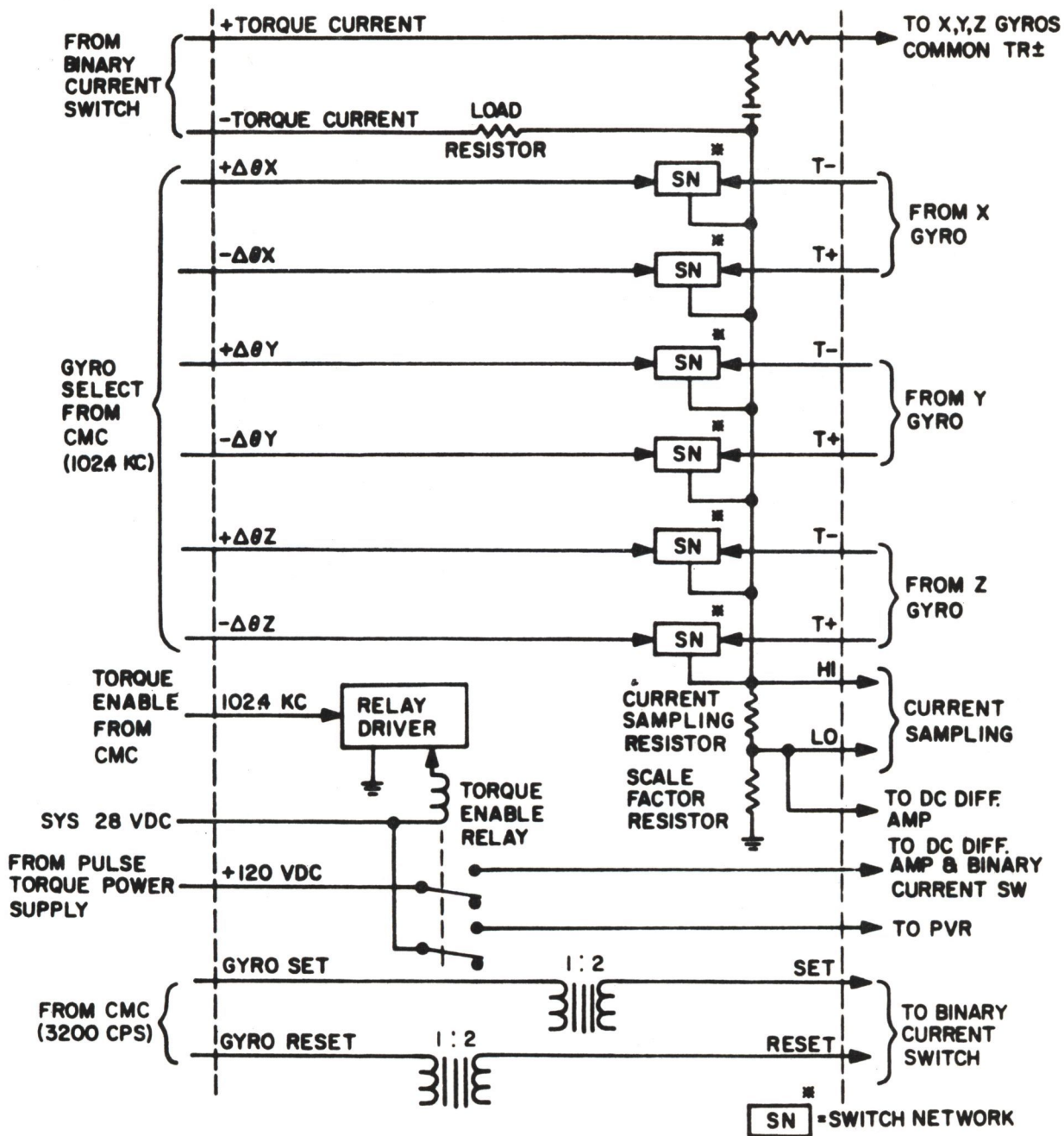
28V
6VDC
set pulse 3200 Hz
6178
Donny LOAD



Gyro Pulse Torquing Electronics



Gyro Torque Computer Pulse Timing

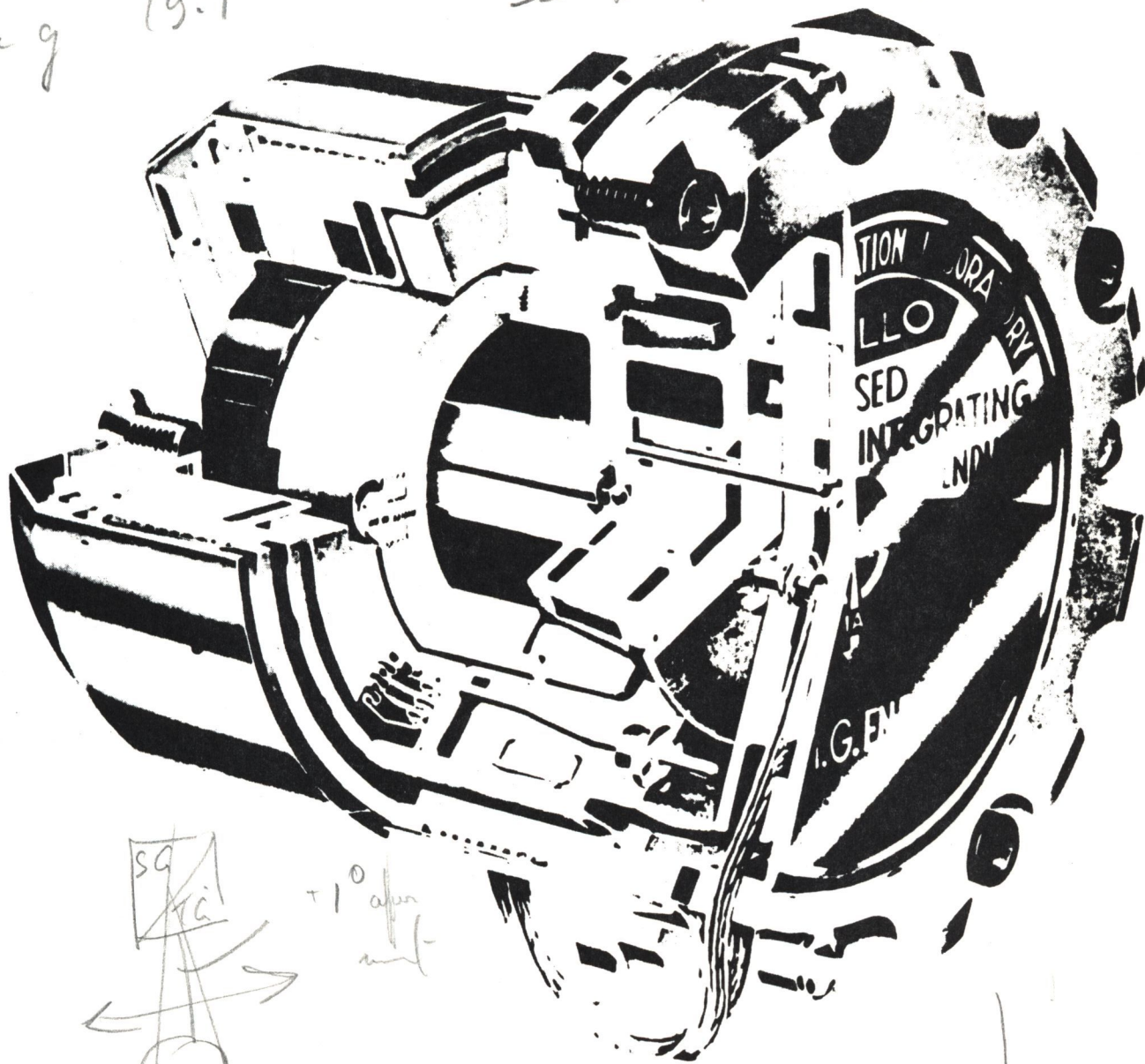


Calibration Circuit

Natural freq of pendulum is 500 cps
 each pulse is $\frac{6}{1000} g$

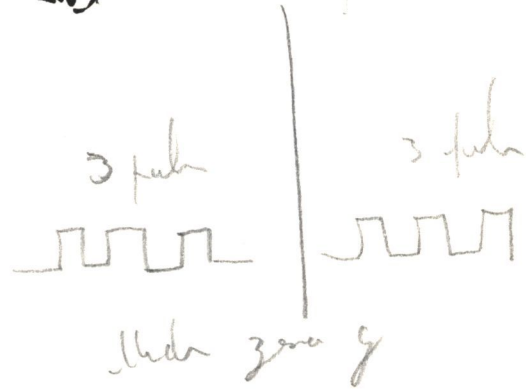
More g

19.1



+1° after
 melt

$533\frac{1}{3}$ CPS

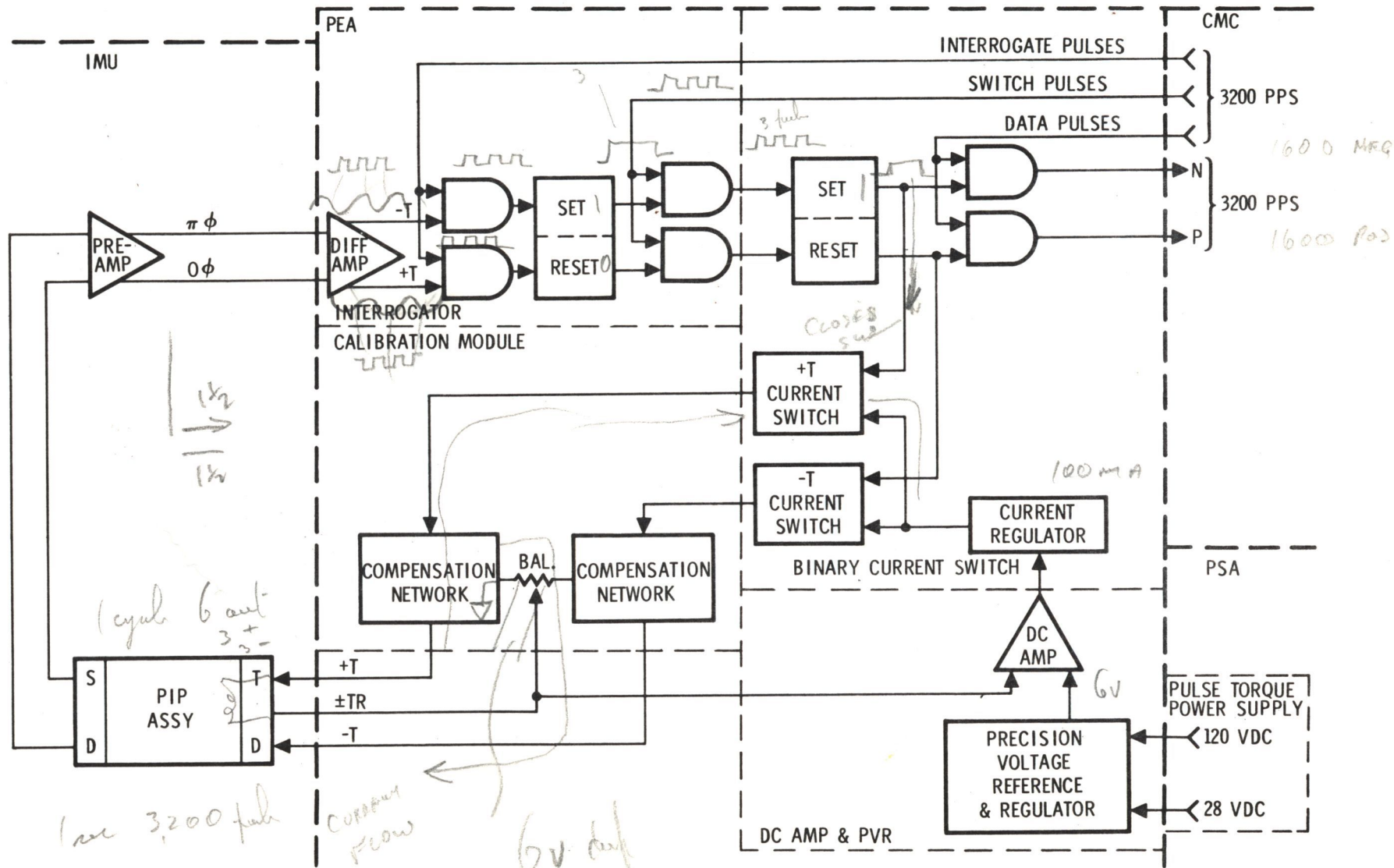


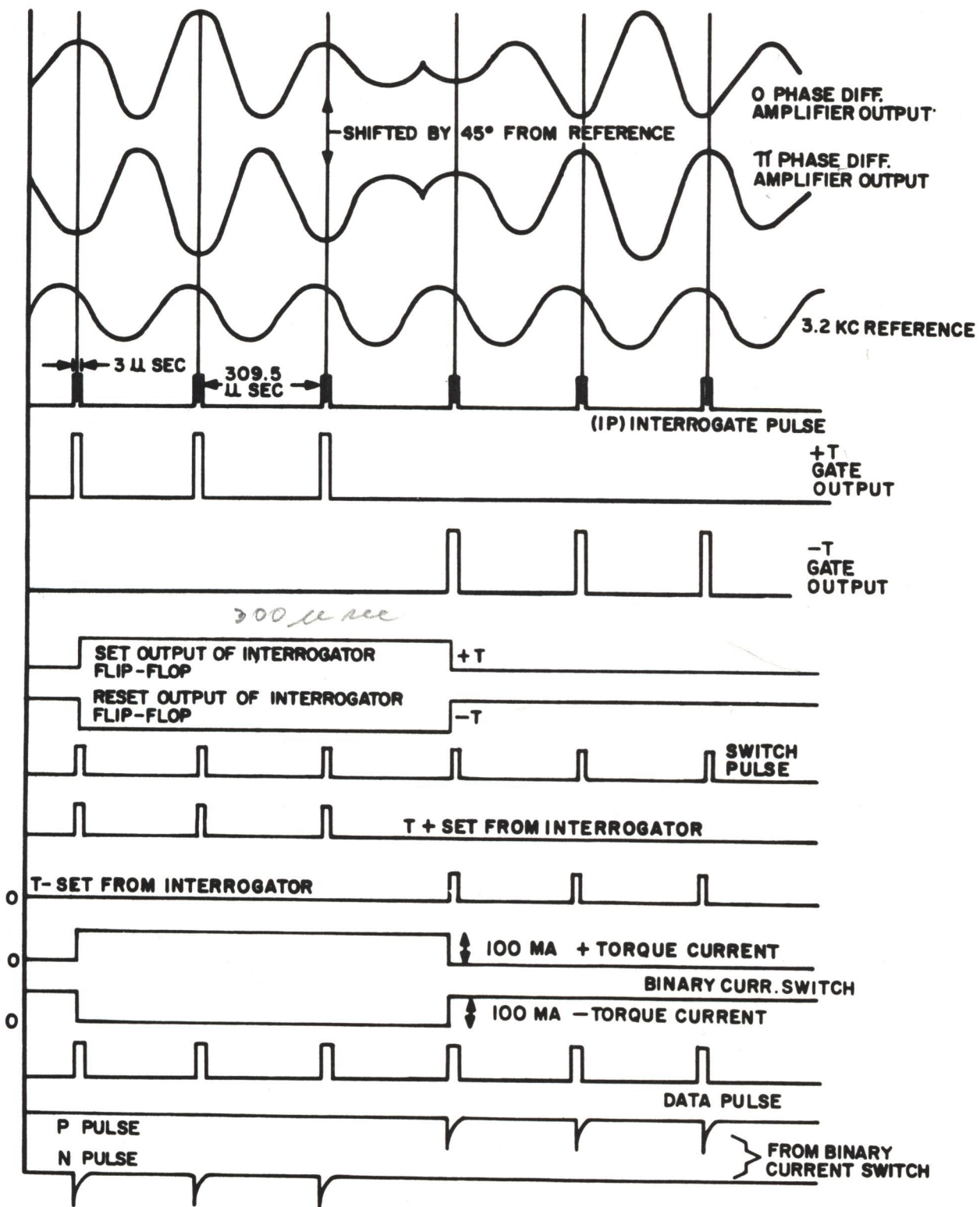
$$533\frac{1}{3} \overline{) 3200} \begin{array}{r} 6. \\ 3200 \end{array}$$

16 PIP

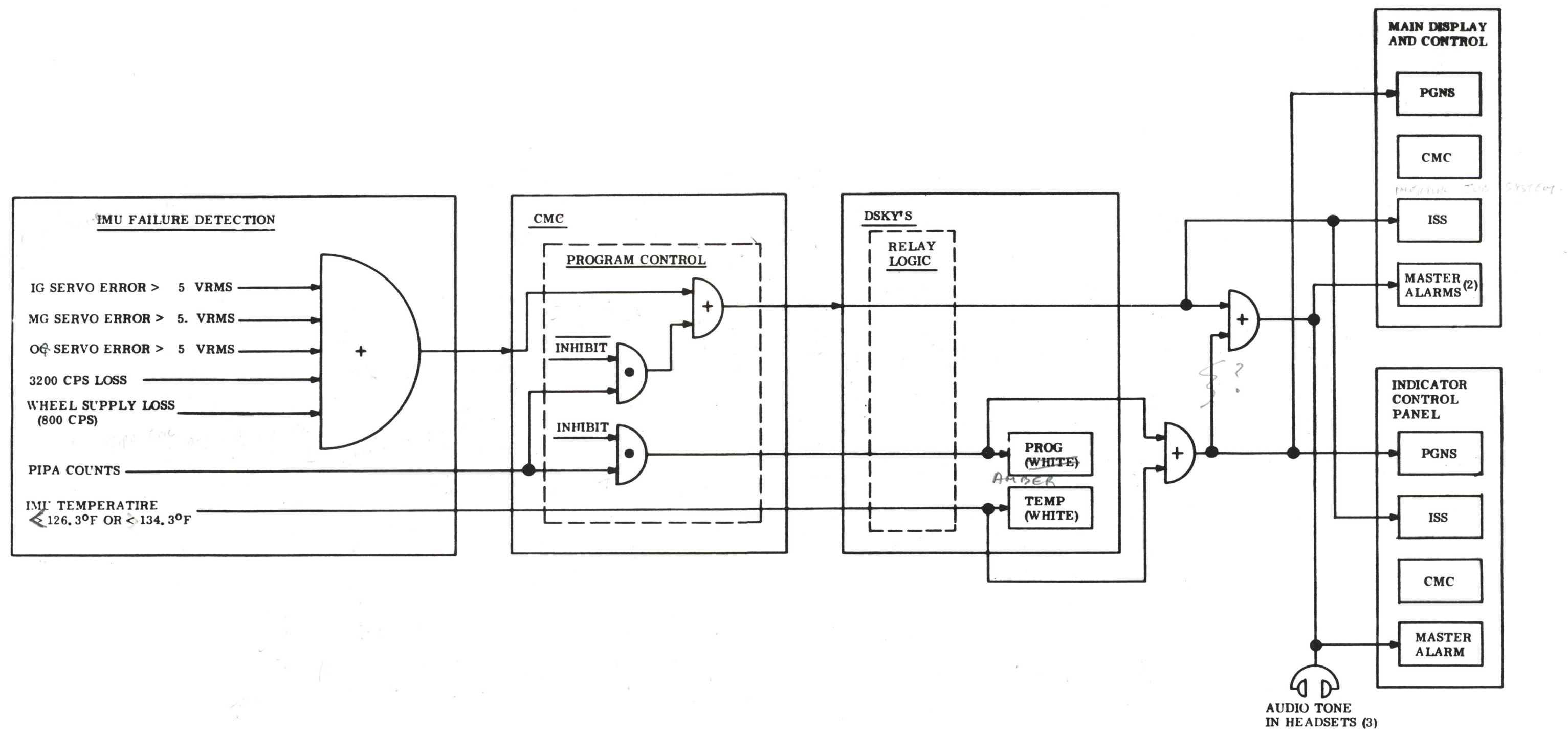
ACCELEROMETER LOOP

BLOCK II

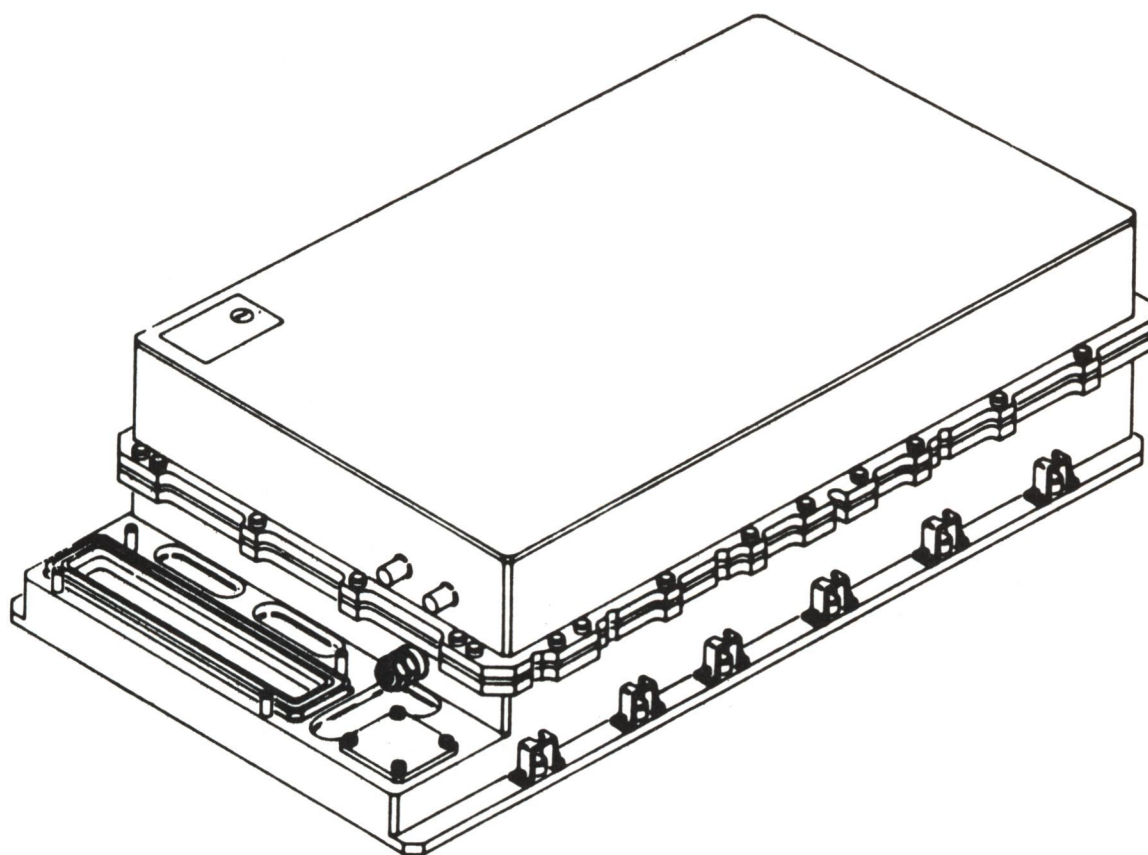




Pulse Diagram - PIPA Loop



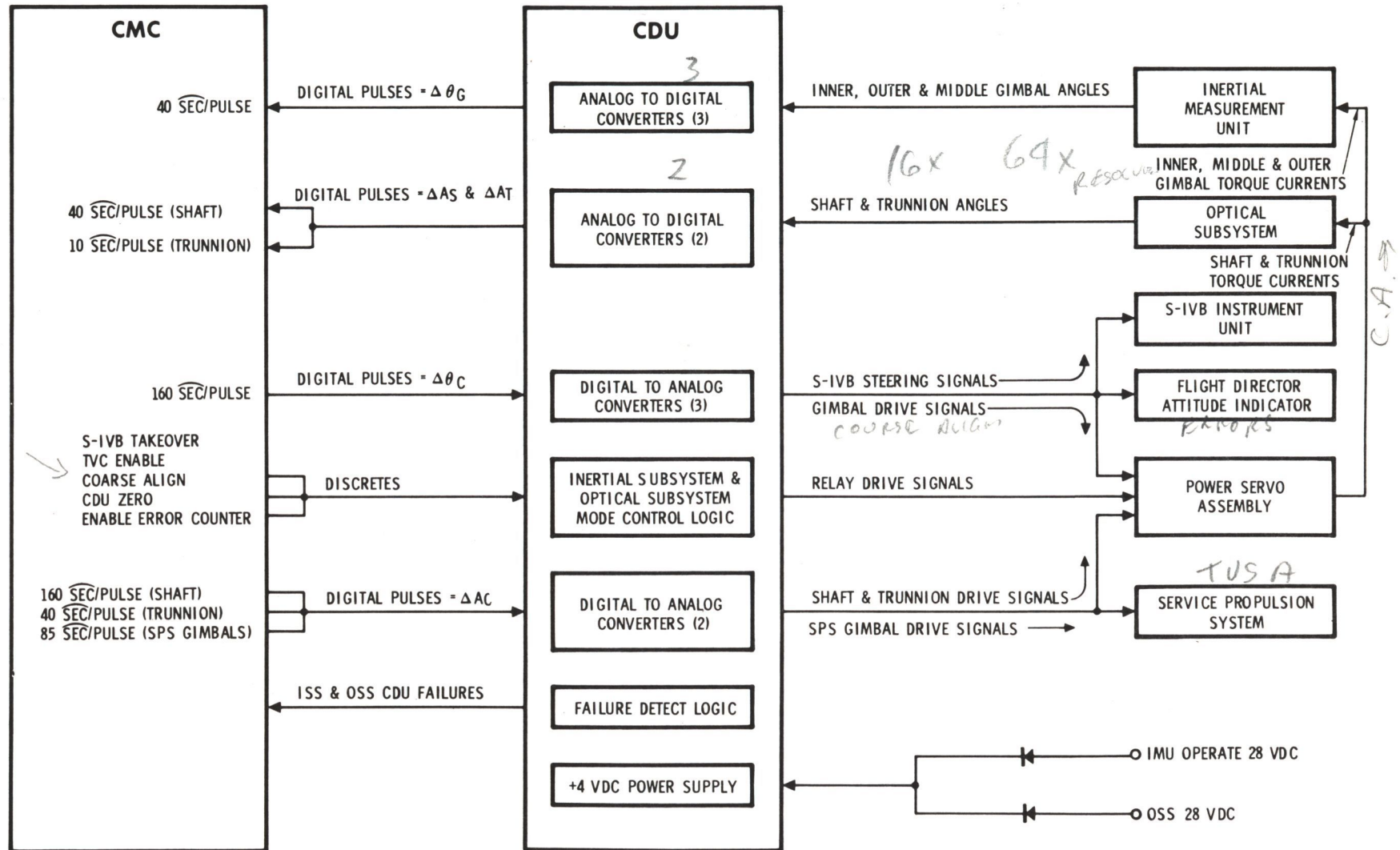
ISS Failure Detection



16072

Coupling Data Unit

CDU FUNCTIONAL INTERFACES

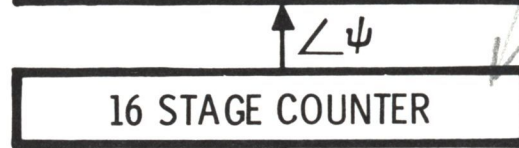
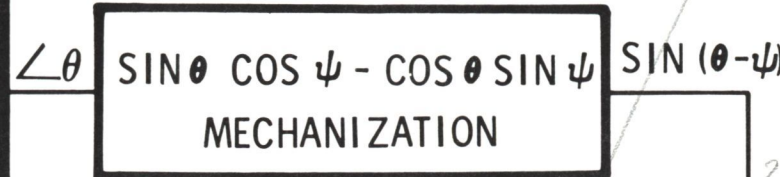
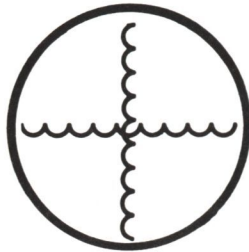


ALL DESCRIBE
SIGNALS

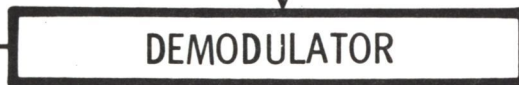
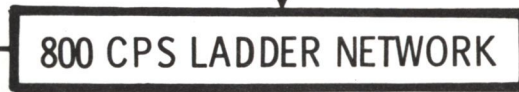
CDU SINGLE CHANNEL

CDU

RESOLVER



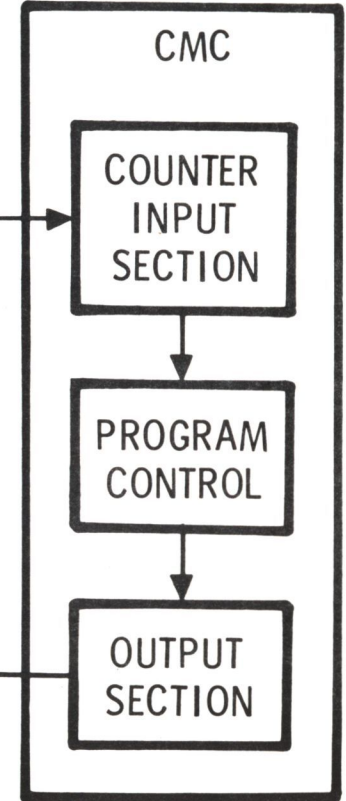
ANALOG TO DIGITAL CONVERTER



DIGITAL TO ANALOG CONVERTER

AC
DRIVE SIGNALS •

DC
DRIVE SIGNALS •



655536 counts to amplifier

65535

359.59' 40" + 20

360
↑
counts meter to C

1 count
↓
20 sec
19. ...
are the actual values

amplitude to output is 1 bit for 2nd stage counter.

45
64,800 20 sec counts in 360°

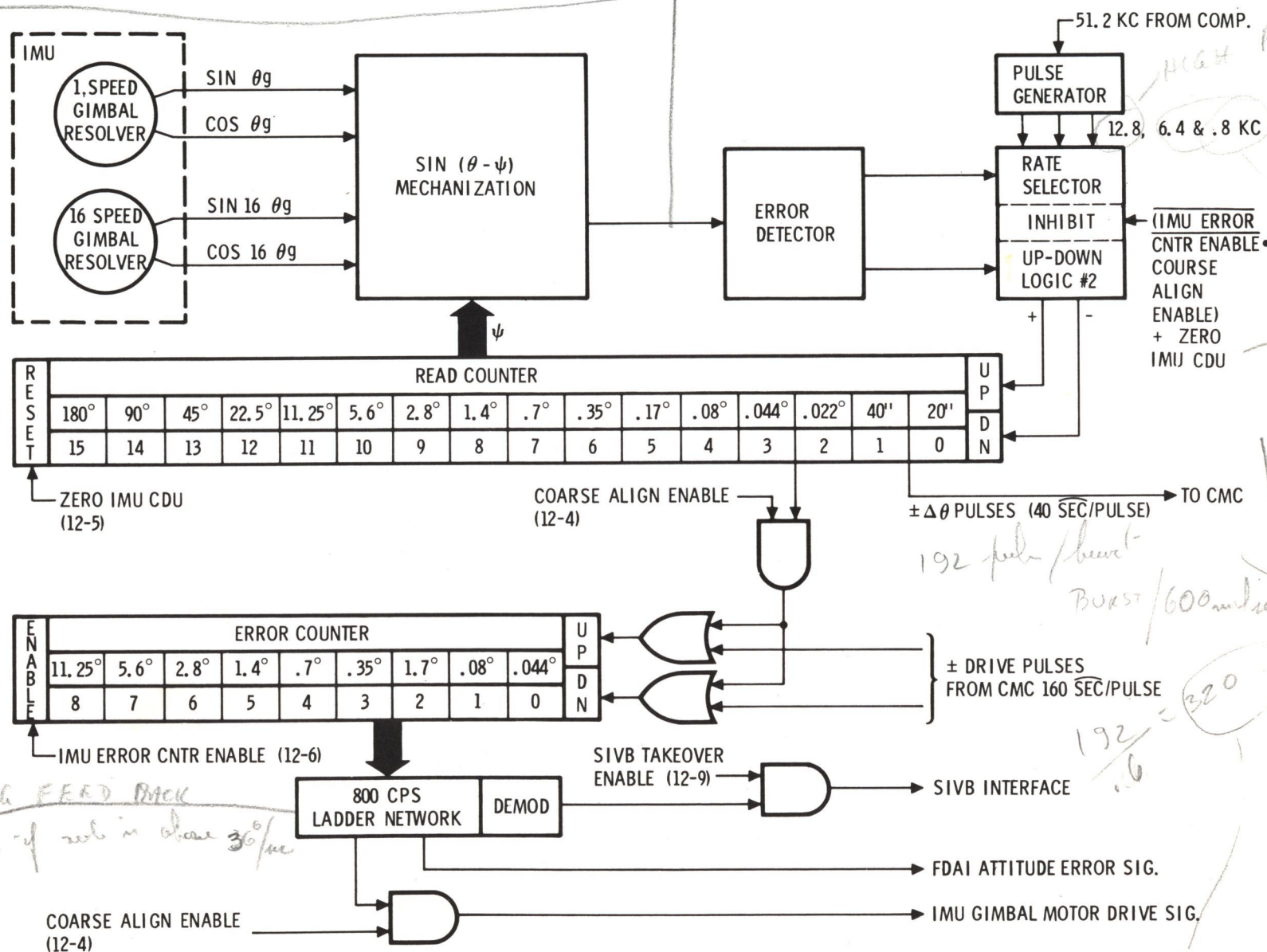
System will load at approx 72° per rate

for count \rightarrow 12.8 KP/sec
 $\times 20$

256×10^3 one sec per

approx 72° per

ICDU FUNCTIONAL BLOCK DIAGRAM



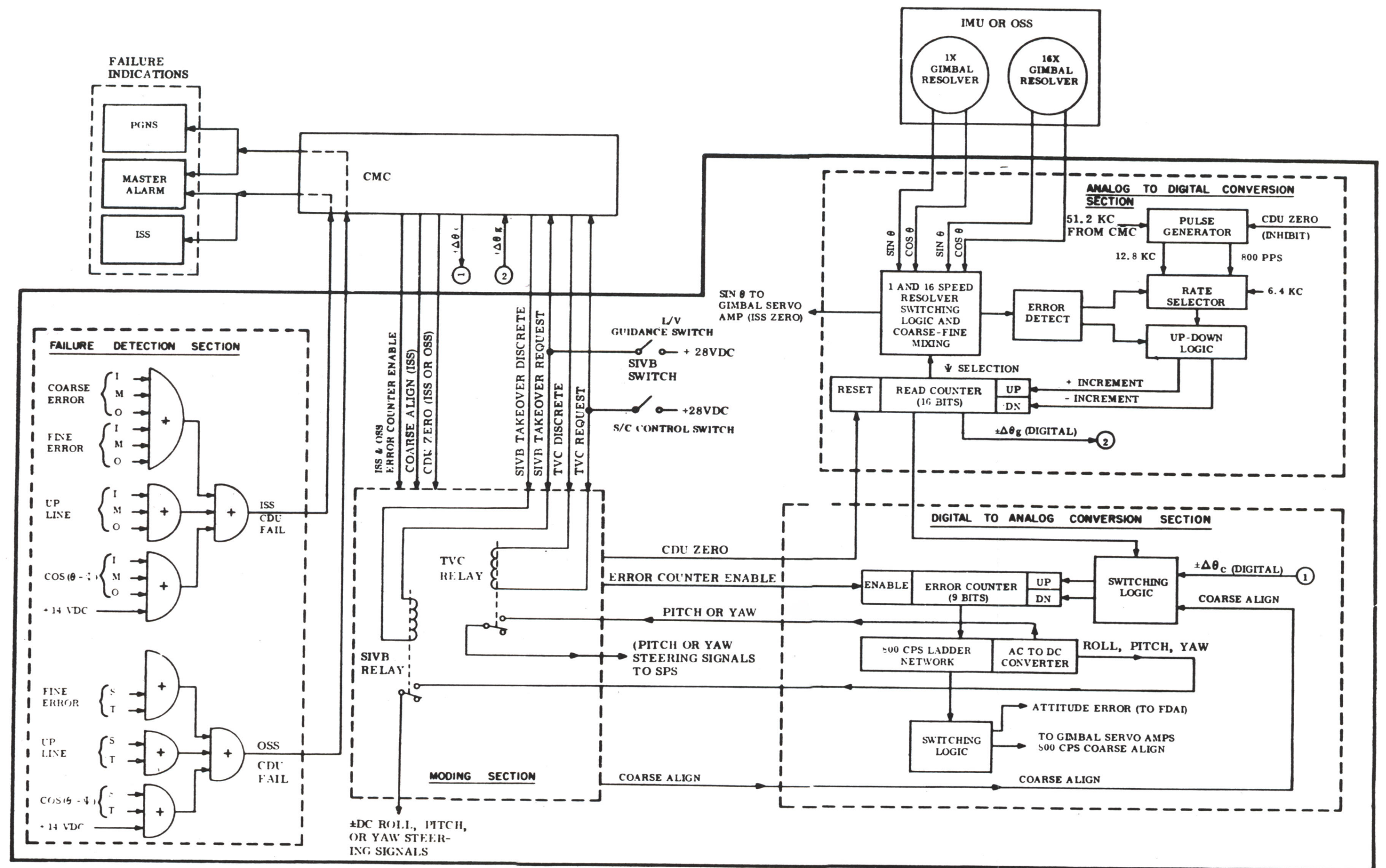
36°/sec drive rate

NEG FEED BACK
occurs if rate is above 36°/sec

HIGH RATE
LOW RATE
REC. CH (17)

192 = 220

will interface with counter



CDU Functional Diagram

ISS - SYSTEM MODES OF OPERATION

INTRODUCTION

This section of the study guide is primarily concerned with the modes of operation which involve the IMU. This covers both the ISS modes and the PGNCS system modes. These modes interface with the CSS and may be entered by D and C panel switch, by DSKY input and/or by program input. Table 4-1 contains a list of these modes of operation, a list of appropriate CMC input-output channels and a matrix showing the discrete and mode relations.

4.1 ISS TURN-ON MODE

The purpose of the ISS turn-on mode is to initialize the ISS. This is accomplished under program control of the CMC. The following is a list of functions which are initiated by the CMC's T4 rupt routine:

- a. zero the IMU gimbal angles.
- b. allows the gyro wheels to run up to speed.
- c. inhibits the pulse torque power supply for 90 sec.
- d. zeros and inhibits the ISS read and error counters in the CDU.
- e. zeros the CDU counters in E memory.

The CMC controls the ISS turn-on mode by accepting, issuing, timing and inhibiting selected discretes. The timed sequence for handling these discretes is as follows: The CMC recognizes the ISS operate (CH 30-09) and the ISS turn-on delay request (CH 30-14) discretes as requests for program control of the turn-on sequence. This causes the CMC to remove the ISS enable error counter (EEC) (CH 12-06) and the ISS turn-on delay complete (CH 12-15) discretes if they exist. Then the ISS coarse align (CA) (CH 12-04) and ISS CDU zero (Z) (CH 12-05) discretes are issued and the "NO ATTITUDE" lights on the DSKY's are turned on. This is followed by the inhibiting of the PIPA fail (CH 33-13), ISS CDU FAIL (ICDU) (CH 30-12) and the IMU fail (CH 30-13) discretes. After a 90 second delay, the 90 sec delay complete (CH 12-15) discrete is issued, the "NO ATTITUDE" lamps are turned off, the CDU counters in E memory are set to zero, and the CA and Z discretes are removed. Four seconds later, the PIPA, the ICDU, and the IMU fail inhibits and the 90 sec delay complete discretes are removed.

Standby power is applied to the PGNCS by way of circuit breakers CB58 and/or CB59. To initiate the ISS turn-on mode, ISS operate power must be applied to PGNCS by way of CB56 and/or C57 and the IMU G & N power switch (S2) on the lower equipment bay (LEB). Reference figure 4-1. ISS operate power is applied directly to CH 30-09 (ISS operate) discrete and through the deenergized contacts of the auto cage relay to CH 30-14 (ISS turn-on delay request) and to the cage relays.

ISS - System Modes of Operation	CMC Output									CMC Input							
	Gyro Torque Enable (CH 14-06)	ISS CDU Zero (CH 12-05)	Coarse Align Enable (CH 12-04)	ISS Error Counter Enable (CH 12-06)	SIVB Take-over Enable (CH 12-09)	Thrust Vector Control Enable (CH 12-08)	Optics Error Counter Enable (CH 12-02)	Turn-on Delay Complete (CH 12-15)	SPS Engine On/Off (CH 11-13)	RCS Jet Selection (CH 5-1 thru 8) (CH 6-1 thru 8)	IMU Cage (CH 30-11)	Turn-on Delay Request (CH 30-14)	G & C A/P Control (SPS Ready) (CH 30-03)	ISS Operate (CH 30-09)	S/C Control of Saturn (CH 30-10)	S/C Autopilot Control (CH 31-15)	Auto or Hold Function
ISS TURN-ON		X	X					X			X		X				
ISS COARSE ALIGN			X	X									X				
ISS FINE ALIGN	X												X				
ISS INERTIAL													X				
ISS CDU ZERO		X											X				
IMU CAGE		X	X							X			X				
DISPLAY ATTITUDE ERROR				X									X				
GIMBAL LOCK			X										X				
SIVB TAKE-OVER				X	X								X	X			
THRUST VECTOR CONTROL						X	X		X	X		X	X		X		
ATTITUDE CONTROL				X									X			X	

ISS - System Modes of Operation

4.1 ISS TURN ON MODE

4.1.1 PURPOSE. To initialize the ISS by

- a. Driving the IMU gimbals to zero
- b. Driving the CDU read counters to zero
- c. Set the CMC E memory counters to zero.

ERASEABLE

4.1.2 METHODS OF ENTRY. By placing the IMU operation circuit breaker (4-CB-124, Panel XI) to the on position. (with CMC in OPERATE)

4.1.3 DISCRETES. Computer inputs.

- a. IMU operate discrete CH 30-09
- b. ISS turn on delay requests CH 30-14

Computer outputs.

- a. IMU CDU zero CH 12-05
- b. Coarse align enable CH 12-04
- c. ISS turn on delay request complete CH 12-15

4.1.4 COMPUTER ROUTINES. T4RUPT (Sampled for turn on every 480 msec)

4.1.5 DISPLAY AND CONTROL INDICATION. "No Attitude" light on DSKY turned on for 90 seconds.

Inhibit PIPA fail, ISS CDU fail and IMU fail.

4.1.5 OPERATION. The CMC controls the ISS turn-on mode by accepting, issuing, timing and inhibiting selected discrettes. The timed sequence for handling these discrettes is as follows: The CMC recognizes the ISS operate (CH 30-09) and the ISS turn-on delay request (CH 30-14) discrettes as requests for program control of the turn-on sequence. This causes the CMC to remove the ISS enable error counter (EEC) (CH 12-06) and the ISS turn-on delay complete (CH 12-15) discrettes if they exist. Then the ISS coarse align (CA) (CH 12-04) and ISS CDU zero (Z) (CH 12-05) discrettes are issued and "NO ATTITUDE" lights on the DSKY's are turned on. This is followed by the inhibiting of the PIPA fail (CH 33-13), ISS CDU FAIL (ICDU) (CH 30-12) and the IMU fail (CH 30-13) discrettes. After a 90 second delay, the 90 sec delay complete (CH 12-15) discrete is issued, the "NO ATTITUDE" lamps are turned off, the CDU counters in E memory are set to zero, and the CA and Z discrettes are removed. Four seconds later, the PIPA, the ICDU, and the IMU fail inhibits and the 90 sec delay complete discrettes are removed.

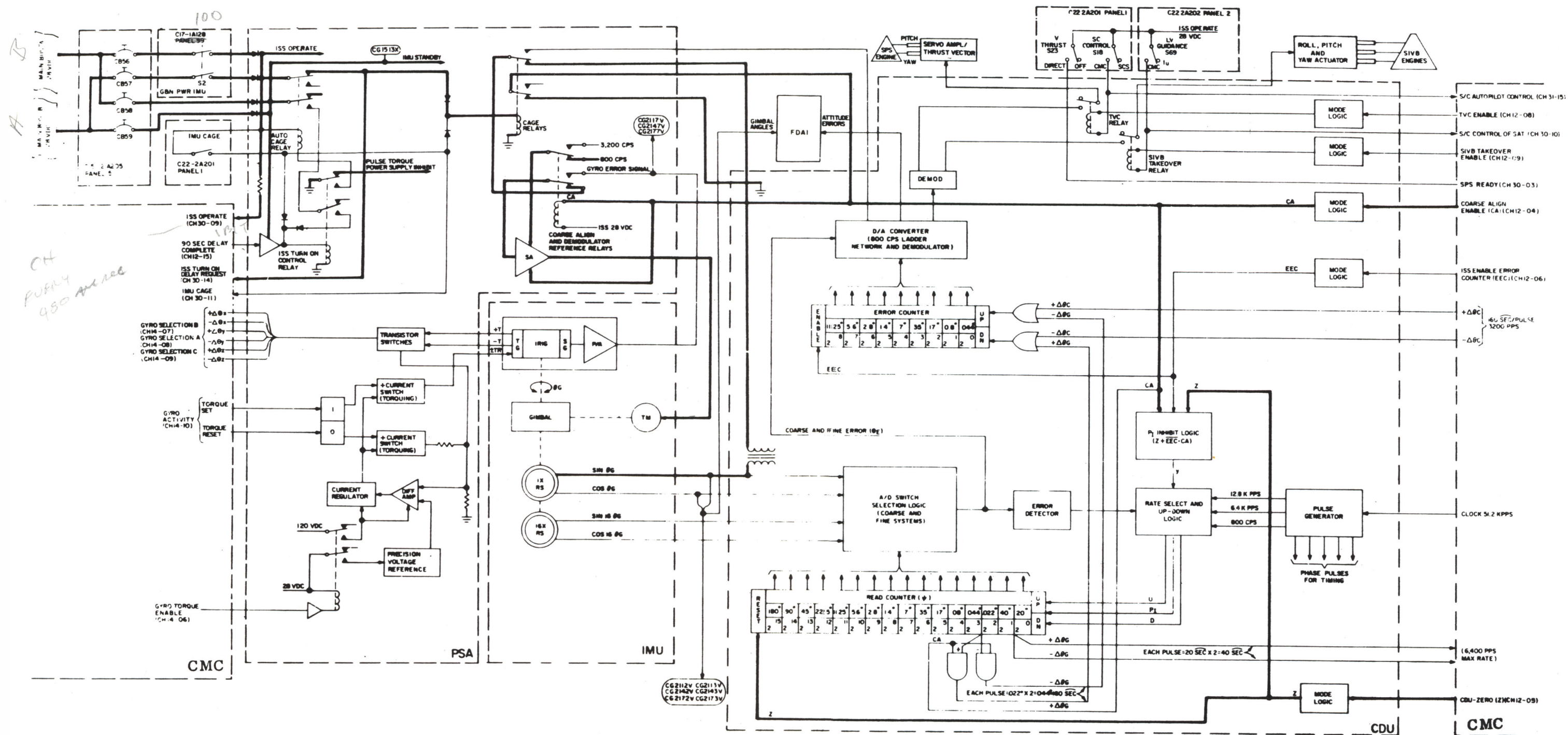
Closure of the switch (S2) applies 28 vdc to the cage relays through the deenergized contacts of the auto cage relay, and applies 28 vdc to CH 30-14 of the CMC. The cage relays energize and, in turn, cause the coarse align relays to be energized. The cage relays route the 1X gimbal resolver sine winding outputs through the contacts of the coarse align relays to the respective gimbal servo amplifiers. The gimbal servo amplifiers drive the gimbals until the resolver signals are nulled. The operation of the caging loops is discussed further in the IMU cage mode description.

Upon receipt of the ISS turn on delay request discrete, the CMC sends the ISS CDU zero discrete and the coarse align enable discrete to the CDU for a minimum period of 90 seconds. The CDU zero discrete clears the read counters and inhibits the incrementing pulses to the read counters. The coarse align enable discrete provides a redundant means of energizing the coarse align relays.

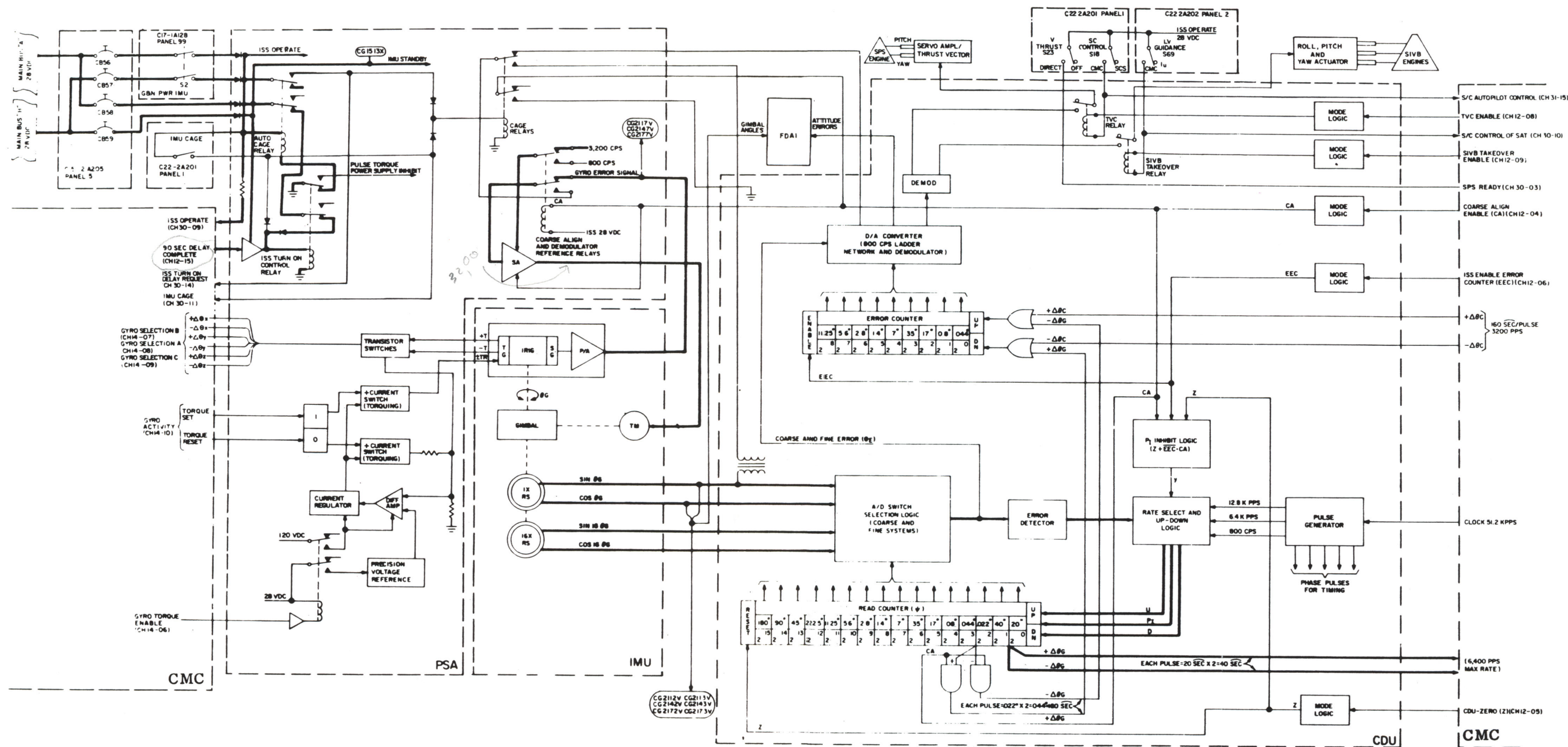
A second set of deenergized contacts on the ISS turn on control relay routes a ground to the time delay circuit of the pulse torque power supply which inhibits the operation of the power supply and thus prevents accelerometer pulse torquing during the 90 second turn on period. This allows time for the accelerometer floats to be centered and the gyro wheels to run up prior to torquing.

After the 90 second delay has been completed, the CMC sends the ISS turn on delay complete discrete. This discrete acts through a relay driver to energize and latch in the ISS turn on control and the auto cage relays. Refer to figure 4-1.

Energizing the ISS turn on control relay deenergizes the cage relay, removes the ISS turn on delay request discrete, and removes the inhibit from the pulse torque power supply. The computer program can then place the ISS in the inertial reference mode by removing both the CDU zero and the coarse align enable discrettes, or it can initiate the coarse align mode by removing only the CDU zero discrete and sending the ISS enable error counter discrete. The IMU turn on circuit will be reset whenever 28 vdc IMU operate power is turned off.



ISS Turn-on Mode (Sheet 1 of 2)



ISS Turn-on Mode (Sheet 2 of 2)

4.2 ISS COARSE ALIGN

4.2.1 PURPOSE. To allow the CMC to rapidly align the IMU to a desired position with a limited degree of accuracy.

4.2.2 METHODS OF ENTRY.

a. Computer routine

b. DSKY entry V41 N20E

4.2.3 DISCRETES.	Computer Inputs:	IMU operate
	Computer Outputs:	Coarse Align Enable IMU Error Counter Enable

4.2.4 COMPUTER ROUTINES. IMU COARS Routine.

4.2.5 DISPLAY AND CONTROL INDICATIONS. No attitude lamp on during routine.

4.2.6 OPERATION. The CMC knowing the actual gimbal angle registered in the read counters, will calculate the desired amount of change of gimbal angles required to reposition the gimbals to the desired angles and loads this information in the appropriate CMC X, Y, or Z command registers. The CMC converts this change into a number of $\pm\Delta\theta C$ pulses and sends these pulses to the error counters. The $\pm\Delta\theta C$ pulses are sent to the error counters at a rate of 3,200 pps in bursts of 192 pulses. Bursts are sent every 600 millisecc. Each $\Delta\theta C$ pulse is equal to a change in gimbal angle of 160 arc seconds. The error counter, having been enabled, accepts the pulses and counts up or down as necessary until all the pulses have been registered.

The ladder decoder in the D/A converter module supplies an 800 cps, amplitude modulated analog error signal equivalent to the digital information in the error counter. Refer to figure 4-2. The ladder decoder signal is summed with a feedback signal and applied through a mixing amplifier, also located in the D/A converter module, to the gimbal servo amplifiers to drive the gimbals to the desired angles. The coarse align error signal output of the mixing amplifier is applied to the gimbal servo amplifiers through the contacts of the coarse align relays located in the PSA. The coarse align relays, which are energized by the coarse align enable discrete acting through the mode logic, switch the input of the gimbal servo amplifiers from the gyro preamplifiers to the coarse align error signal output of the ISS D/A converters. The demodulator reference relay is also energized by the coarse align enable discrete and switches the reference frequency of the demodulator in the gimbal servo amplifiers from 3,200 cps to 800 cps. The coarse align enable discrete also energizes a relay in the gimbal servo amplifiers which switches additional capacitance into the amplifier's compensation networks to tune them for 800 cps operation.

As the gimbals are driven, $\pm\Delta 2^2$ pulses, representing the change in actual gimbal angle, are generated by the read counter and applied to the error counter. The $\pm\Delta 2^2$ pulses are also equal to 160 arc seconds and decrease the $\pm\Delta\theta C$ pulses registered in the error counter. The error counter output to the ladder decoder, therefore, represents the difference between the desired amount of change in gimbal angle and the amount of change actually accomplished. The error counter reaches a null or reads zero, and the gimbals stop moving, when the actual gimbal angle has changed by an amount equal to the total value of the $\pm\Delta\theta C$ pulses sent by the computer to the error counter. The CMC checks the contents of the read counter 2.1 seconds after the CMC has sent the last coarse align torquing pulse to the error counter. If the gimbal angles are not within two degrees of the desired angle, the computer issues an alarm.

The rate at which the gimbals are driven is limited to prevent damage to the gyros and to assure that the read counter can track the gimbal angle accurately. The rate of gimbal movement is limited by feeding back the CDU fine error signal $\sin 16(\theta - \Psi)$ to the input of the mixing amplifier located in the D/A converter module. The fine error signal is out of phase with the output of the ladder decoder and has an amplitude proportional to the difference between the actual gimbal angle (θ) and the angle registered in the read counter (Ψ). The fine error signal is applied through a voltage limiting circuit to the summing junction of the mixing amplifier where it is summed with the 800 cps ladder decoder output signal. The D/A converter ladder decoder output is applied to the mixing amplifier through a scaling amplifier and a voltage limiting diode network. The scaling amplifier controls the signal gain to produce a scale factor of 0.3 volt rms per degree. The output of the mixing amplifier will be at a null when the D/A converter ladder decoder output, after limiting, is equal to the fine error feedback signal. The fine error signal will be a constant value only when the gimbal and the CDU are going at the same rate and with the gimbal angle leading the CDU angle. Since the CDU is constrained to counting at one of two speeds, the gimbals will be constrained to a rate equal to one of these two speeds. During the coarse align mode, the CDU is constrained to a high counting speed of 6.4 kpps and a low counting speed of 800 cps. At all other times, the high counting speed is 12.8 kpps.

If the gimbals are moving at a faster rate than the rate at which the CDU is counting, the fine error signal will increase causing a retarding torque to be developed by the gimbal servo amplifier. If the gimbals are moving at a rate slower than the rate at which the CDU is counting, the fine error signal will decrease causing the gimbal servo amplifier to apply an accelerating torque to the gimbals. By adjusting the gain of the fine error signal into the mixing amplifier, the gimbal rate is limited to either 35.5 degrees per second (6.4 kpps CDU counting rate) or 4.5 degrees per second (800 cps CDU counting rate).



4.3 ISS FINE ALIGN MODE

4.3.1 PURPOSE. To reposition the stable member to a fine alignment by torquing the gyros.

4.3.2 METHODS OF ENTRY.

a. Computer Routine

b. DSKY Entry - V42E (Fine Align IMU)

4.3.3 DISCRETES.

Computer Input - IMU Operate

Computer Output - Gyro Torque Enable

4.3.4 COMPUTER ROUTINES.

IMU Fine Routine

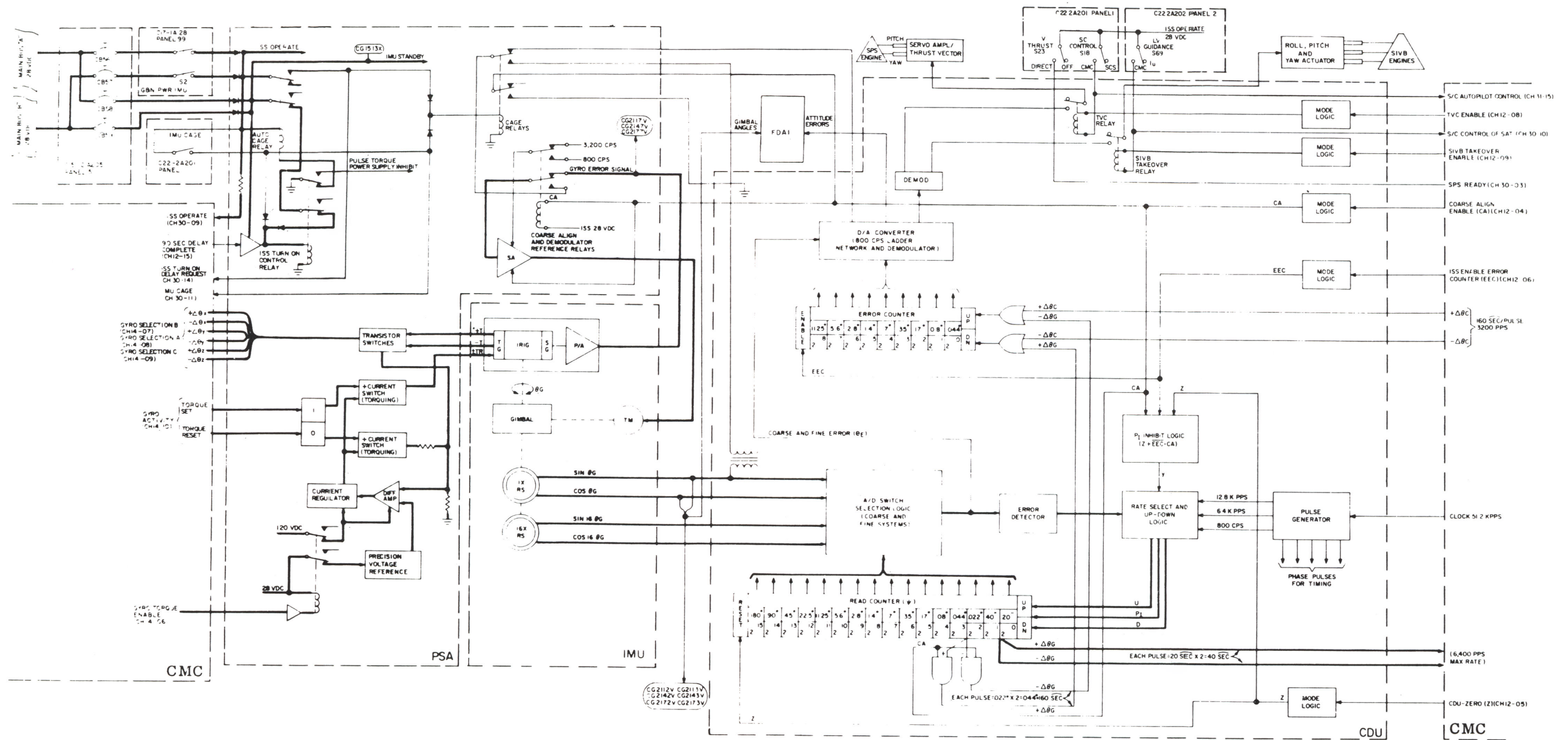
IMU Pulse Routine

4.3.5 DISPLAY AND CONTROL INDICATIONS. None if entered via computer routine.

4.3.6 OPERATION. The torquing current to the gyros is provided by the fine align electronics located in the PSA. The fine align electronics are enabled and controlled by LGC pulses sent directly to the fine align electronics. Refer to figure 4-3. The LGC routine will place the desired number of pulses in the gyro D counter and then decrement the counter at the rates of 3200 pulses per second. These pulses are routed to the IRIG's. Each pulse is worth 0.617981 arc seconds of gimbal rotation.

The ISS is in the inertial reference mode prior to the enabling of the fine align electronics and returns to that mode when the fine align electronics are disabled. The fine align electronics torques the gyros on a time shared basis. The CMC sends four types of pulse trains to the fine align electronics. The first pulse train to be sent is the torque enable command which enables the fine align electronics. The second pulse train is a gyro select command which selects a particular gyro and the direction it is to be torqued by means of a switching network which closes the current path through the proper torque ducosyn coil. The third and fourth types of pulse trains are the torque set and torque reset commands which control a binary current switch to start and stop the current flow through the selected torque ducosyn coil. The amount of current flow through the torque ducosyn coils is precisely controlled at a fixed value. The amount of gyro torquing to be accomplished is determined by the amount of time torque current is applied, that is, the time duration between the receipt of the torque set and the torque reset commands. The factor is calculated by the CMC based on optical alignment measurements. The torque ducosyn displaces the gyro float causing the ducosyn signal generator to apply an error signal to the stabilization loop. The stabilization loops drive the gimbals to reposition the stable member. Upon completion of the torquing, the torque enable command is removed after which the ISS remains in inertial reference mode until further change is commanded.

During the fine align mode, the ISS error counters remain cleared and inhibited. The read counters continue to repeat the gimbal angles and send angular data ($\pm\Delta\theta G$) to the CMC.



Fine Alignment Mode

17604

4.4 ISS INERTIAL MODE

4.4.1 PURPOSE. To provide a coordinate reference system on which attitude and velocity measurements and calculations may be based.

4.4.2 METHODS OF ENTRY.

a. Computer Routine - via IMU fine routine

4.4.3 DISCRETES. None

4.4.4 COMPUTER ROUTINE. None

4.4.5 DISPLAY AND CONTROL INDICATIONS. None

4.4.6 OPERATION. During the inertial reference mode, the stable member is held fixed with respect to inertial space by the stabilization loops. Refer to figure 4-4. The ISS CDU read counters provide the LGC with changes in gimbal angles with respect to the stable member. The ISS is in the inertial reference mode during any operating period in which there is an absence of moding commands. During the inertial reference mode, the fine align electronics is inhibited and the ISS error counters are cleared and inhibited.



4.5 ISS CDU ZERO MODE

4.5.1 PURPOSE. To insure synchronization between the IMU gimbal angles, the CDU read counters and the LGC E memory registers.

4.5.2 METHODS OF ENTRY.

a. Computer Routine

b. DSKY - V40 N20

4.5.3 DISCRETES.

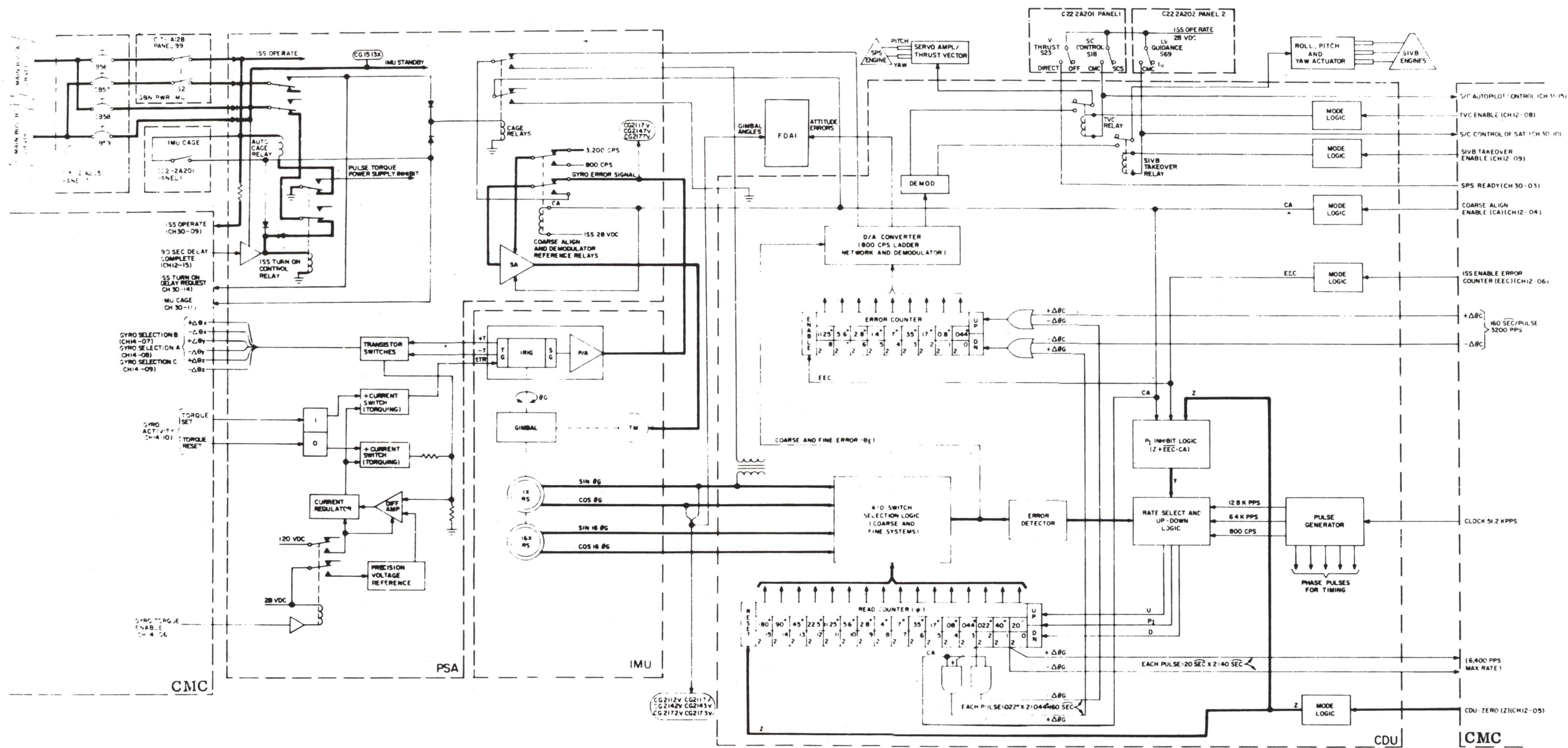
Computer Inputs - IMU OPERATE

Computer Outputs - IMU CDU ZERO

4.5.4 COMPUTER ROUTINE. IMU Zero Routine

4.5.5 DISPLAY AND CONTROL INDICATIONS. None

4.5.6 OPERATION. When the computer enters this routine, it will inhibit the ICDU FAIL (CH 30-12) and IMU FAIL (CH 30-13) discrettes, issue the ISS CDU zero (CH 12-05) discrete and then execute a 320 millisecc delay. During this 320 millisecc the ICDU read counters are zeroed and inhibited. Refer to figure 4-5. When the delay has been completed, the computer will set the X, Y, and Z CDU counters in E memory to zero and then remove the ICDU zero discrete. The removal of the zero discrete will allow the read counters to increment up to the gimbal angles and the X, Y, and Z CDU counters in E memory will follow along. After another mode is complete.



IMU CDU Zero Mode

4.6 IMU CAGE MODE

4.6.1 PURPOSE. To drive the IMU gimbals to their zero position.

4.6.2 METHODS OF ENTRY.

a. Inherent part of ISS turn on sequence

b. IMU cage switch (IS49)

4.6.3 DISCRETES.	Computer Inputs	IMU Operate
		IMU Cage

4.6.4 COMPUTER ROUTINE. None

4.6.5 DISPLAY AND CONTROL INDICATIONS. No attitude lamp on DSKY

4.6.6 OPERATION. When IMU cage mode is initiated by the astronaut pressing the IMU CAGE switch the switch is held until the gimbals settle at the zero position (five seconds maximum). The gimbal position may be observed on the FDAI. The IMU CAGE switch routes a 28 vdc discrete signal to the CMC and to the cage relays located in the PSA. The cage discrete energizes the cage relays which in turn cause the coarse align relays, the demodulator reference relay, and a relay in the gimbal servo amplifiers to be energized. The relay in the gimbal servo amplifiers switches additional capacitance into the RC compensation networks to tune them for 800 cps operation. The demodulator reference relay changes the gimbal servo amplifier demodulator reference signal from 3,200 cps to 800 cps. The cage relays switch the 1X gimbal resolver sine winding outputs through the energized contacts of the coarse align relays into the corresponding gimbal servo amplifier inputs. The gimbal servo amplifiers drive the gimbals until the resolver signals are nulled which occurs at zero gimbal angle.

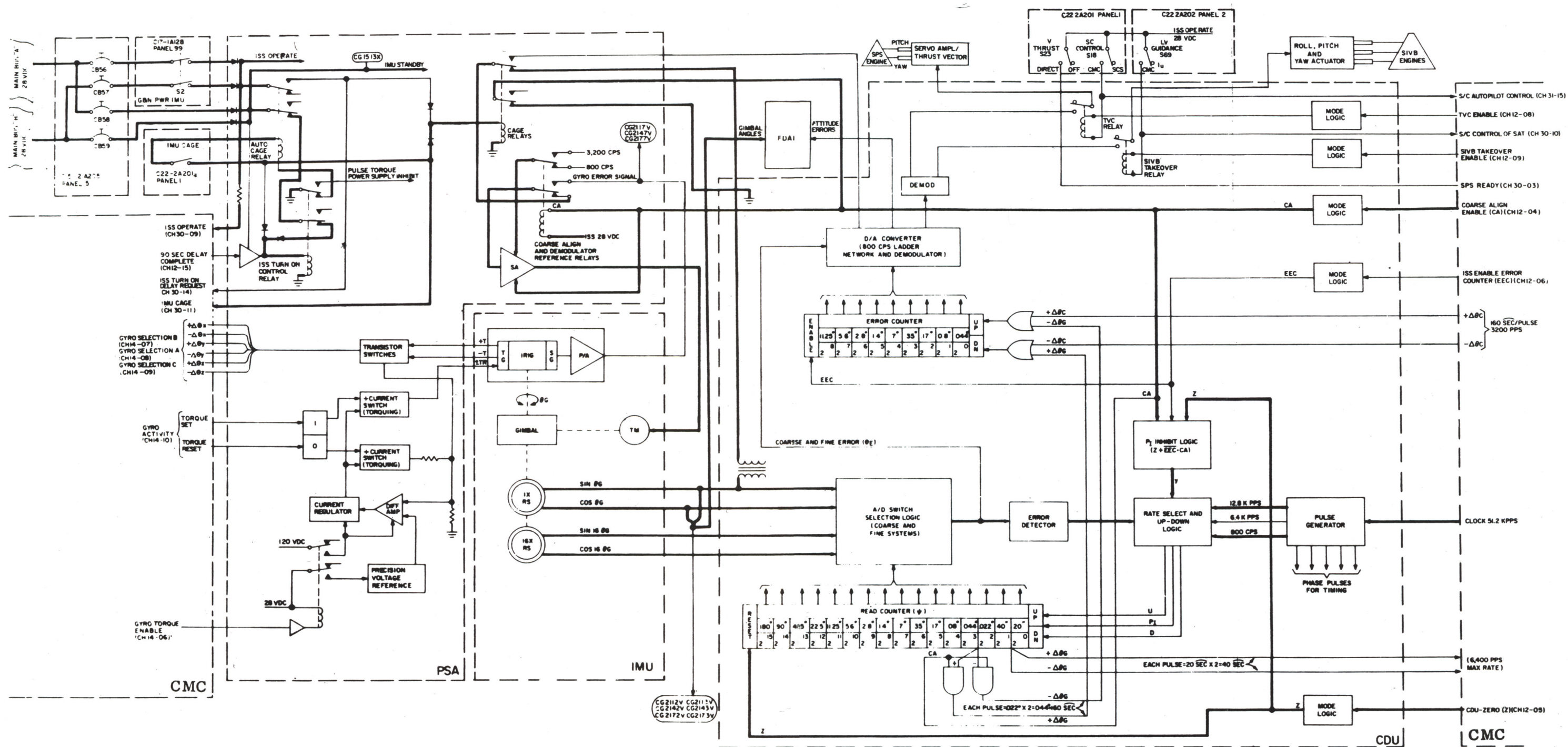
Upon receipt of the IMU cage discrete (CH 30-11), the computer will terminate gyro and ICDU driving, remove ICDU enable error counter and ISS turn-on delay complete discrettes, and issue the ISS coarse align and ISS CDU zero discrettes. Then the computer will turn on the NO ATTITUDE lamp (DSKY), inhibit PIPA, ICDU and IMU fail discrettes, and set the X, Y, and Z CDU and gyro command output counters to zero.

After the IMU cage switch is released, the CMC will allow the read counters to settle, then will place the PGNCS in an inertial mode. During the time the IMU cage discrete is present and while the read counters are settling, the NO ATTITUDE lamp on the DSKY is lighted.

The IMU cage mode will also be entered automatically whenever the IMU is turn on. During the normal turn on sequence, the closure of the ISS OPERATE circuit breaker will route 28 vdc through the deenergized contacts of the ISS turn on control relay to the cage relays. The cage relays energize and cage the gimbals. After the 90 second turn on time delay has been completed the CMC will (if it is on) send the ISS turn on delay complete discrete which will energize the ISS turn on control relay which, in turn, deenergizes the cage relays. If, however, the CMC is off or in standby when the IMU is turned on, the ISS turn on control relay will remain deenergized and the ISS will remain in the IMU cage mode. See figure 4-6.

If the IMU cage mode is entered as a result of an IMU turn on with the CMC off or in standby, the ISS may be placed in the inertial reference mode by allowing 90 seconds for gyro runup, then pressing the IMU CAGE switch. The IMU CAGE switch will energize and latch the auto cage relay control which removes the ISS 28 vdc which had been energizing the cage relays. With the auto cage relay control latched, the cage relay will deenergize when the IMU CAGE switch is released. Deenergizing the cage relays causes the coarse align relays to be deenergized which connects the gyro error signals to the respective gimbal servo amplifiers. The stabilization loops will maintain the stable member inertially reference to the orientation established by the caging loops.

During the ISS turn-on mode, the cage function is safe because the gyro wheels are not turning. However, when used to recover a tumbling platform, the combination of the gimbal drive rates and the precessional torques are sufficient to cause the gyros to be driven into their rotational and radial stops. This action may cause both temporary and permanent bias shifts on the order of several MERU's.



IMU Cage Mode

17607

4.7 ATTITUDE ERROR DISPLAY MODE

4.7.1 PURPOSE. To supply attitude error signals to the FDAI

4.7.2 METHODS OF ENTRY.

a. Computer Routine

b. DSKY Entry.

4.7.3 DISCRETES.

Computer Inputs - IMU Operate

Computer Outputs - Error Counter Enable

4.7.4 COMPUTER ROUTINE. None

4.7.5 DISPLAY AND CONTROL INDICATIONS. Needles on FDAI's indicate attitude error.

4.7.6 OPERATION. In this mode of operation the computer is informed of the gimbal angles.

The computer is aware of the present attitude of the spacecraft. The digital autopilot routine provides a desired S/C attitude associated with the present time and position. Any difference between the desired and actual S/C attitude is an attitude error. The attitude error is converted to $\Delta\theta$ pulses, each pulse being equivalent to 160 arc seconds of error, which are sent to the error counter at a rate of 3200 pps. The error counter is incremented to contain the number of pulses commanded by CMC. The contents of the error counter are converted to an 800 cps error signal by the DAC. The phase of the DAC output is determined by logic in the EC&L module.

The 800 cps with a maximum amplitude of 5 vrms zero or pi phase is displayed on the attitude error needles of the FDAI as an attitude error. The digital feedback from one read counter to the error counter is disabled during this mode of operation allowing only the CMC generated $\Delta\theta$ commands to increment or decrement the error counter.

Total spacecraft attitude can also be displayed on the FDAI. This information is taken from the 1X gimbal angle resolver sine and cosine windings. Pitch, yaw and roll can be displayed from the inner, outer and middle gimbals respectively.



4.8 GIMBAL LOCK MODE

4.8.1 PURPOSE. The purpose of the gimbal lock mode is to provide the astronaut with a discrete indication of a large middle gimbal angle and to disable the stab loop when gimbal lock actually occurs.

4.8.2 METHOD OF ENTRY. Computer Routine

4.8.3 DISCRETES.

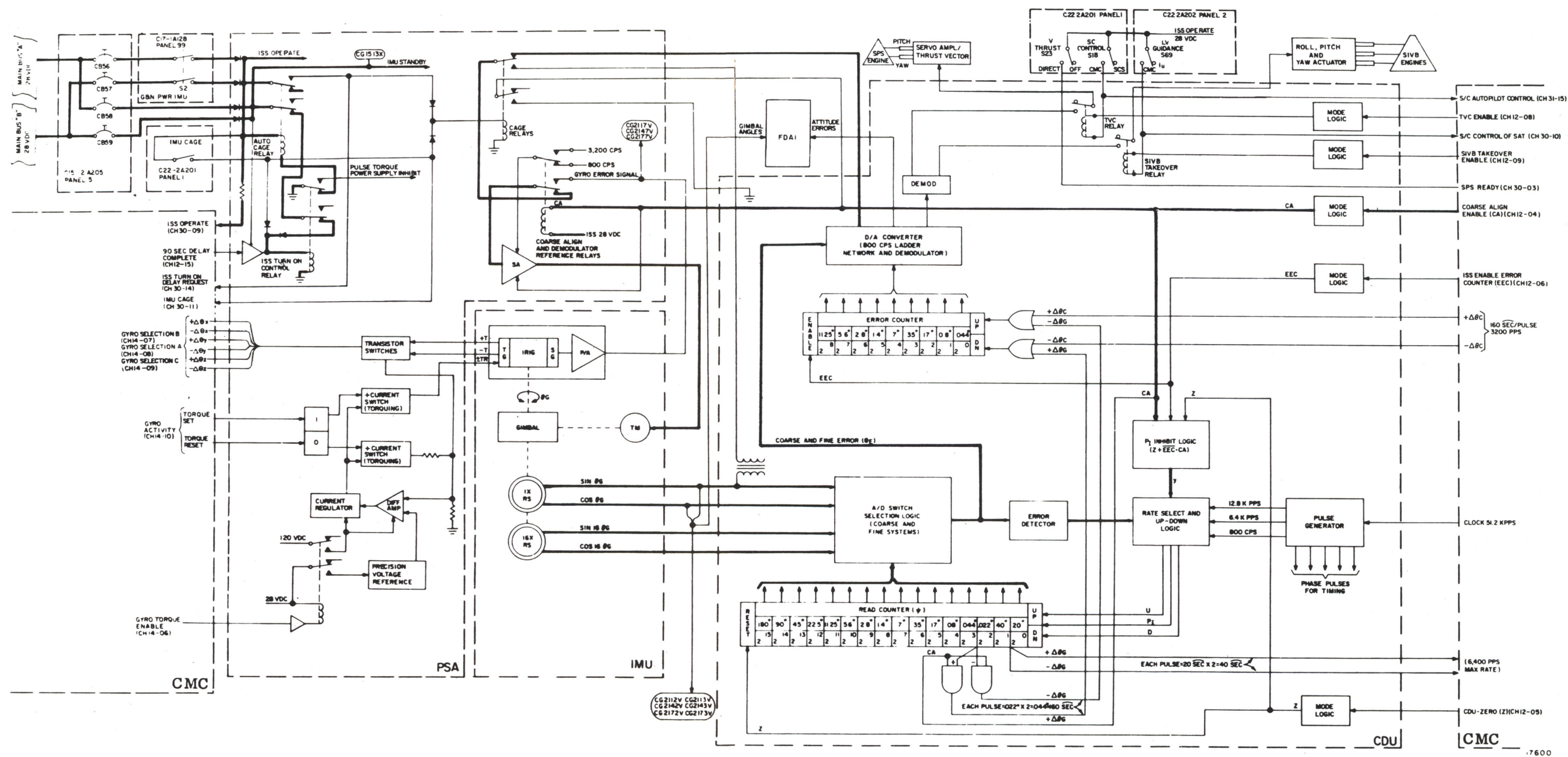
Computer Inputs - IMU OPR

Computer Output - Coarse Align Enable

4.8.4 COMPUTER ROUTINE. T4RUPT Routine

4.8.5 DISPLAY AND CONTROL INDICATIONS. Gimbal lock lamp on DSKY
No ATTITUDE lamp on DSKY

4.8.6 OPERATION. This mode is a function of the T4RUPT routine. Every 480 millisecond, the T4RUPT routine checks the Z CDU counter in E memory (middle gimbal angle). When the magnitude in this counter is greater than 70.0° , the computer will turn on the GIMBAL LOCK lamp on the DSKY. This light will be turned off as soon as the T4RUPT routine finds the magnitude in this counter below 70.0° . However, if the middle gimbal angle in the Z CDU counter increases to greater than 85° degrees, the computer will light the NO ATTITUDE lamp on the DSKY, issue the ISS coarse align discrete, and inhibit the IMU fail. Issuing the ISS coarse align discretess will open the stab loops, which will reference the platform to the spacecraft. Refer to figure 4-9. The combination of the coarse align (CA) and not the enable error counter (EEC) will prevent the read counters from being incremented. The coarse and fine error signals to the D/A converter will be the only signal inputs to the stab amps. These signals, if any, will cause the gimbals to drive to the angle in the read counter. The astronaut can leave this mode by requesting the coarse alignment mode via DSKY input.



Gimbal Lock Mode

4.9 SIVB TAKE-OVER MODE

4.9.1 PURPOSE. To use the command module guidance system as a backup system for the Saturn guidance system if the Saturn guidance system fails during earth ascent, earth orbit, or translunar injection.

4.9.2 METHODS OF ENTRY. Switching the vehicle guidance switch (S69) from the IU Position to the CMC Postilion.

4.9.3 DISCRETES.

Computer Inputs

IMU Operate

S/C control of Saturn

Computer Outputs

SIVB Takeover

ISS Error Counter Enable

OPERATION: During the S-4B take-over mode, the CMC controls spacecraft steering by sending attitude error signals to the Saturn guidance system through the ISS CDU. This mode is a backup for the Saturn guidance system if the Saturn guidance system IMU fails during earth ascent, translunar injection, or earth orbit. The S-4B take-over mode is initiated by the astronaut by placing S69 on the main D and C panel to the CMC position. Closure of this switch routes +28 vdc to one side of the SIVB takeover relays. The +28 vdc discrete is also routed to the CMC. Receipt of this discrete by the CMC signals the CMC to issue the S-4B take-over discrete. The S-4B take-over discrete energizes the control relays which connect the D/A converters dc outputs to the Saturn guidance system. The CMC issues the enable error counter discrete 40 milliseconds after the S-4B take-over discrete. With the error counters enabled and the D/A converters dc outputs connected to the Saturn guidance system, the CMC can send steering signals to the Saturn guidance system. The CMC calculates the amount of yaw, pitch, and/or roll required for proper spacecraft attitude and determines the amount of $\pm \Delta \theta C$ pulses to be sent to the error counters. The error counters receive the $\pm \Delta \theta C$ pulses and count up or down as required until all pulses have been received. The error counters send this digital information to the D/A converters where it is converted to a dc signal and sent to the Saturn guidance system for attitude control. The CMC monitors the spacecraft response to the attitude signals through the read counters and the PGNCS PIP's. During this mode, the digital feedback signals from the read counters to the error counters are inhibited.

Prior to the CMC issuing the S-4B take-over discrete, the CMC checks to see if the error counters are in use. If the error counters are in use, the CMC removes the enable error counter discrete which inhibits and clears the error counters. The S-4B take-over discrete will then be issued after a 1/2-second delay.



4.10 THRUST VECTOR CONTROL MODE

4.10.1 PURPOSE. To allow the computer to control the thrusting of the SPS engine.

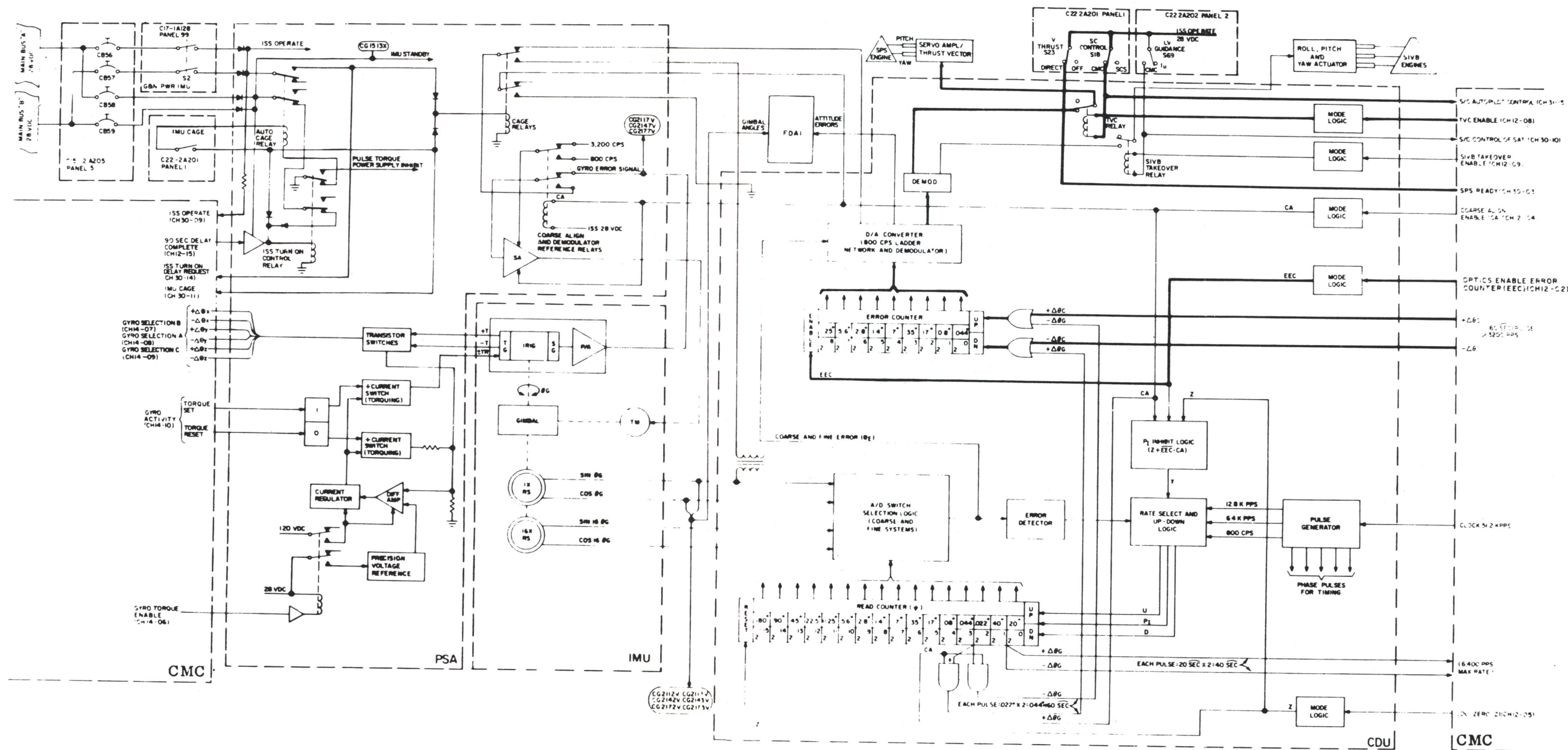
4.10.2 METHODS OF ENTRY. By placing the ΔV thrusting switch (S23) in the Direct Position, and the S/C control switch (S18) in the CMC Position.

4.10.3 DISCRETES.

Computer Inputs	IMU OPERATE	CH 30-09
	S/C Auto Pilot Control	CH 31-15
	SPS Ready	CH 30-03
Computer Outputs	TVC ENABLE	CH 12-08
	Optics Enable Error Counter	CH 12-02

OPERATION: The astronaut places the SC control switch (S18) into the CMC position and the V thrust switch (S23) into the direct position. The computer issues the TVC enable discrete which passes through mode logic which in turn provides a ground path for the TVC relay. The energized TVC relay connects the optics CDU D/A converter dc outputs to the SPS engine gimbal amplifier. The CMC issues the optics D/A enable discrete 40 milliseconds after the thrust vector control discrete. With the optics error counters enabled and the optics CDU D/A converter dc output connected to the SPS engine gimbal amplifier, the CMC can send steering control signals to position the SPS engine gimbals. The CMC calculates the amount of pitch or yaw required for proper trajectory and then determines the amount of $\pm\Delta\theta C$ pulses to be sent to the error counters. The error counters receive the $\pm\Delta\theta C$ pulses and count up or down as required until all pulses have been received. The error counters send this digital information to the D/A converters where it is converted to a dc signal and routed to the SPS engine gimbal amplifiers. The CMC monitors spacecraft response to the engine gimbal steering signals through the ISS CDU read counters and the PGNCS PIP's. During this mode, the digital feedback signals from the read counters to the error counters are inhibited.

Prior to the CMC issuing the thrust vector control discrete, the CMC checks to see if the optics CDU error counters are in use. If the error counters are being used, the CMC removes the optics D/A enable discrete which inhibits and clears the error counters. The CMC will then issue the thrust vector control discrete.



Thrust Vector Control Mode

4.11 ATTITUDE CONTROL MODE

4.11.1 PURPOSE. Allows the PGNCs to maintain spacecraft attitude.

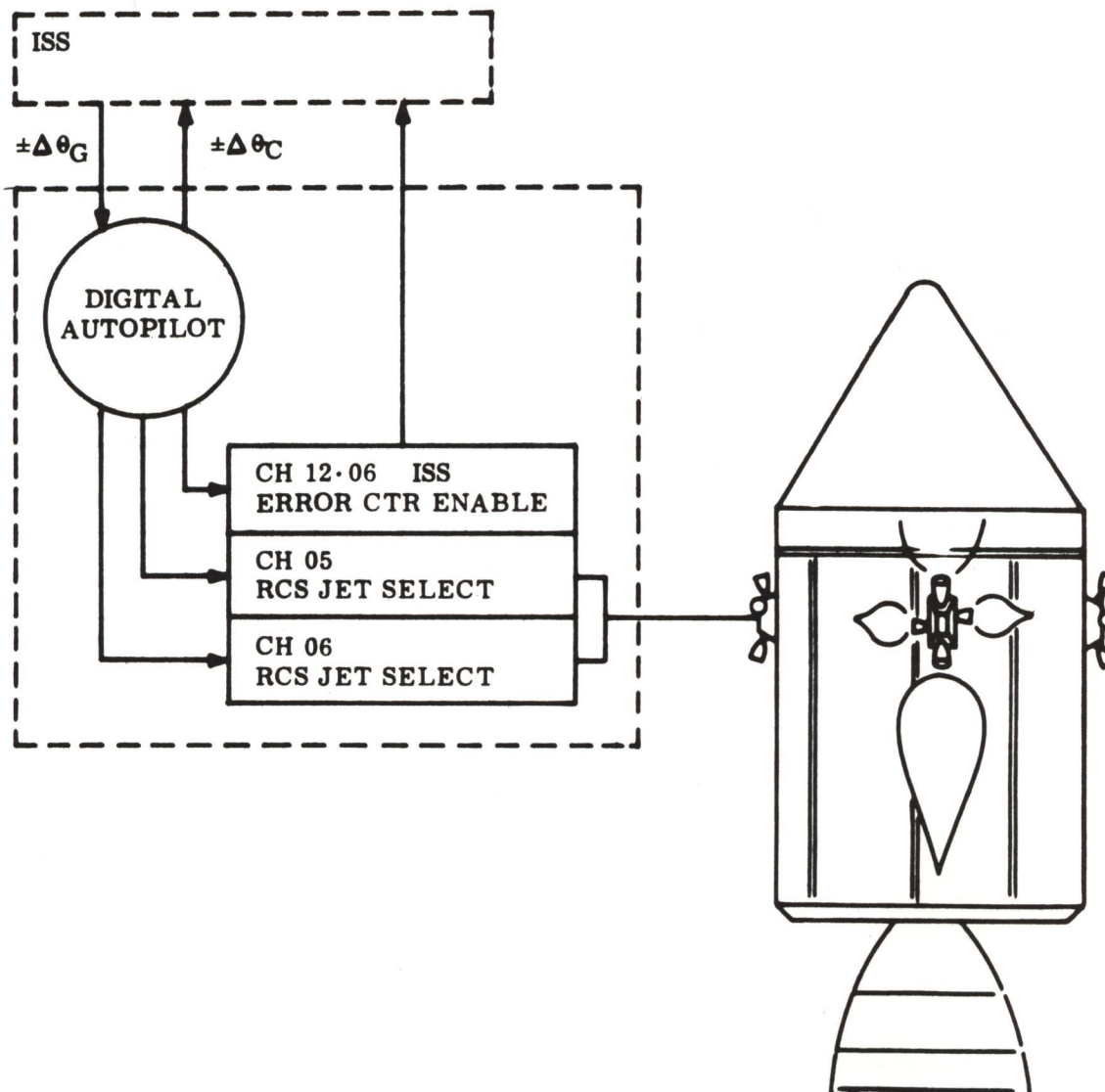
4.11.2 DISCRETES.

Computer Inputs	IMU Operate	CH 30-09
	Auto or Hold Function	CH 31-13
Computer Outputs	ISS Error Counter Enable	CH 12-06
	RCS Jet Selection	CH 05 & 06

4.11.3 COMPUTER ROUTINE. Digital Auto Pilot Routine.

The attitude control mode, a PGNCs mode, utilizes the digital autopilot to maintain spacecraft attitude. The ISS stabilization loops maintain an inertial reference from which spacecraft attitude can be determined. The spacecraft attitude is compared to a desired attitude by the digital autopilot. If any error exists, the RCS jets are used to change the spacecraft attitude. Attitude errors are displayed on the FDAI.

During the attitude control mode, the error counter is enabled. The computer sends the desired change in gimbal angle orientation to the error counters. The output of the error counters is developed into an analog error signal (attitude error signal) by the 800 cps ladder network and the output is fed to the FDAI. The computer develops discretizes that control the firing of RCS jets and, therefore, change the orientation of the spacecraft. The change in spacecraft orientation is sensed by the IMU stabilization loops and results in changing IMU gimbal angles. The gimbal resolver output is sent to the FDAI to display total attitude and to the summing logic and coarse fine mixing circuit. Resulting digital information is sent to the read counter. The read counter supplies the changing gimbal angle pulses to the CMC. The CMC uses the information in determining when to stop firing the RCS jets. The FDAI error counter is pulsed to zero, nulling the attitude error signal on the FDAI.



17617

Attitude Control Mode

IMU TEMPERATURE CONTROL SYSTEM

INTRODUCTION

The purpose of the IMU Temperature Control System is to maintain the temperature of the IRIG's and PIP's within their required temperature limits. This system is designed to supply and remove heat as required to maintain heat, with minimum power consumption. This system is divided into two functional sections. The first section is used for adding heat to the inertial components, and the second section is used for removing excess heat. Heat is added to the inertial components via resistance wire heaters which are controlled by several different circuits. Excess heat is removed from the stable member by thermostatically controlled fans. Refer to figure 5-1. The IMU is pressurized with dry nitrogen to one atmosphere. This allows the fans to cause a forced convection mode of operation which circulates the dry nitrogen between the middle gimbal and the IMU case. The IMU case contains the ECS's water-glycol heat exchanger. The water-glycol input temperature is approximately 45° F.

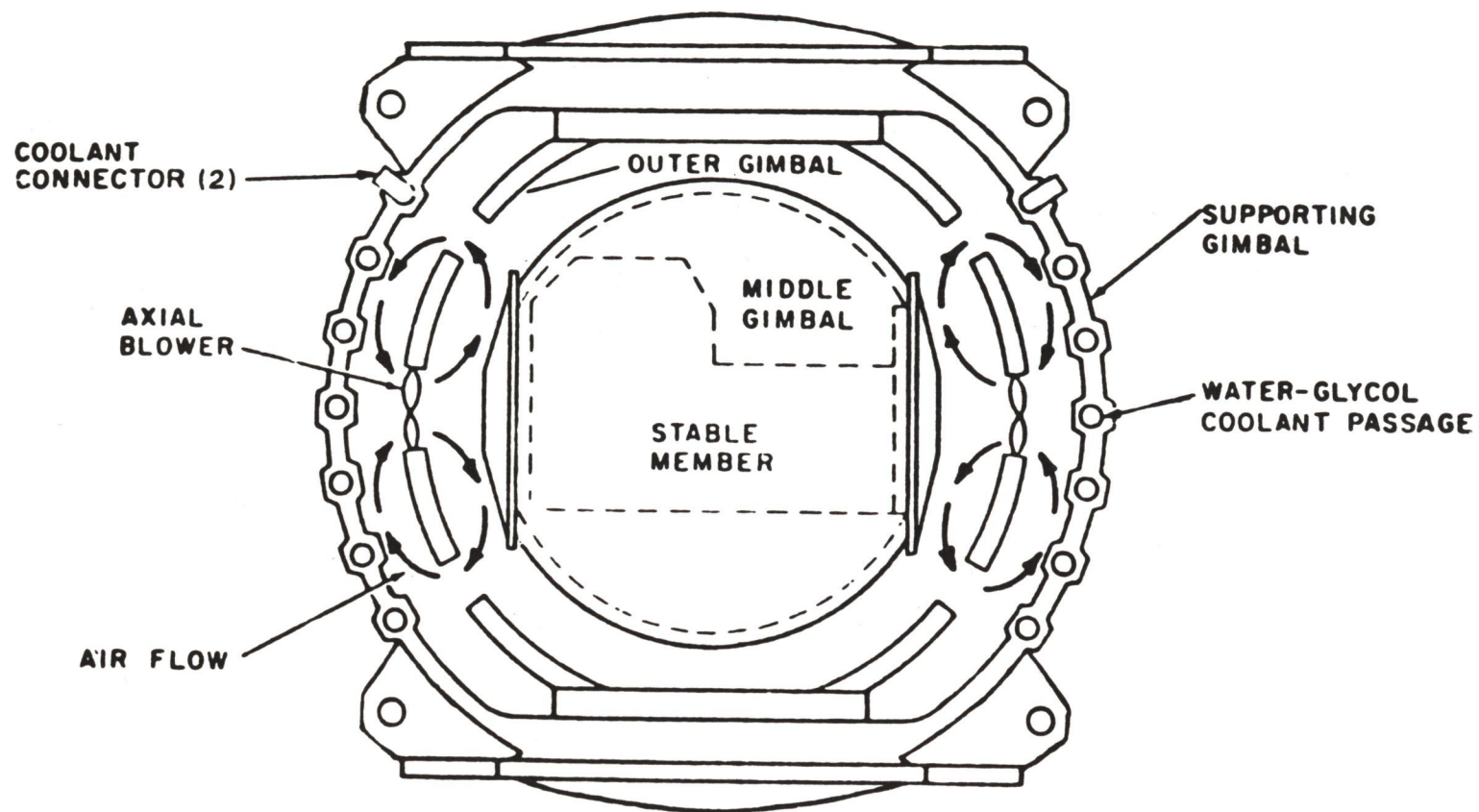
The temperature control system is divided into four circuits. All four circuits are shown on figure 5-2. The name and function of each circuit is as follows:

- a. The temperature control circuit - adds heat during ISS standby and operate modes.
- b. The blower control circuit - removes heat during ISS operate.
- c. The temperature alarm circuit - monitors platform temperature during system operation, ISS standby and CSS standby.
- d. External temperature circuit - separate heaters and sensors used for platform temperature control below standby.

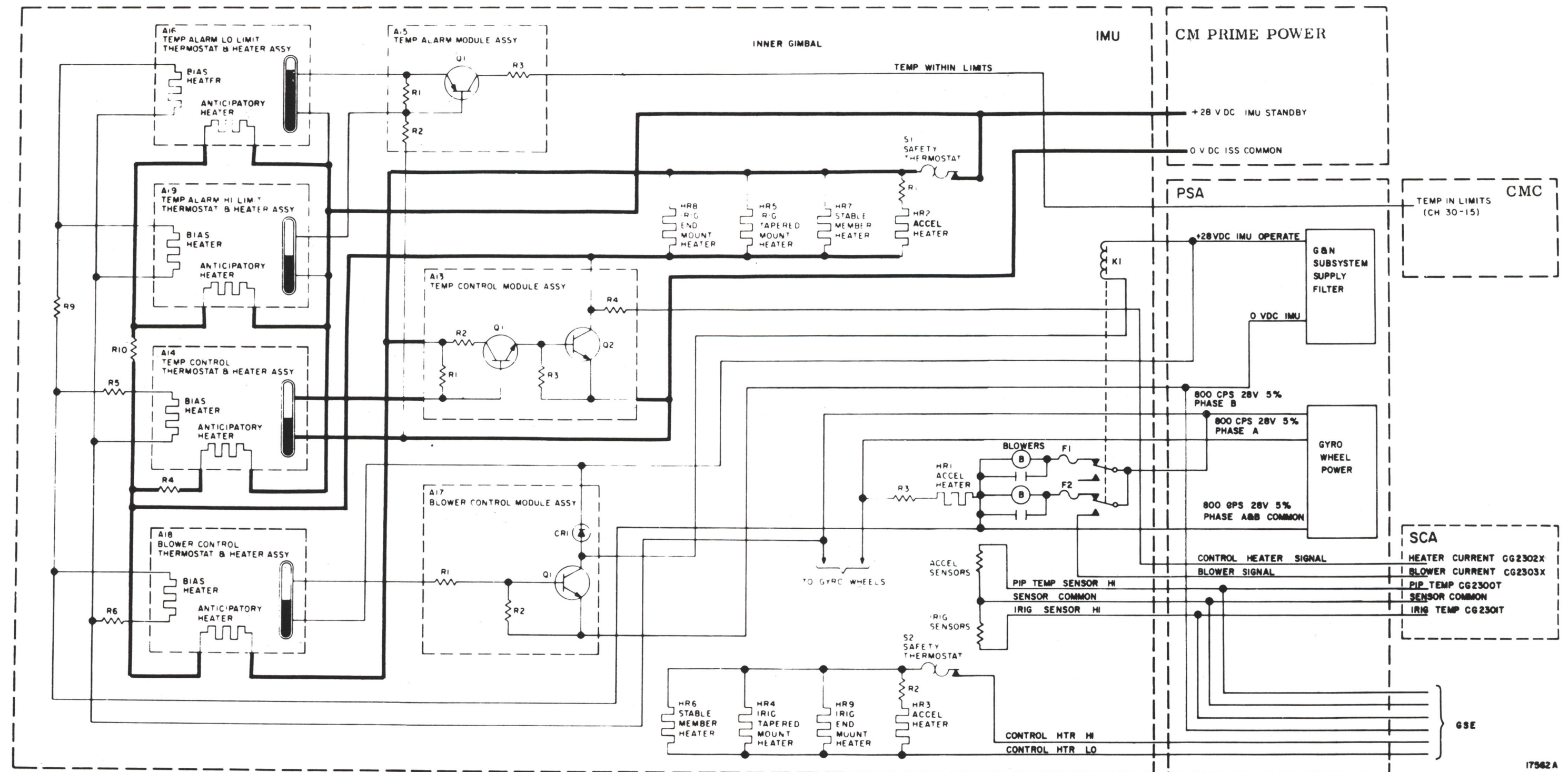
5.1 TEMPERATURE CONTROL CIRCUIT

The temperature control circuit maintains the gyro and accelerometer temperature. The temperature control circuit consists of a temperature control thermostat and heater assembly, a temperature control module, three IRIG end mount heaters, three IRIG tapered mount heaters, two stable member heaters, three accelerometer heaters, and four anticipatory heaters. The thermostat and heater assembly is located on the stable member and contains a mercury-thallium thermostat, a bias heater, and an anticipatory heater. Except for the bias and GSE heater, all heaters (a total of 15) are connected in parallel, and are energized by 28 volts dc through the switching action of transistor Q2, which completes the dc return path. The thermostat which senses the temperature of the stable member controls switching transistors Q1 and Q2. Refer to figure 5-2.

When the temperature falls below 130 (± 0.2) degrees Fahrenheit, the thermostat opens, transistors Q1 and Q2 conduct, and current flows through the fifteen heaters. Because of the large mass of the stable member, its temperature will increase at a relatively slow rate as compared to the gyros which have a heater in each end mount. The anticipatory heater improves the response of the thermostat to insure that the magnitude of the temperature cycling of the gyros and the accelerometers is as small as possible. When the temperature rises above 130 (± 0.2) degrees Fahrenheit, the thermostat closes and the base of transistor Q1 is shorted to ground, cutting off transistors Q1 and Q2 and deenergizing the heaters. The thermostat has a 0.5 degree deadband which is the difference between contact closing with rising temperature and contact opening with falling temperature. The temperature



Forced Convection in IMU



17562A

Temperature Control
Circuit (Standby)

control circuit will maintain the average of the gyro temperatures at 135 (± 1) degrees Fahrenheit under normal ambient conditions. The temperature difference between the gyros and the accelerometers is adjusted by properly proportioning the amount of power in each heater. The balance is obtained by decreasing the current through each accelerometer heater by the proper selection of resistor R1.

During IMU operation, power is applied to the fixed accelerometer heaters to compensate for the additional heat supplied to the gyros by the gyro wheel motor heat dissipation. Power is also applied to a bias heater on the control thermostat. The bias heater supplies a fixed amount of heat to the control thermostat to maintain the proper absolute temperature level of the gyros and accelerometers. The amount of bias heat is determined by the value of R5. The power for the fixed accelerometer heaters and the thermostat bias heater is the -90 degree output from the 28 vac power supply which is also used for gyro wheel power.

The 28 vdc heater power is applied to the heaters through the contacts of a safety thermostat which provides protection against an extreme overheat condition in case a malfunction occurs in the temperature control circuit. The safety thermostat contacts open at 139.5 (± 3.0) degrees Fahrenheit and close at 137 (± 3) degrees Fahrenheit. Refer to figure 5-3.

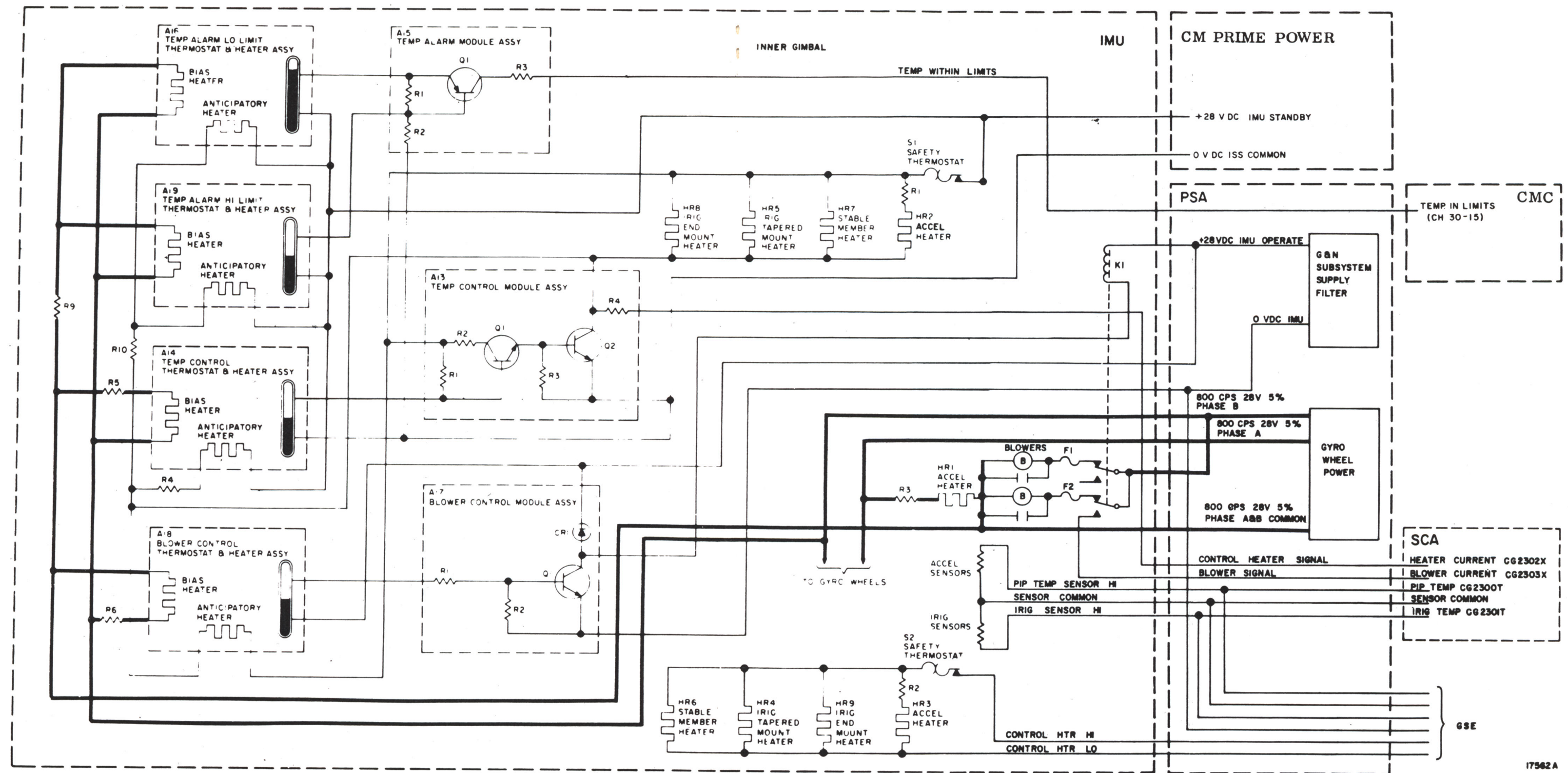
5.2 BLOWER CONTROL CIRCUIT

The blower control circuit maintains IMU heat balance by removing heat. The blower control circuit consists of a blower control thermostat and heater assembly, a blower control module assembly, two axial blowers, and a relay. The contacts of the thermostat contained in the blower control thermostat and heater assembly close at 139 (± 0.2) degrees Fahrenheit and remain closed at higher temperatures. Resistor R6 is provided to limit the current through the bias heater in the blower control thermostat and heater assembly. The amount of heat supplied by the bias heater is a constant. If the duty cycle of the temperature control circuit exceeds 50 percent, enough additional heat will be provided by the anticipatory heater to increase the temperature of the blower control thermostat and heater assembly to 139 degrees Fahrenheit. When the thermostat contacts close, transistor Q1 conducts and relay K1 is energized to remove the power from the blowers. The normal duty cycle of the temperature control circuit, with the IMU in a 75 degree Fahrenheit ambient temperature, is approximately 15 to 20 percent. Under this condition the blowers will operate continuously. Only a very low ambient temperature will cause a blower off condition. Refer to figure 5-4.

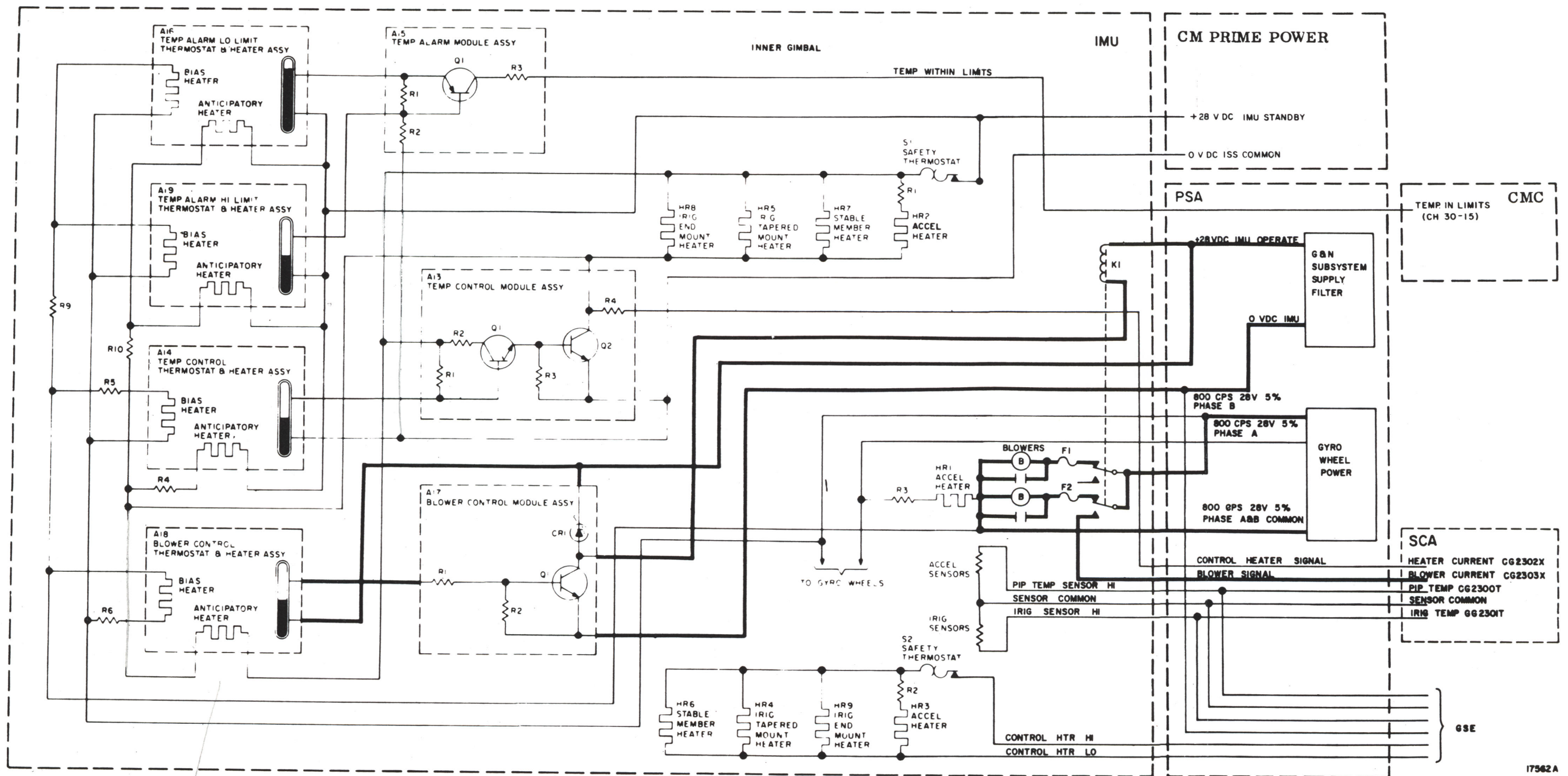
Power to the blowers is supplied from the -90 degree output of the 28 volt, 800 cps, 5 percent power supply which also provides gyro wheel motor power. Fused phase shift networks are associated with each blower so that excitation and control current can be supplied from the same source.

5.3 TEMPERATURE ALARM CIRCUIT

The temperature alarm circuit which monitors the temperature control system, consists of a temperature alarm high limit thermostat and heater assembly, a temperature alarm low limit thermostat and heater assembly, and a temperature alarm module assembly. If a high or low temperature is sensed by the thermostats located on the stable member a discrete is sent to the computer. When the temperature is within the normal range, the low limit thermostat contacts are open. Transistor Q1 is then properly biased for conduction through a grounding system in the computer. Refer to figure 5-5.

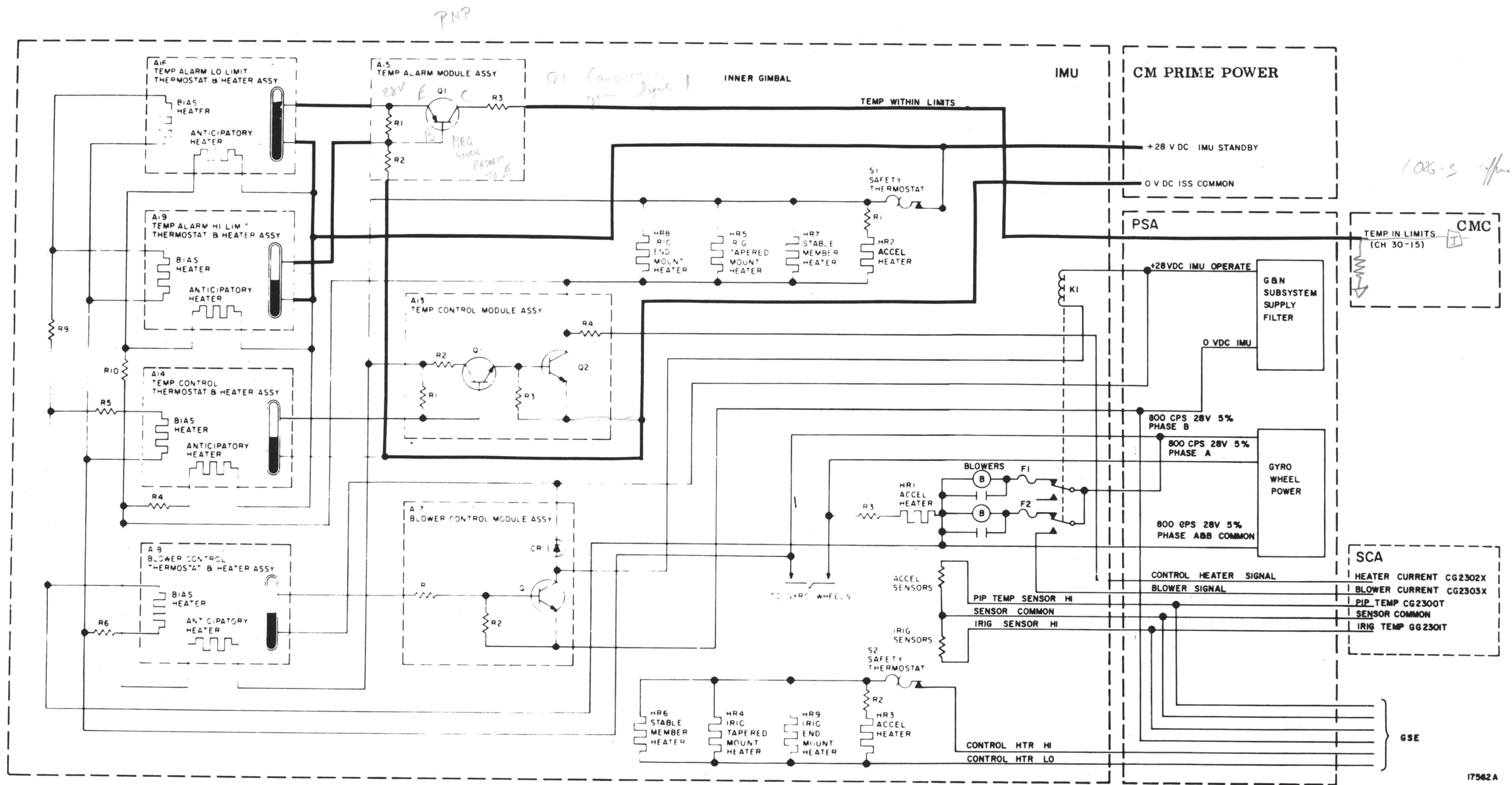


Temperature Control (Operate)



17562A

Blower Control Circuit



Temperature Alarm Circuit

At temperatures below 126.0 (± 0.2) degrees Fahrenheit both the low limit thermostat contacts and the high limit thermostat contacts are open. At temperatures above 134.0 (± 0.2) degrees Fahrenheit, both the low limit thermostat contacts and the high limit thermostat contacts are closed. In either case, transistor Q1 is not able to conduct. Non-conduction of transistor Q1 signals the CSS of an alarm condition. There is no differentiation between a high or low temperature alarm. When the CSS senses a temperature alarm, it causes the TEMP and PGNCS lamps to light. When the IMU auxiliary module receives a temperature alarm, it sends the information to telemetry.

5.4 EXTERNAL TEMPERATURE CONTROL CIRCUIT

External temperature control of the IMU is provided by ground support equipment (GSE) control heater circuits in the IMU. The circuits are controlled externally to the airborne equipment by the portable temperature controller or the temperature monitor control panel of the optics inertial analyzer (OIA). The GSE control heater circuitry consists of a safety thermostat, six gyro heaters, two stable member heaters, three accelerometer heaters, temperature indicating sensors, and an IMU standby power sensor which disables the GSE when airborne power is on. The temperature indicating sensors act as the control sensing element of the external control and indicating circuitry. The heaters are connected in parallel. The six gyro temperature indicating sensors (two in each gyro) are connected in series to sense the average temperature of the gyros. The three accelerometer temperature indicating sensors (one in each accelerometer) are connected in series to sense the average temperature of the accelerometers. All of the GSE control heater circuitry is not available as a backup system in flight. The GSE temperature indicating sensors are used as the telemetry sensors during flight. Refer to figure 5-6.

The optical subsystem is used for taking precise optical sightings on celestial bodies and for taking fixes on landmarks. These sightings are used for aligning the IMU and for determining the position of the spacecraft. The system includes the navigational base, two of the five CDUs, parts of the power and servo assembly, controls and displays, and the optics, which include the scanning telescope (SCT) and the sextant (SXT).

2.2.3.2.1

Optics.

The optics consist of the SCT and the SXT mounted in two protruding tubular sections of the optical base assembly. The SCT and SXT shaft axes are aligned parallel to each other and afford a common line-of-sight (LOS) to selected targets. The trunnion axes may be parallel or the SCT axis may be offset, depending upon the mode of operation.

The sextant is a highly accurate optical instrument capable of measuring the included angle between two targets. Angular sightings of two targets are made through a fixed beam splitter and a movable mirror located in the sextant head. The sextant lens provides 1.8-degree true field-of-view with 28X magnification. The movable mirror is capable of sighting a target to 50 degrees LOS from the shaft axis. The mechanical accuracy of the trunnion axis is twice that of the LOS requirement due to mirror reflection which doubles any angular displacement in trunnion axis.

The scanning telescope is similar to a theodolite in its ability to accurately measure elevation and azimuth angles of a single target using an established reference. The lenses provide 60-degree true field-of-view at 1X magnification. The telescope allowable LOS errors are 1 minute of arc-rms in elevation with maximum repeatability of 15 arc-seconds and approximately 40 arc-seconds in shaft axis.

2.2.3.2.2

Coupling Data Unit.

Coupling data unit

The identical coupling data unit (CDU) used in the ISS is also used as a part of the OSS. Two channels of the CDU are used, one for the SXT shaft axis and one for the SXT trunnion axis. These CDU channels repeat the SXT shaft and trunnion angles and transmit angular change information to the CMC in digital form. The angular data transmission in the trunnion channel is mechanized to generate 1 pulse to the CMC for 5 arc-seconds of movement of the SXT trunnion which is equivalent to 10 arc-seconds of SLOS movement. The shaft CDU channel issues 1 pulse for each 40 arc-seconds of shaft movement. The location of the SXT shaft and trunnion axes are transmitted to the CDUs through 16X and 64X resolvers, located on the SXT shaft and trunnion axes, respectively. This angular information is transmitted to the CDUs in the form of electrical signals proportional to the sine and cosine of 16X shaft angle and 64X trunnion angle. During the computer mode of operation, the CDU provides digital-to-analog conversion of the CMC output to generate an a-c input to the SXT shaft and trunnion servos. This analog input to the SXT axes will drive the SLOS to some desired position. In addition, the OSS channels of the CDU perform a second function on a time-sharing basis. During a thrust vector control function, these channels provide digital-to-analog conversion between the CMC and the service propulsion system (SPS) gimbals.

APOLLO OPERATIONS HANDBOOK

SYSTEMS DATA

2.2.3.2.3 Operational Modes.

The modes of operation for the optical subsystem are selected by the astronaut using the controls located on the indicator control panel. There are three major modes of operation for the OSS:

- Zero optics
- Manual control
- Computer control.

Within each of these modes there are variations which will be described as a part of that mode description.

Zero Optics Mode. During the zero optics mode, the shaft and trunnion axes of the SXT are driven to their zero positions by taking the outputs of the transmitting resolvers (1X and 64X in trunnion, and 1/2X and 16X in shaft) and feeding them through the two-speed (2X) switches to the motor drive amplifier (MDA). The MDA in turn drives loops to null positions as indicated by zero output from the resolvers. The SCT shaft and trunnion axes follow to a zero position. After 15 seconds, the computer will issue a CDU zero discrete, and will initialize the shaft and trunnion counters in preparation for receiving new data from the CDU.

The zero optics mode can be selected either manually by the flight crew or by the computer after the computer control mode of operation has been manually selected. The computer selects zero optics by energizing a relay in the PSA via a relay driver, which in turn will energize the two-speed switch. The computer is notified of the zero optics mode by a signal from the mode control switch when it is in the zero position.

Manual Mode Operation. The manual mode can be selected to operate under either direct hand control or resolved hand control. Independent control of the SCT trunnion is possible in both of these mode variations.

Manual Direct Operation. When in this mode the hand controller outputs are applied directly to the SXT shaft and trunnion motor drive amplifiers. Forward and back motion of the hand controller commands increasing and decreasing trunnion angles, and right and left motion of the hand controller commands increasing and decreasing shaft angles, respectively. The target image motion is in the R-M coordinate system, the position of which is dependent upon the position of the SXT shaft.

The apparent speed of the image motion can be regulated by the flight crew by selecting either low, medium, or high controller speed on the indicator control panel. This regulates the voltage applied to the motor drive amplifier, A_s and A_t , and therefore the shaft and trunnion drive rates. The maximum rates are approximately 18 degrees per second for the shaft and 9 degrees per second for the trunnion.

SYSTEMS DATA

Slave Telescope Modes. The slave telescope modes provide for alternate operation of the telescope trunnion while the SXT is being operated manually. The alternate modes are selected by the telescope trunnion switch on the mode control panel. There are three possible selections, SLAVE to SXT, 0° , and 25° . With this switch in the SLAVE to SXT position, the SCT trunnion axis is slaved to the SXT trunnion; this is the normal operating position for the SCT. With the switch in the 0° position, the SCT trunnion is locked in a zero position by the application of a fixed voltage to the SCT trunnion 1X receiving resolver. This will cause this position loop to null in a zero orientation. Therefore, the centerline of the SCT 60-degree field-of-view is held parallel to the LLOS of the SXT.

With the switch in the 25° position, an external voltage is applied to the same 1X receiving resolver which will cause the SCT trunnion position loop to null out so that the centerline of the 60-degree field-of-view is offset 25 degrees (A_t of SCT at 12.5 degrees) from the LLOS of the SXT. This position of the SCT trunnion will allow the landmark to remain in the 60-degree field-of-view while still providing a total possible field-of-view of 110 degrees if the SCT shaft is swept through 360 degrees.

Manual Resolved Operation. When in this mode, the hand controller outputs are put through a matrix transformation prior to being directed to the shaft and trunnion motor drive amplifiers. The matrix transformation makes the image motion correspond directly to the hand controller motion. This is, up, down, right, and left motions of the hand controller commands the target image to move up, down, right, and left, respectively, in the field of view. In other words, the image motion is in the X-Y spacecraft coordinate system. The matrix transformation takes place in two steps. The outputs of the hand controller are routed to the 1X resolver on the SXT shaft. Here the drive signals, A_s and A_t , are transformed by the sine and cosine functions of the shaft angle (A_s). One of the two outputs of the 1X resolver is sent to the SXT trunnion motor drive amplifier. The second output is then resolved through the SLOS angle (A_{LOS}) that the target image motion will be independent of SLOS angle. This is accomplished by the cosecant computing amplifier (CSC) and the 2X computing resolver located on the SXT trunnion axis. The net result is that the shaft drive rate, A_s , is inversely proportional to the sine of the SLOS angle. The speed controller is also operational in this mode.

Optics-Computer Mark Logic. The MARK and MARK REJECT buttons on the indicator control panel are utilized to instruct the computer that a navigation fix has taken place, and that SXT shaft and trunnion position and the time should either be recorded or rejected. The mark command is generated manually by the flight crew which energizes the

SYSTEMS DATA

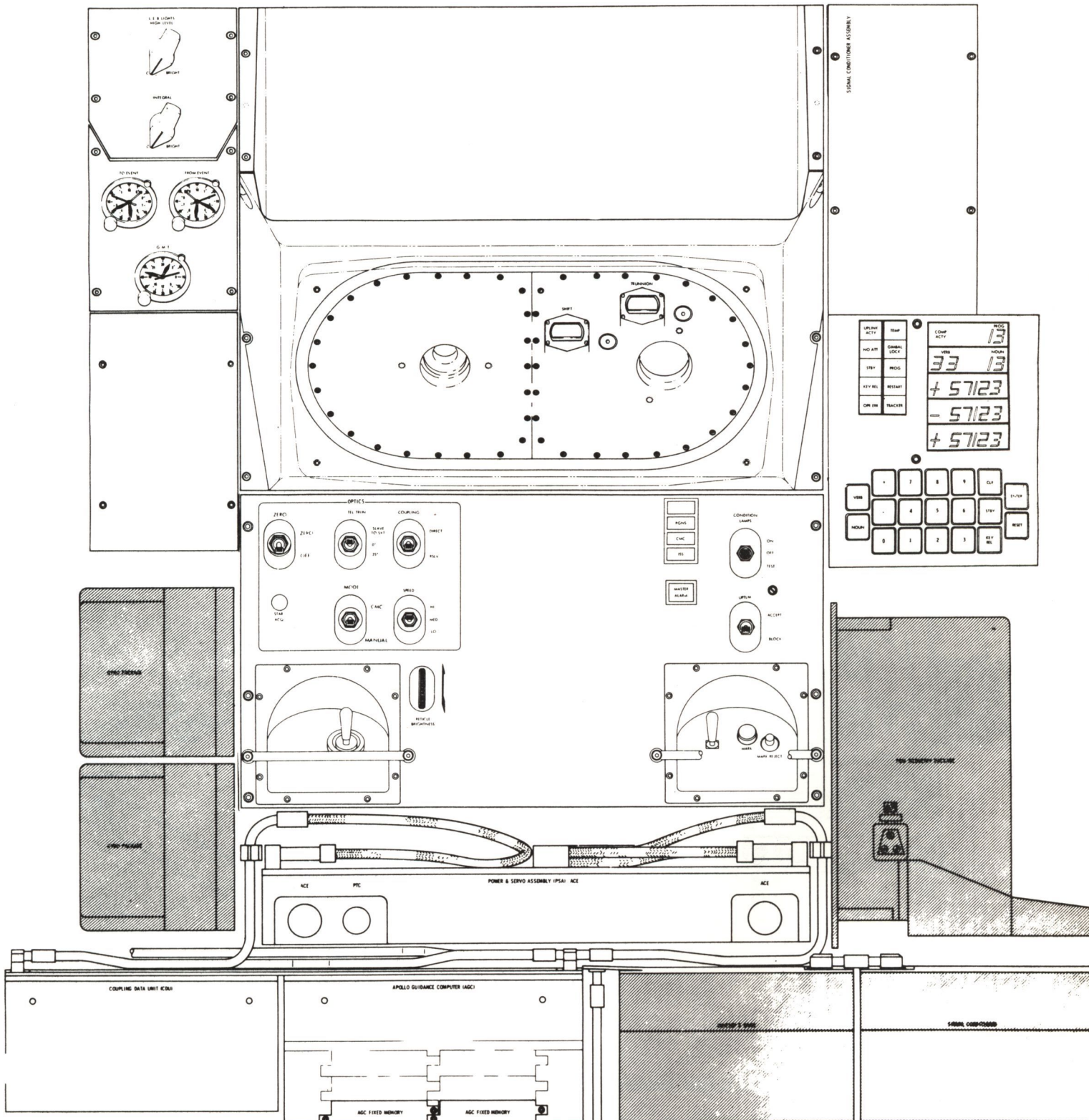
mark relay. The mark relay transmits a mark command to the computer. If an erroneous mark is made, the mark reject button is depressed; this will generate a "mark reject" command to the computer.

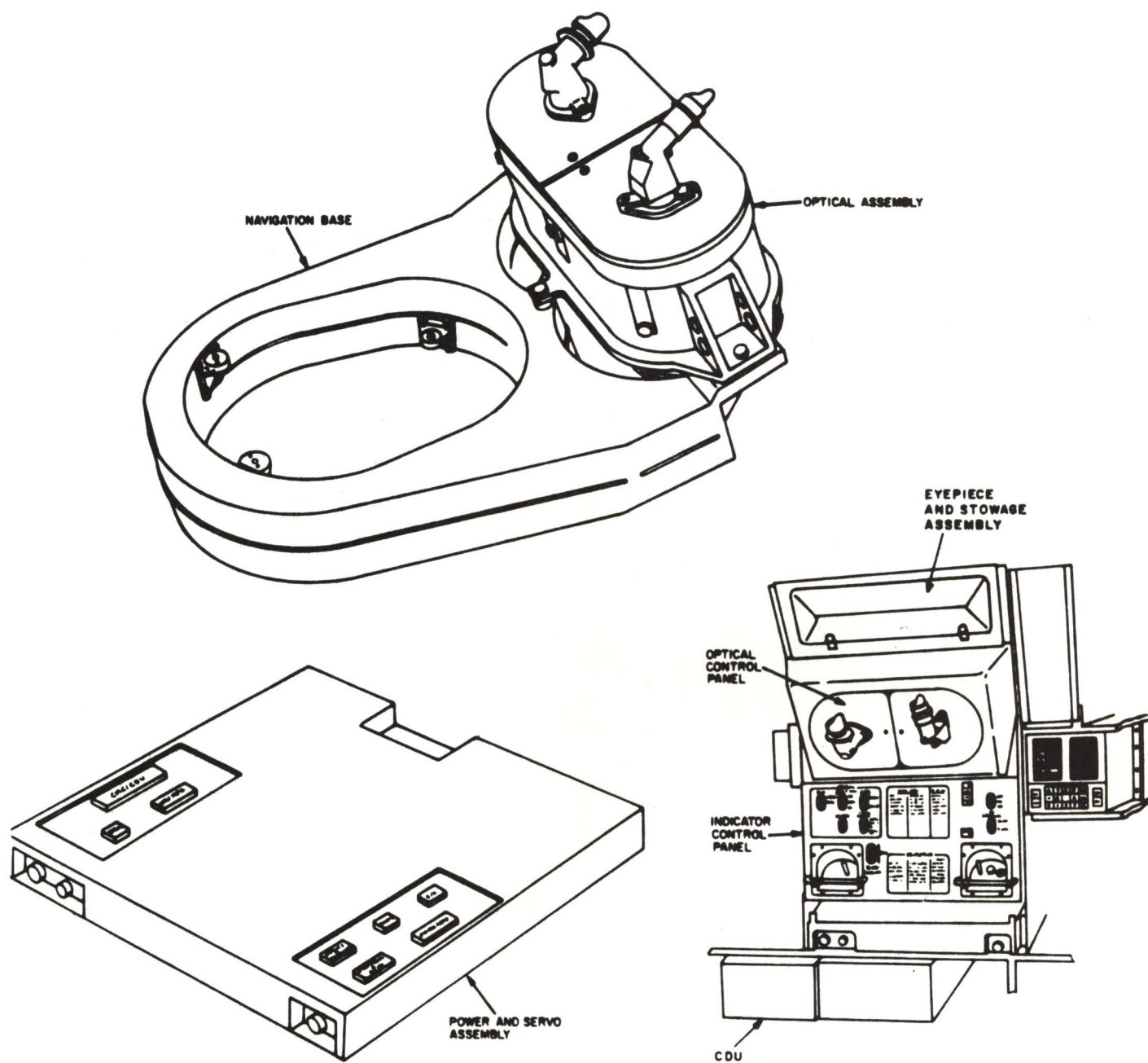
Computer Mode Operation. The computer-controlled operation is selected by placing the moding switch in computer position. The mechanization of this loop is chosen by the computer program that has been selected by the flight crew. The operation of the SXT under computer control is accomplished by completing the circuit from the CDU digital-to-analog converters (DAC) to the shaft and trunnion motor drive amplifier. The computer can then provide inputs to these amplifiers via a digital input to the CDU, which are converted in the DAC to an 800-cycle signal that can be used by the MDA. This mode is used when it is desired to look at a specific star for which the computer has the corresponding star coordinates. The computer will also know the attitude of the spacecraft from the position of the IMU gimbals and will, therefore, be able to calculate the position of the SXT axes required to acquire the star. The computer can then drive the shaft and trunnion of the SXT to the desired position via the DAC.

In the computer mode, the optics can be zeroed via control relays located in the PSA. The relays are selected by a CMC input into a relay driver in the PSA. These relays generally perform the same function as the indicator control panel switches. It should be noted that when the computer selects zero optics, it will also disconnect the DAC from the circuit.

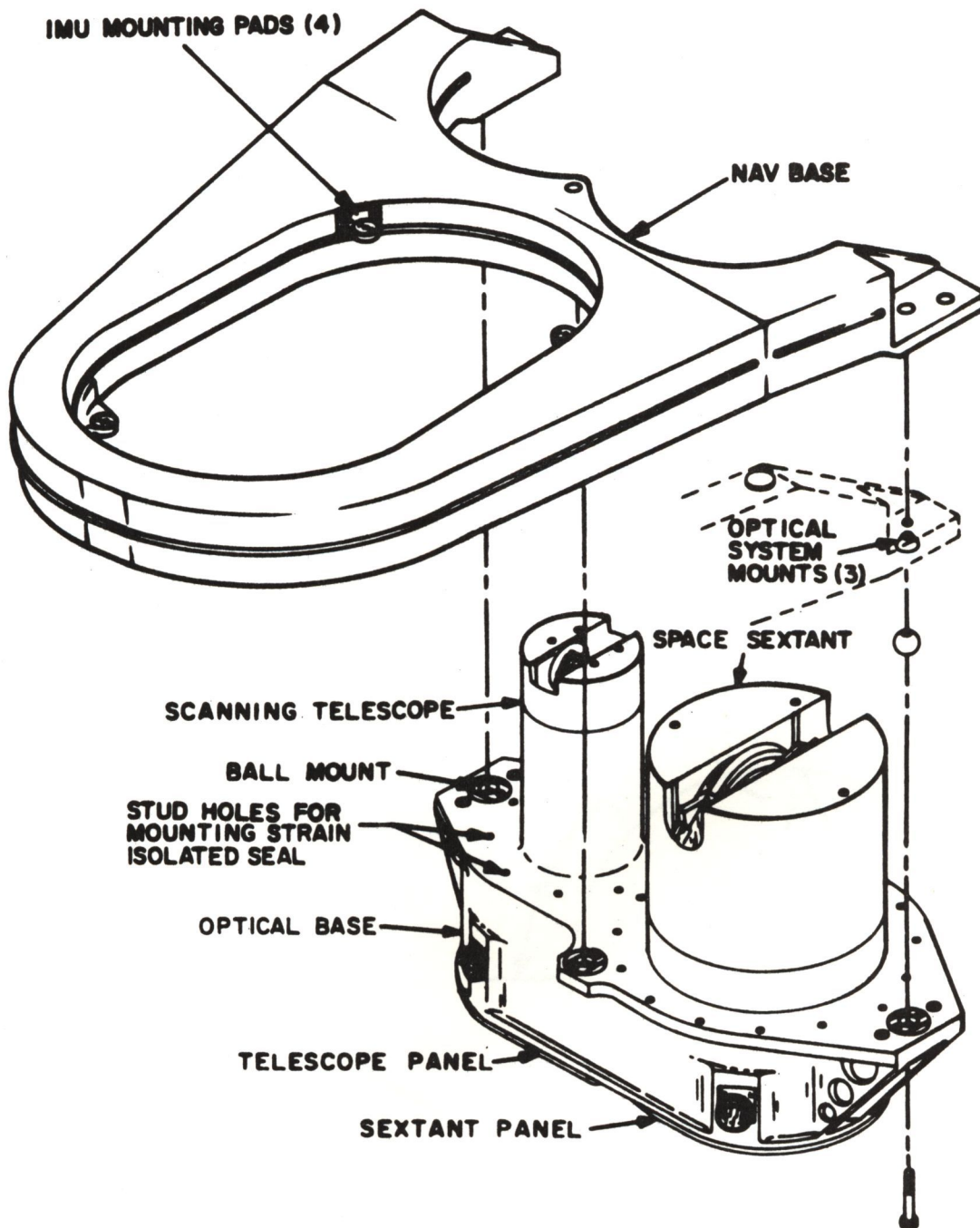
G&N LOWER EQUIPMENT BAY

BLOCK II





Optical Subsystem Equipment

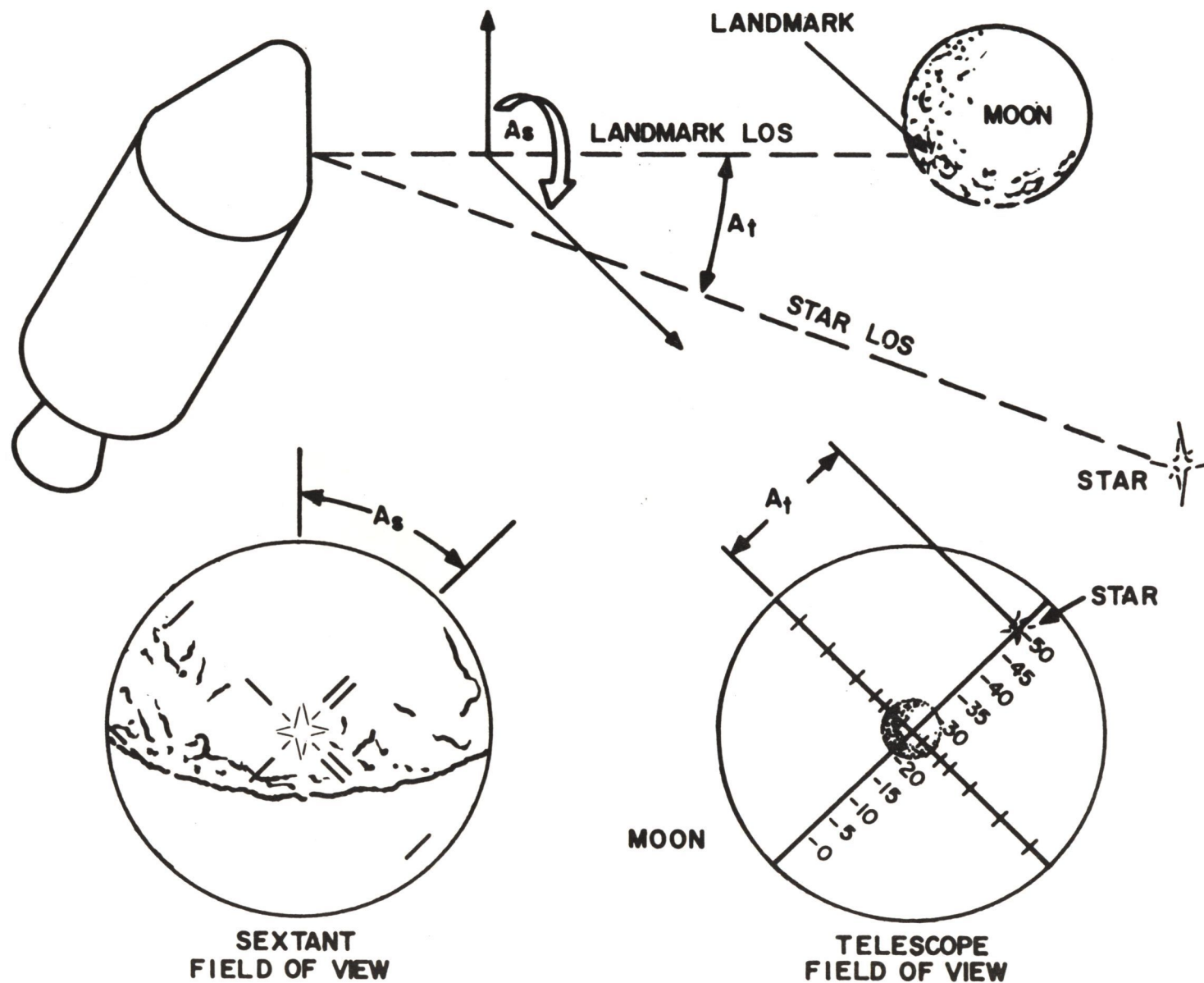


Optical Assembly and Navigation Base

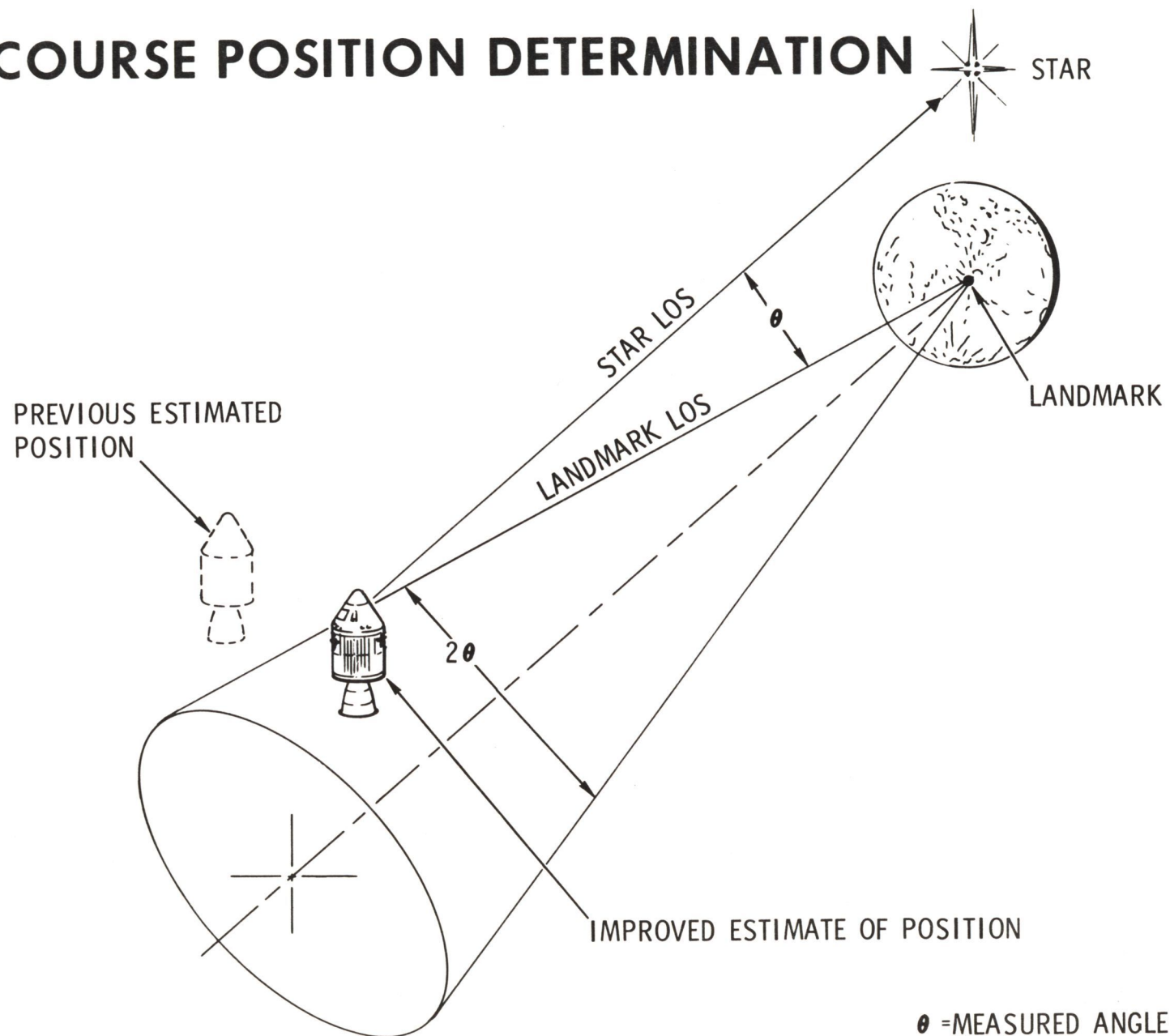


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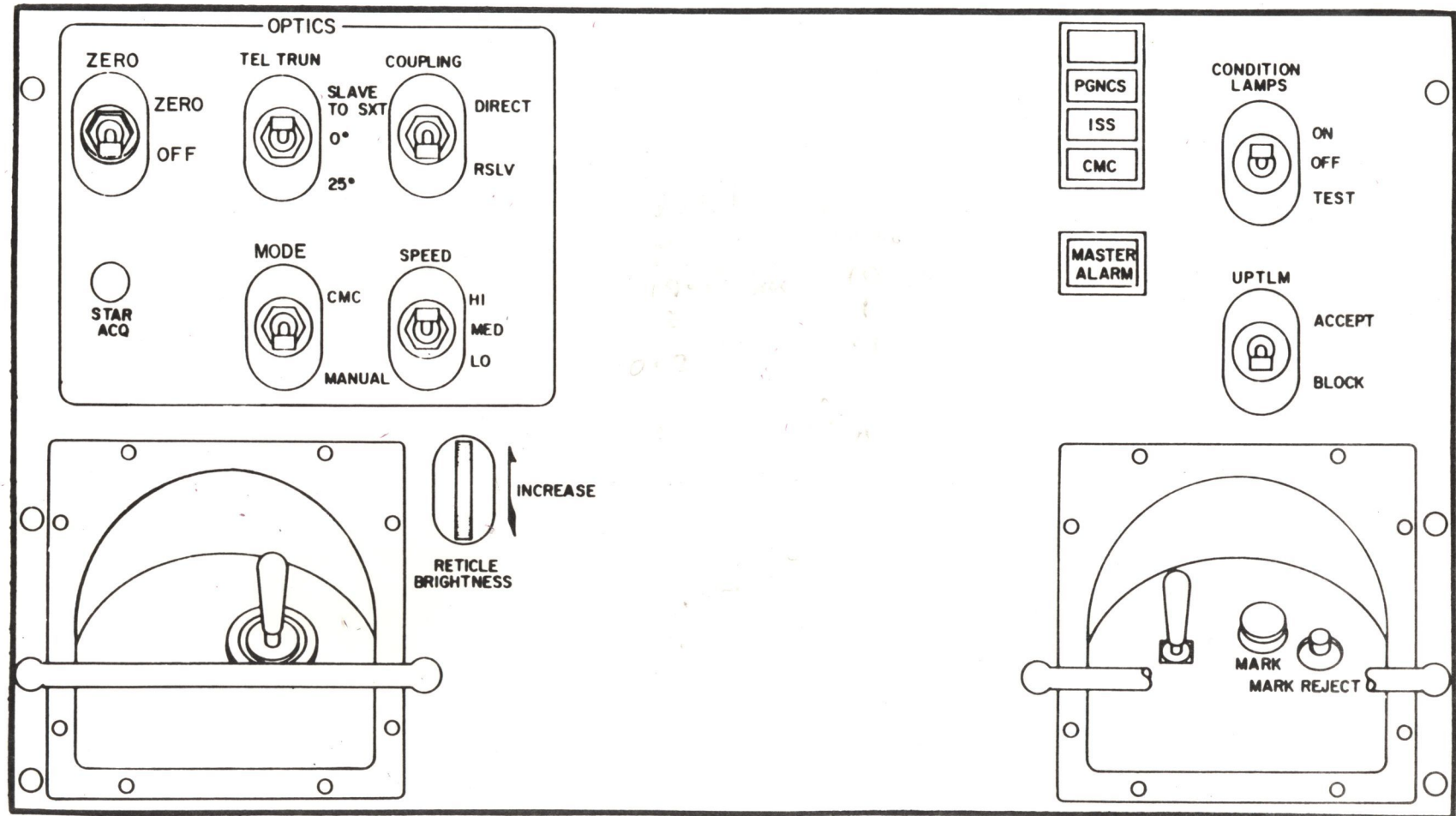
NAVIGATIONAL MEASUREMENT

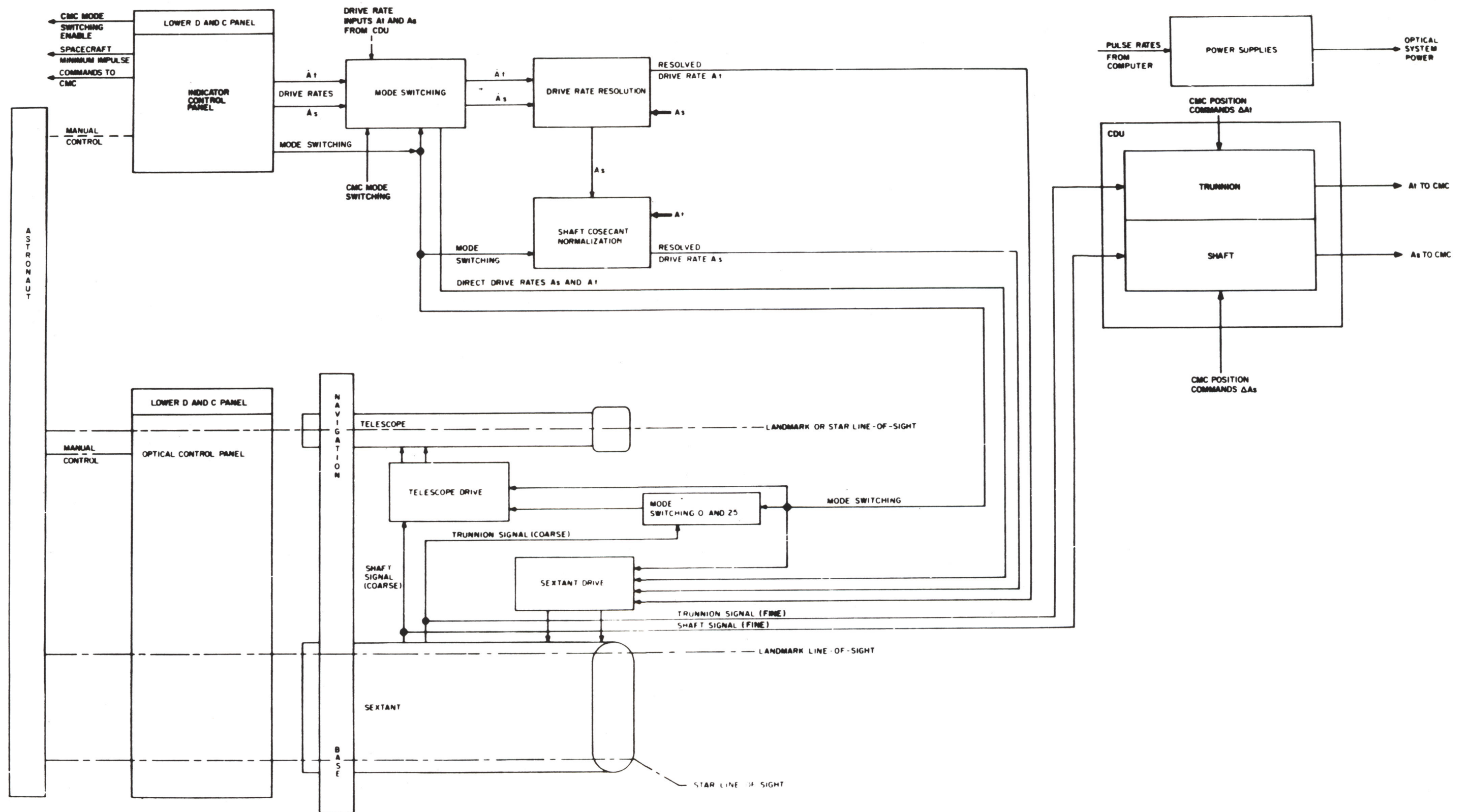


MIDCOURSE POSITION DETERMINATION



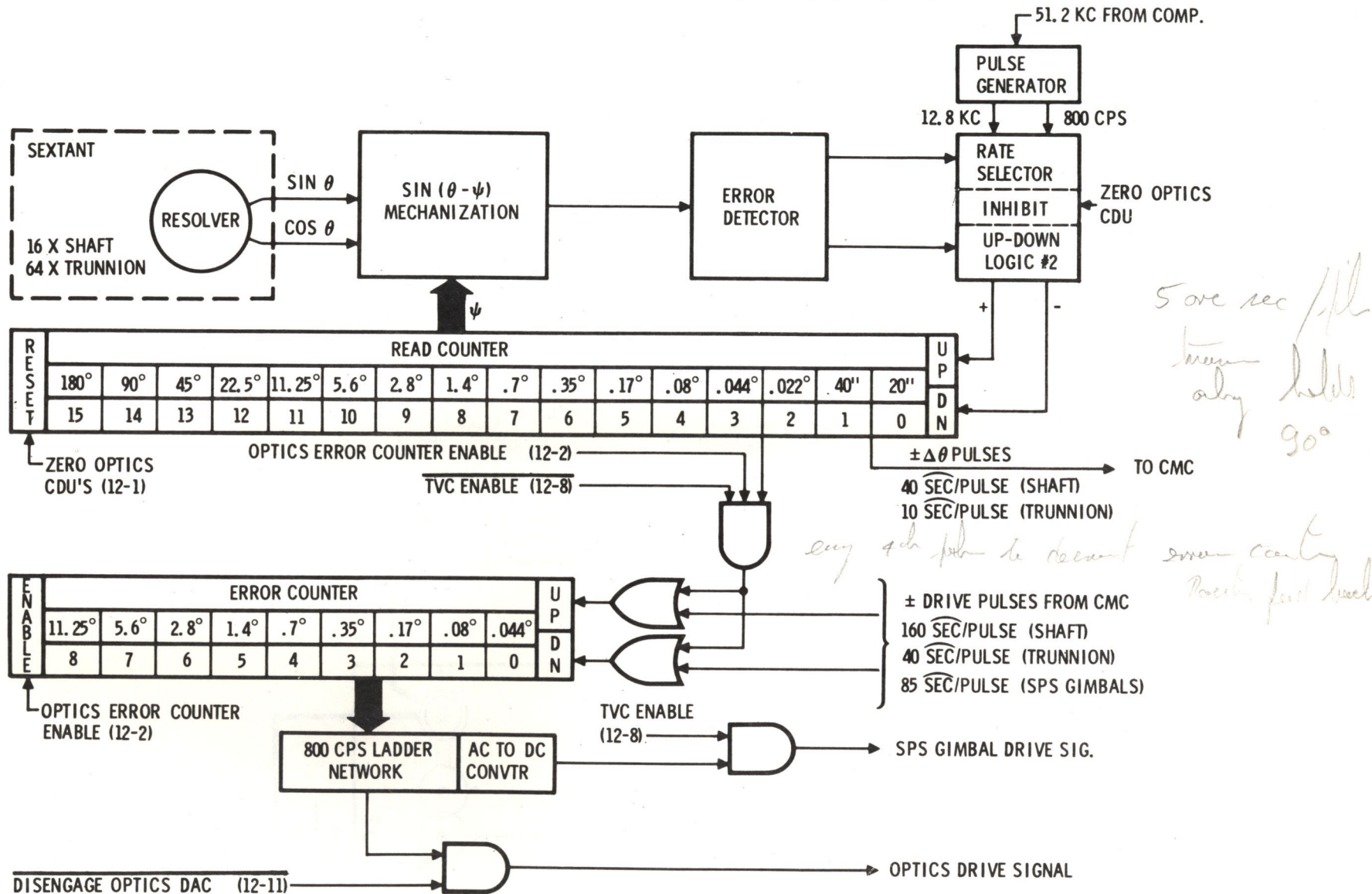
INDICATOR CONTROL PANEL

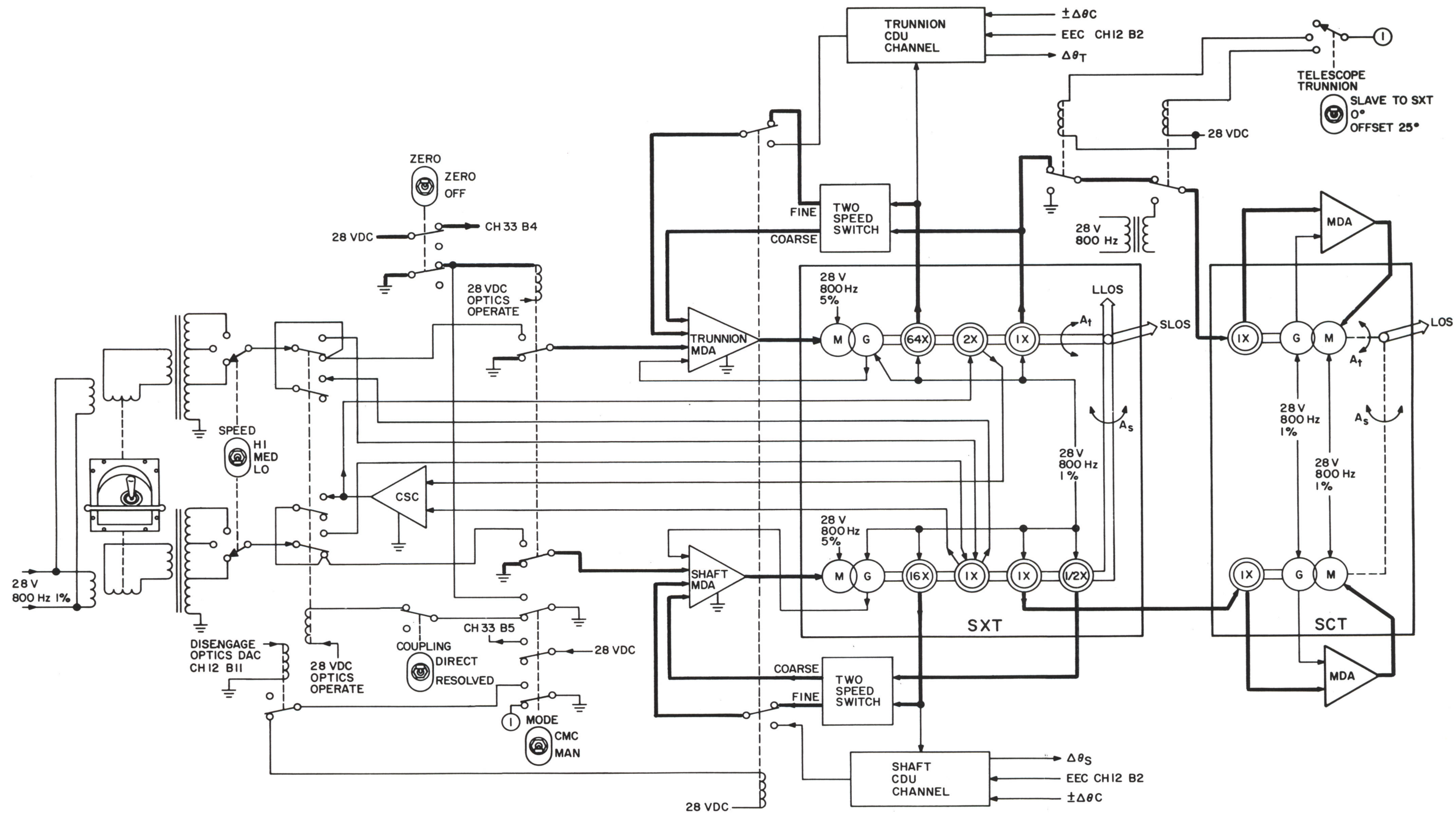




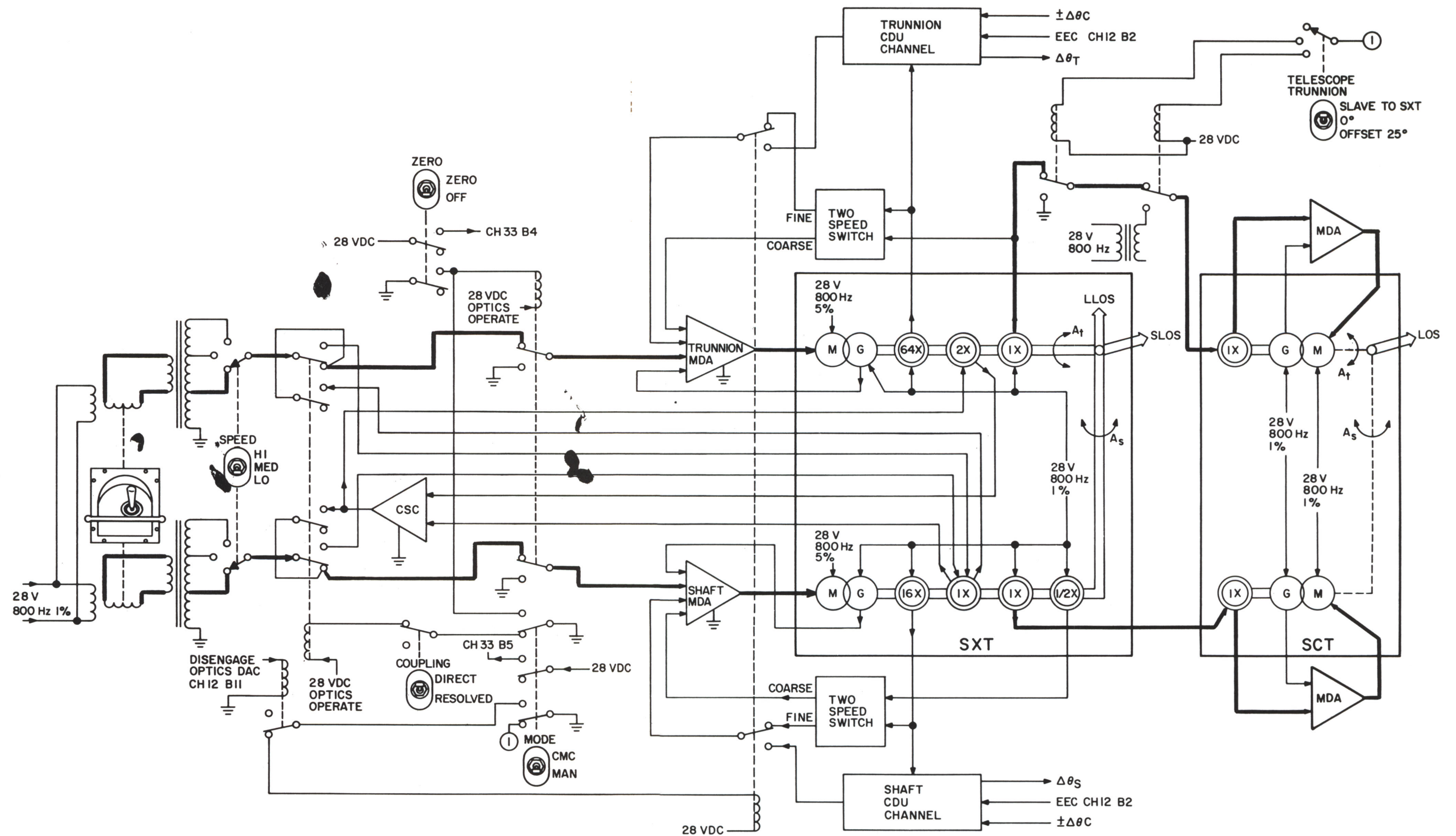
Optical Subsystem Interface

OCDU FUNCTIONAL BLOCK DIAGRAM

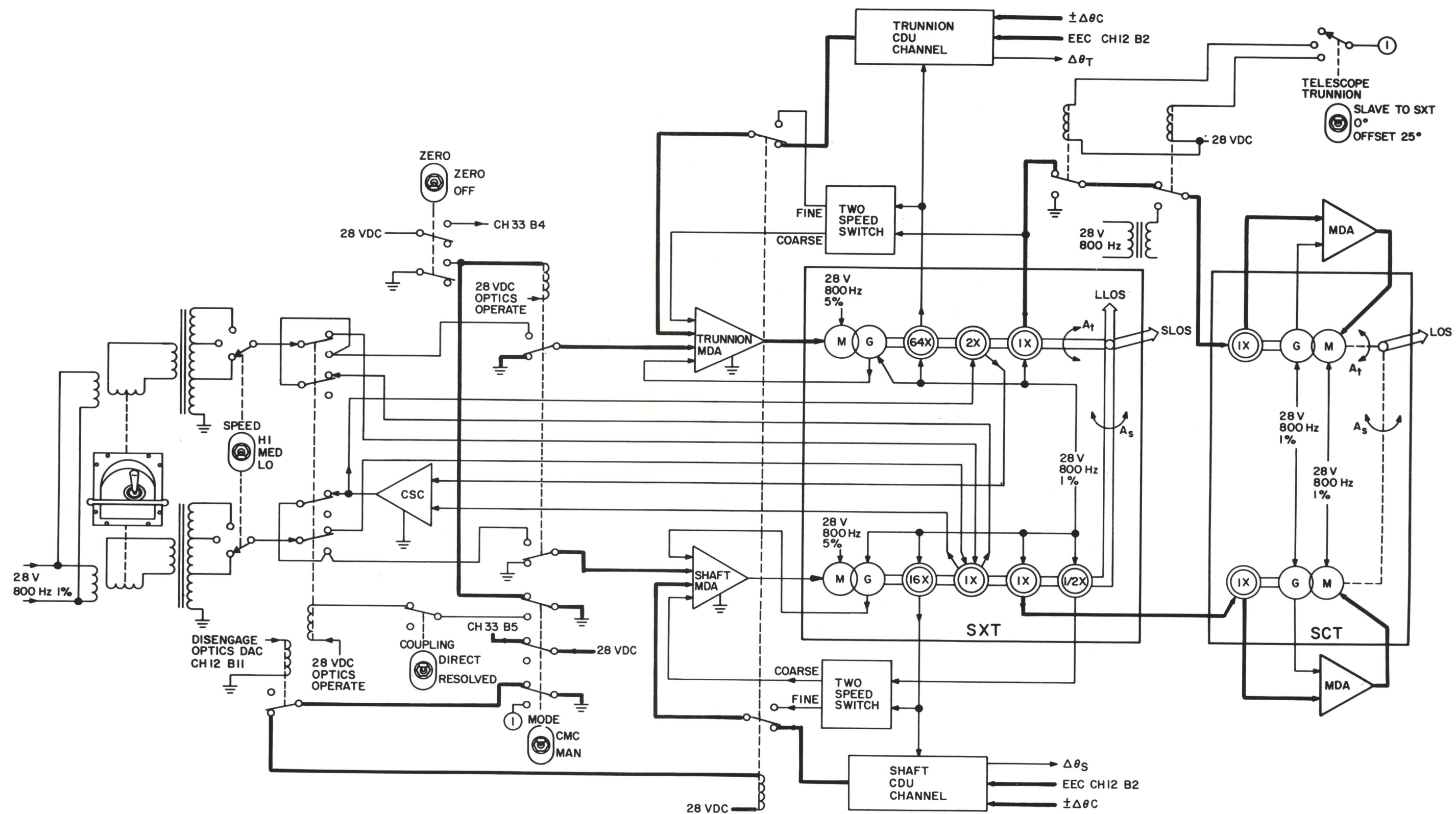




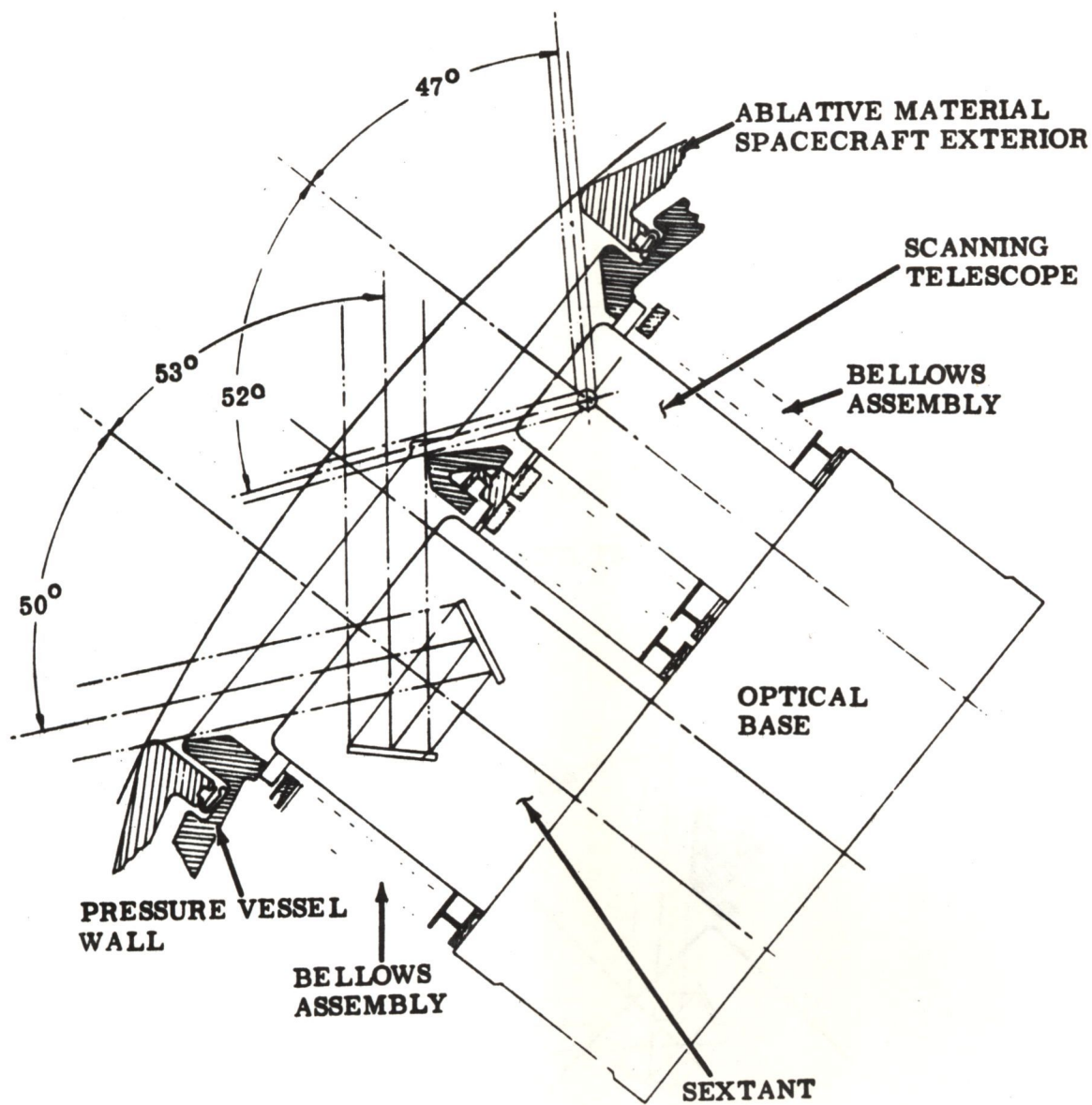
Zero Optics Mode



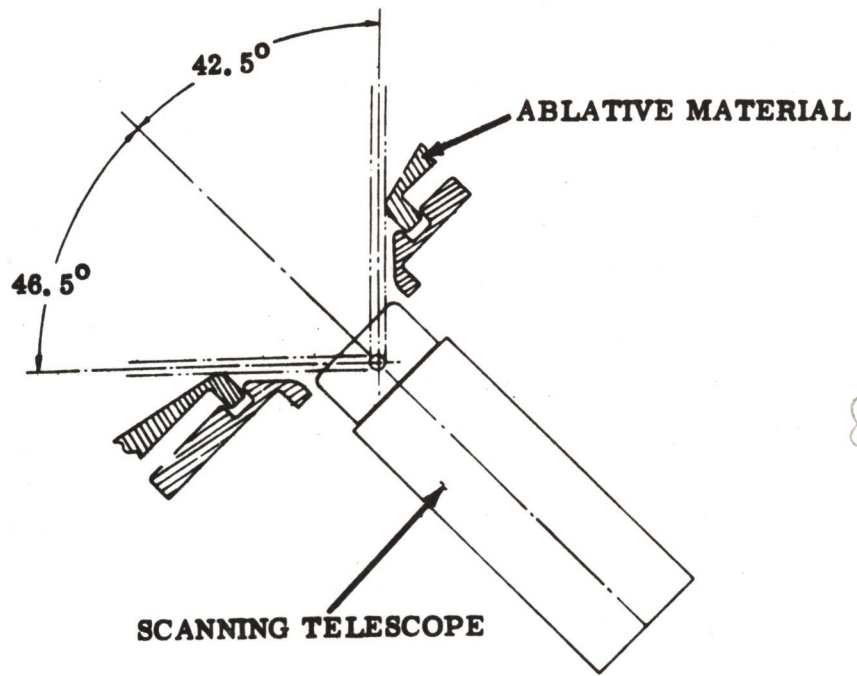
Manual Direct Mode



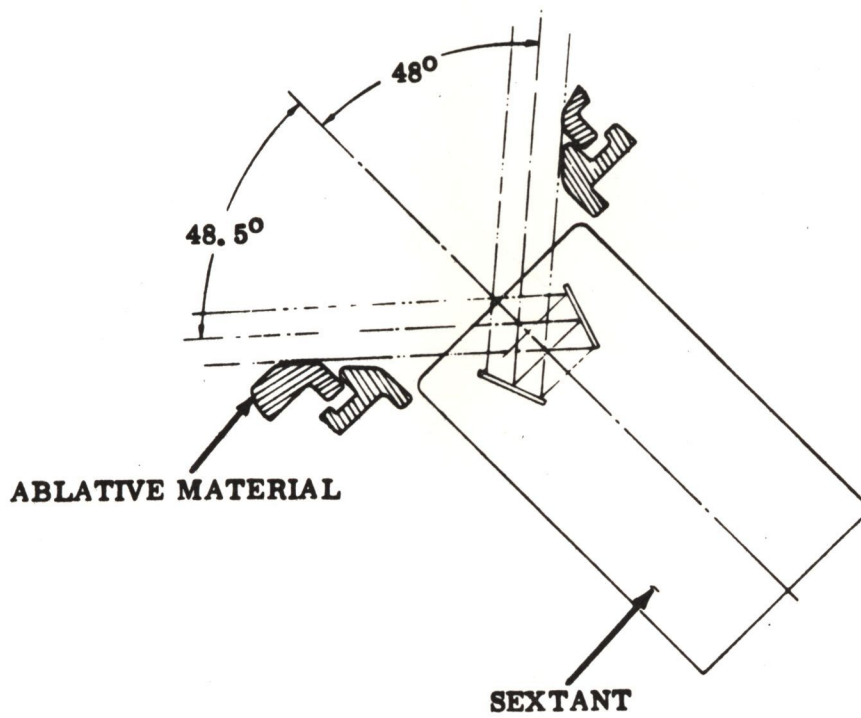
CMC Optics Mode



Optical Unit Horizontal Cross-section

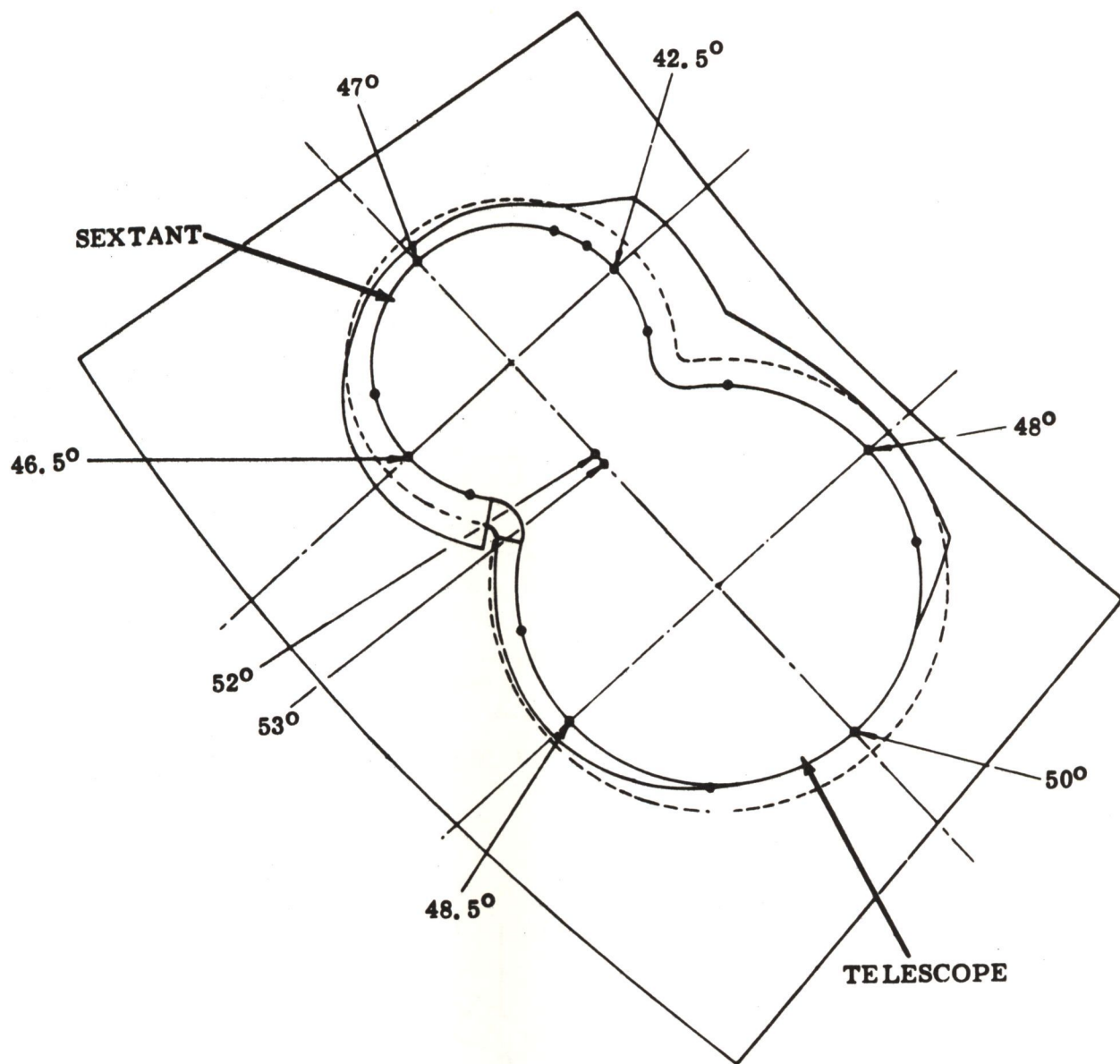


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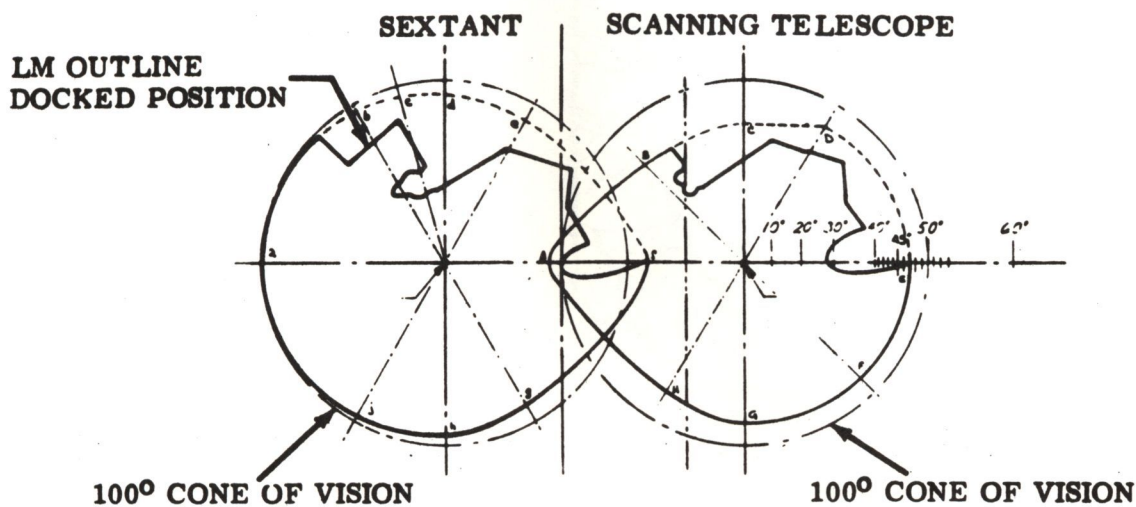
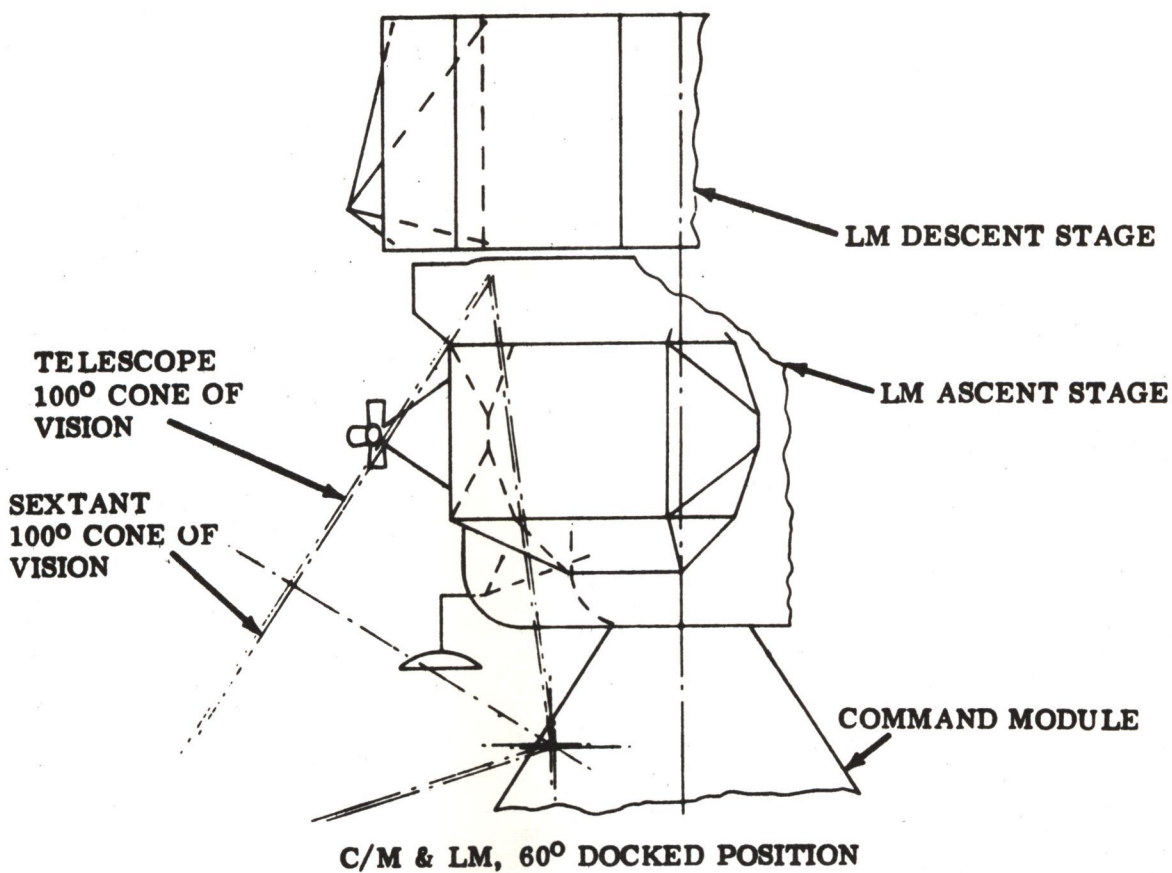


96-1/2

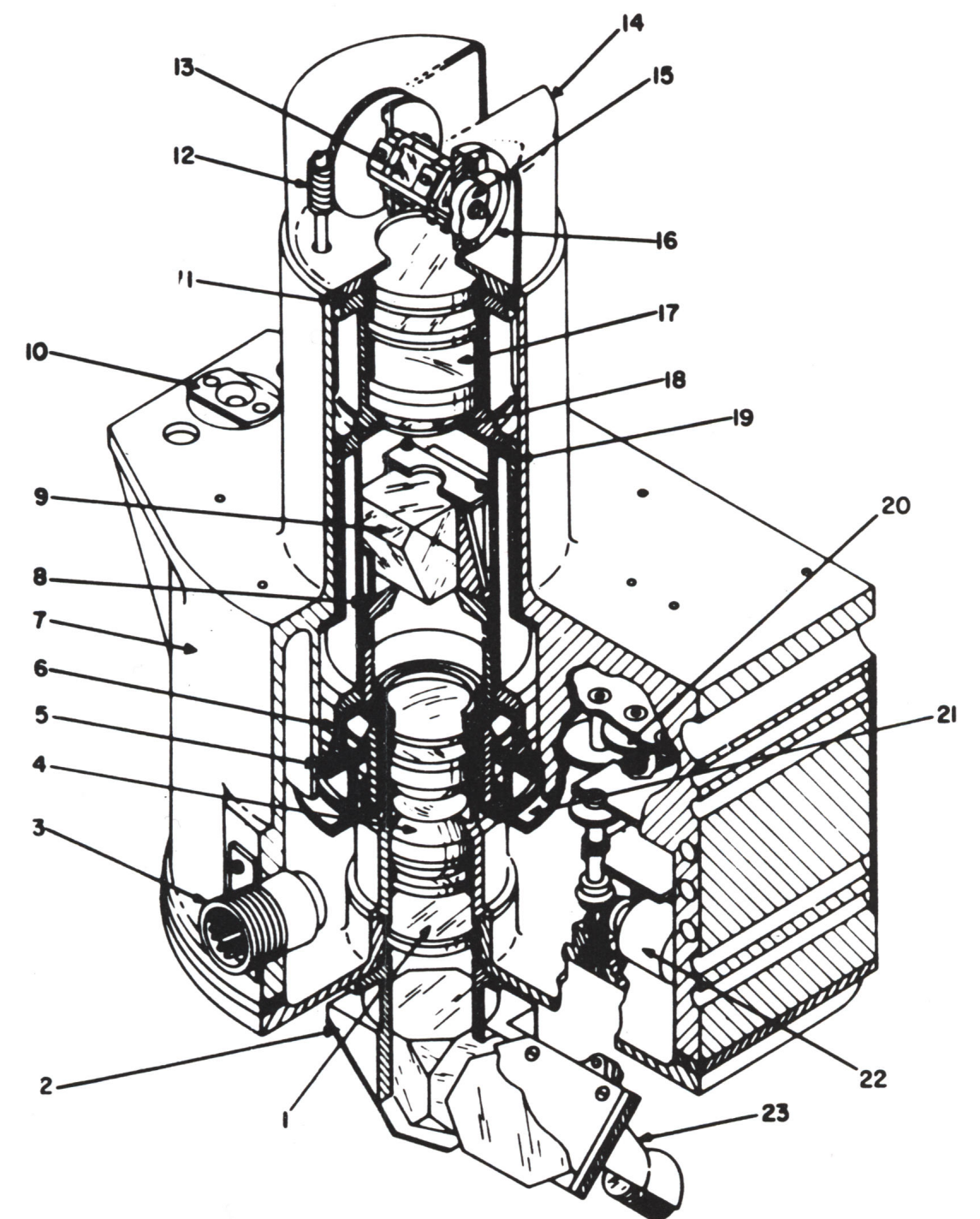
SXT and SCT Vertical Cross-section



SXT and SCT FOV Without LM in Docked Position

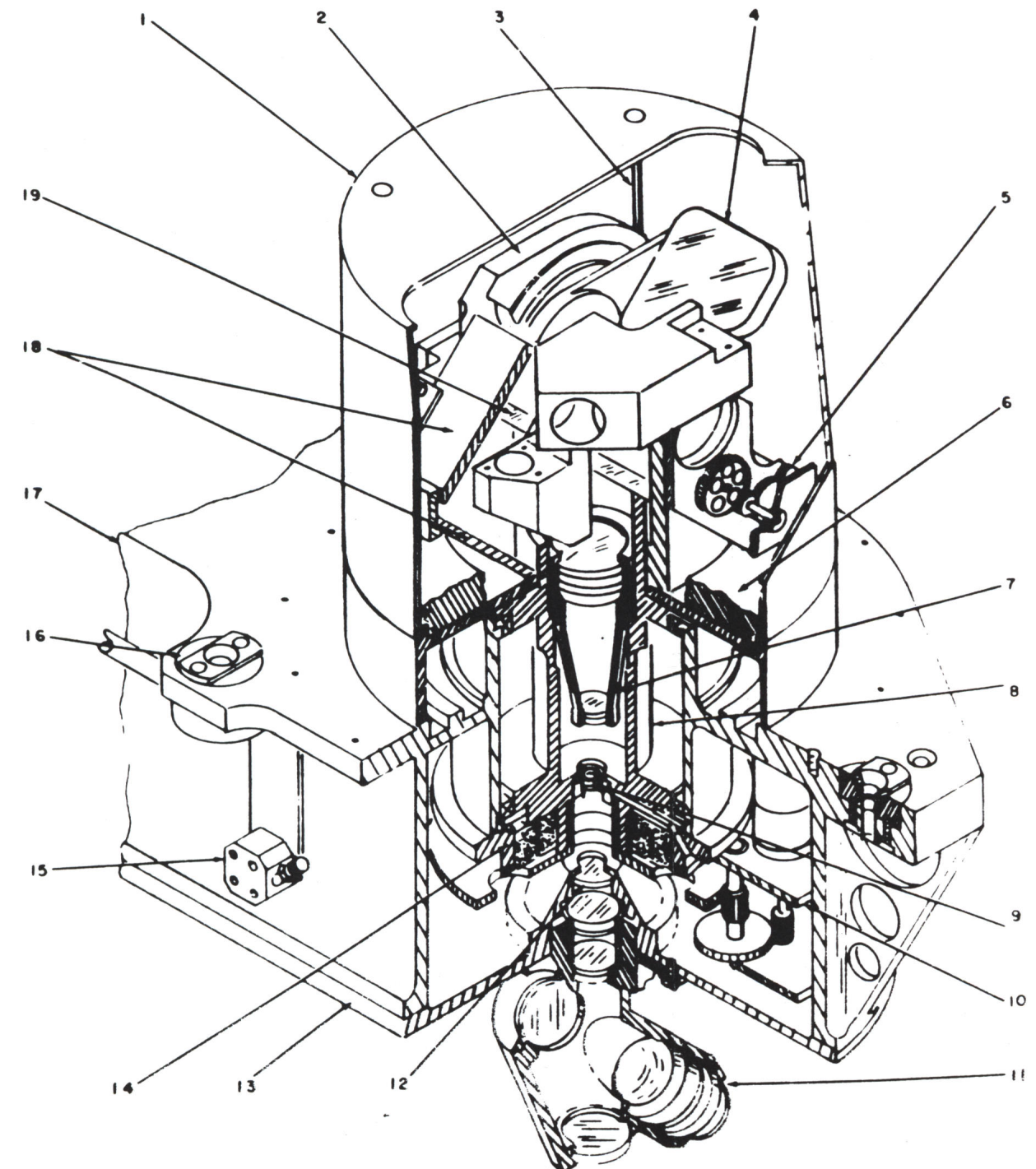


1. Eyepiece window
2. Eyepiece prism housing assembly
3. Electrical connector
4. Relay lens assembly
5. Ball bearing (outer telescope tube assembly)
6. Outer telescope tube assembly
7. Optical base
8. Inner telescope tube assembly
9. Pechan prisms
10. Ball mount (3)
11. Ball bearing (outer telescope tube assembly)
12. Trunnion drive worm shaft
13. Dove prism and mount assembly
14. SCT head cover
15. Anti-backlash cam
16. Anti-backlash spring and cam follower
17. Objective lens assembly
18. Reticle assembly
19. Housing and lamp assembly
20. Shaft drive gear box
21. Cluster gear assembly
22. Shaft angle counter
23. Eyepiece assembly



Scanning Telescope Cutaway

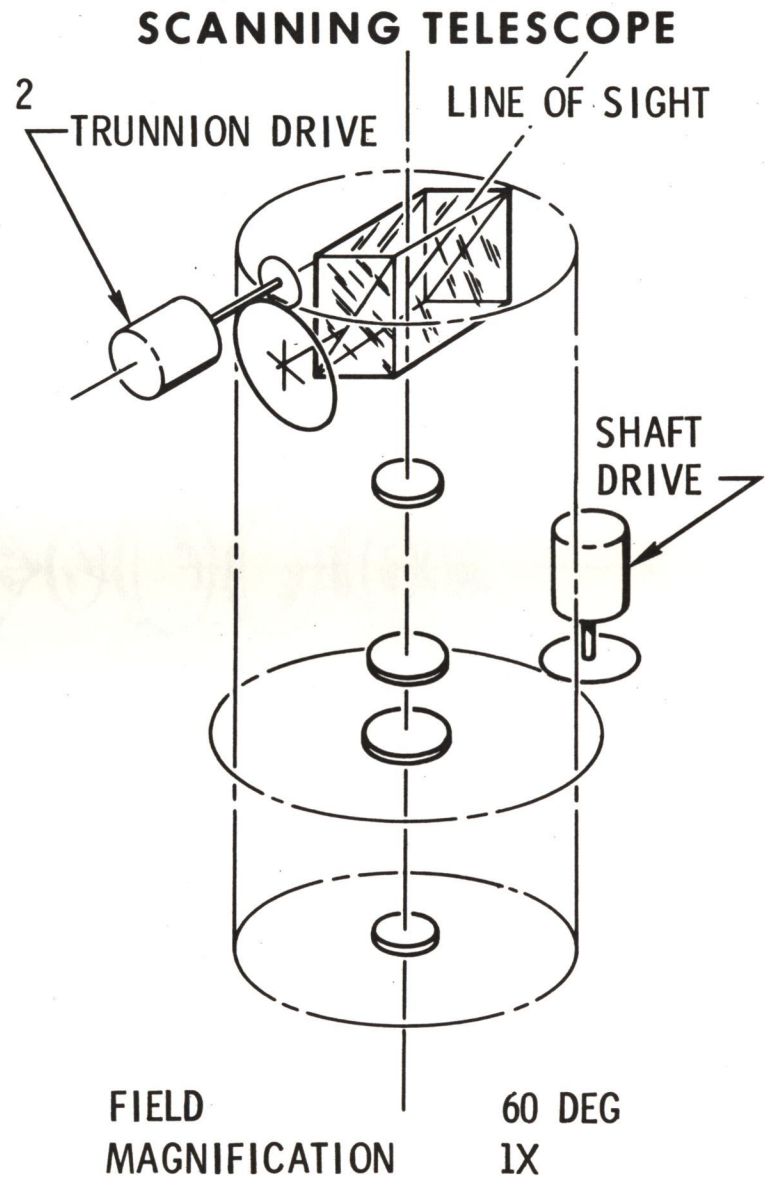
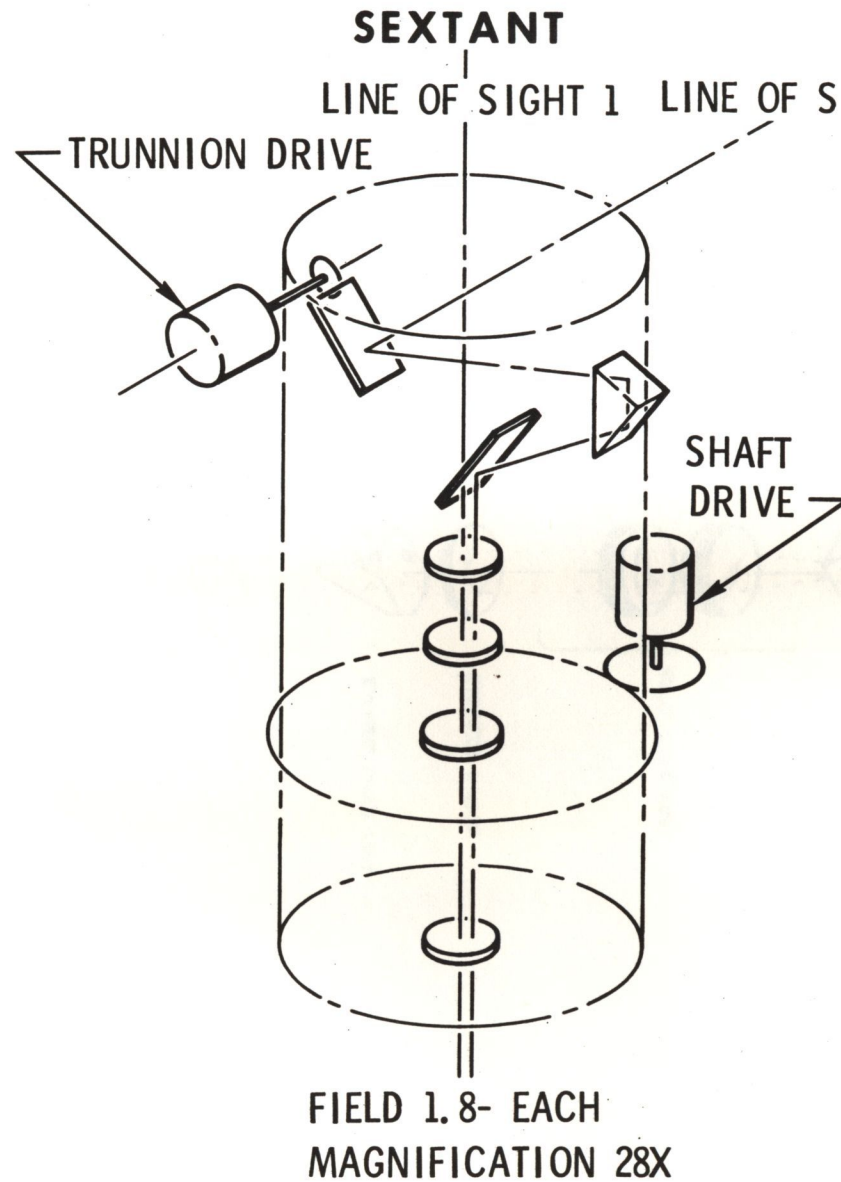
1. SXT head assembly cover
2. Trunnion pancake resolvers
3. Threaded rod (cover support) (2)
4. Trunnion indexing mirrors and mount assembly
5. Trunnion servo gear box
6. Dummy weight
7. Objective lens assembly
8. Shaft axis assembly
9. Reticle assembly
10. Shaft servo gear box
11. SXT eyepiece assembly
12. Eyepiece window
13. SXT panel assembly
14. Shaft resolvers
15. Coolant passages (not used)
16. Ball mount (3)
17. Optical base
18. Right-angle mirrors
19. Beam splitter

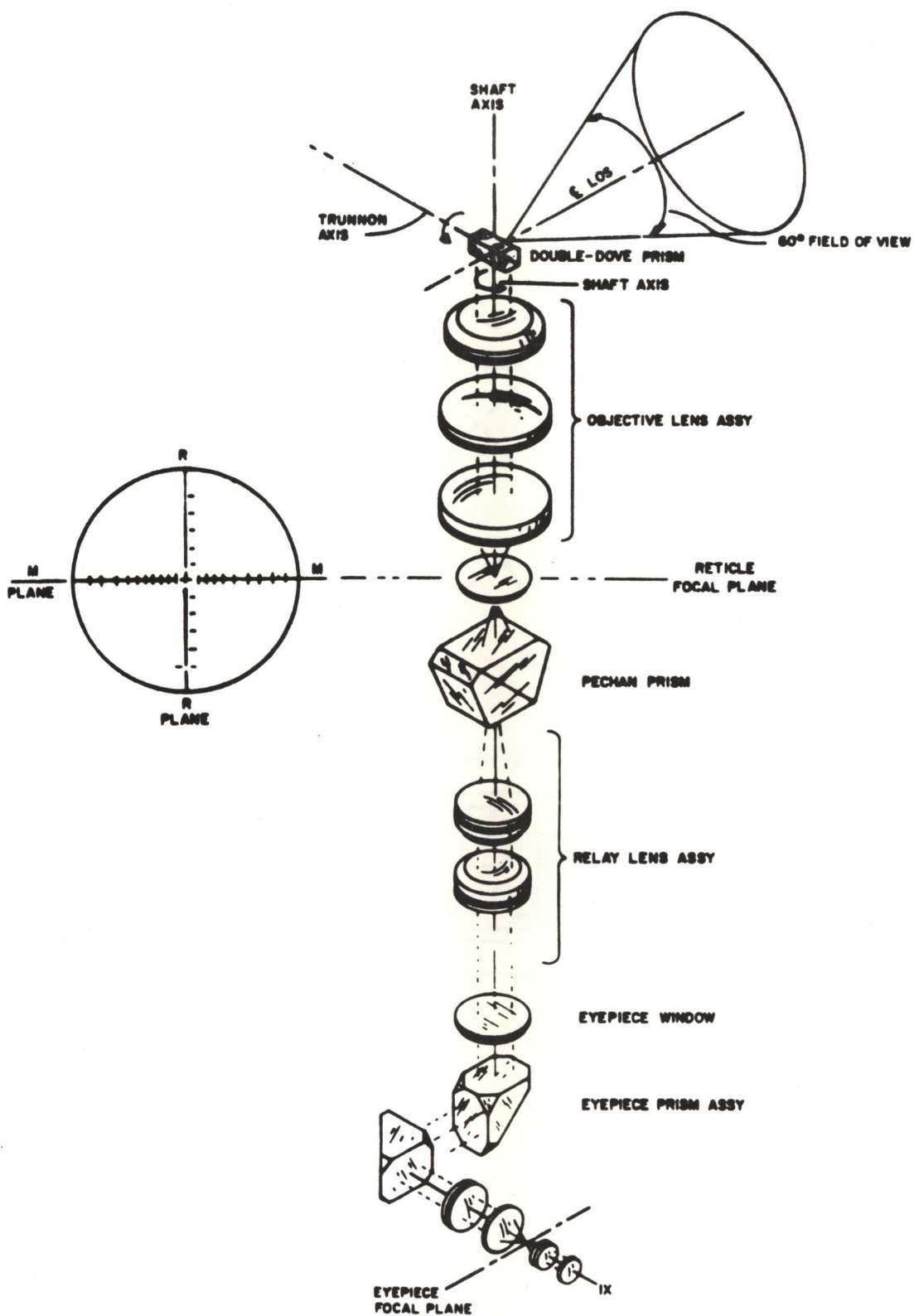


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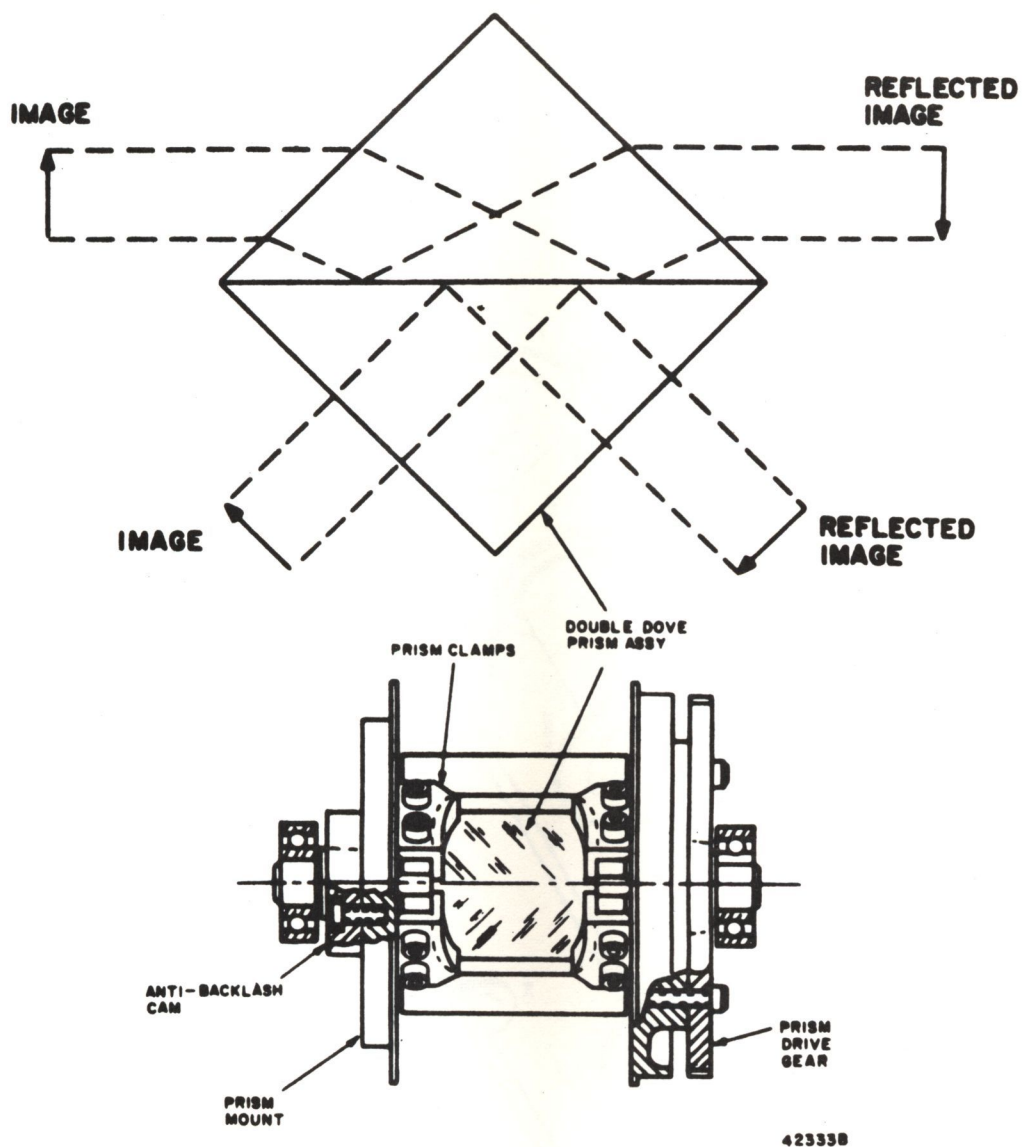
Sextant Cutaway

OPTICAL SCHEMATIC

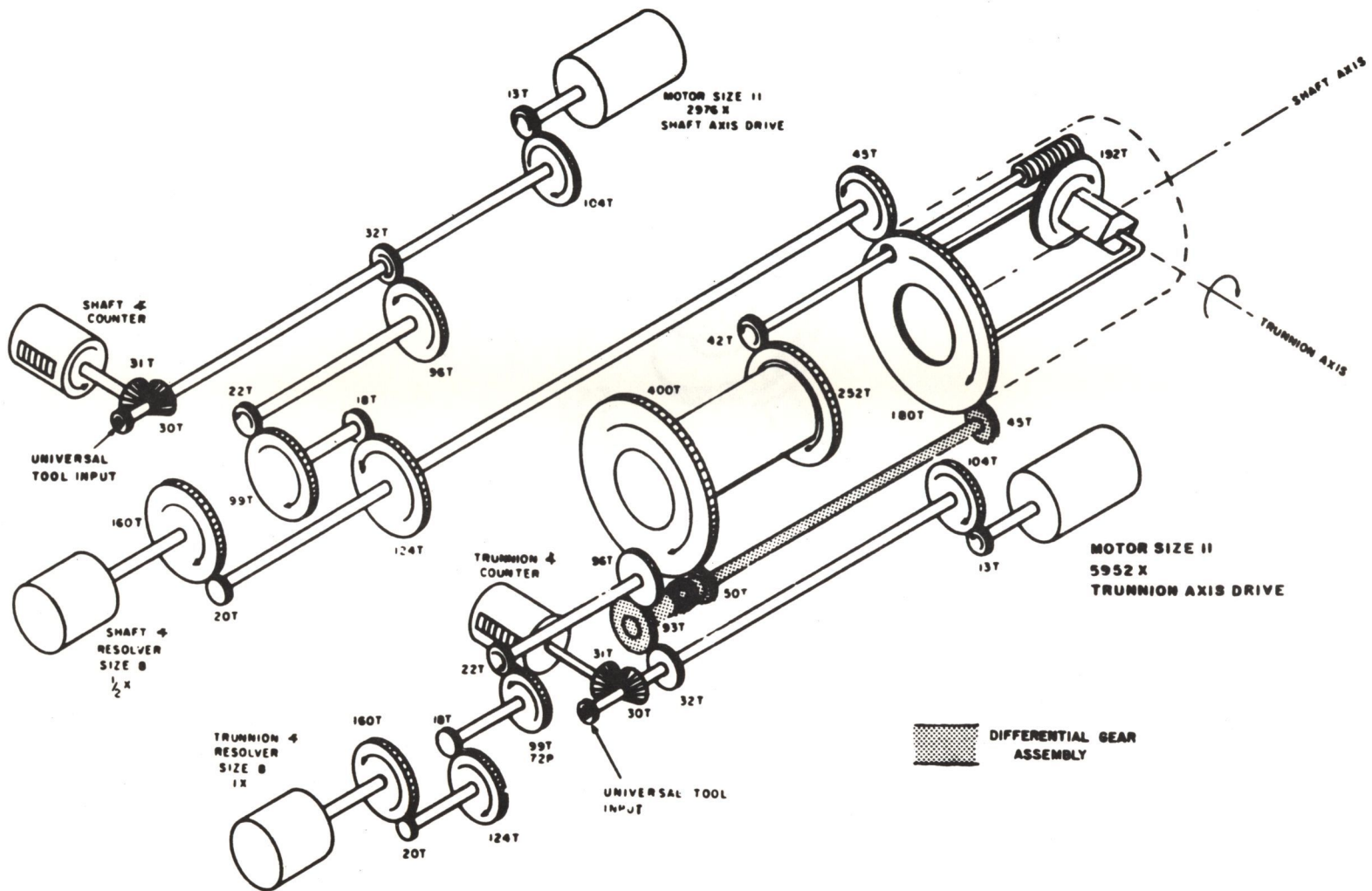




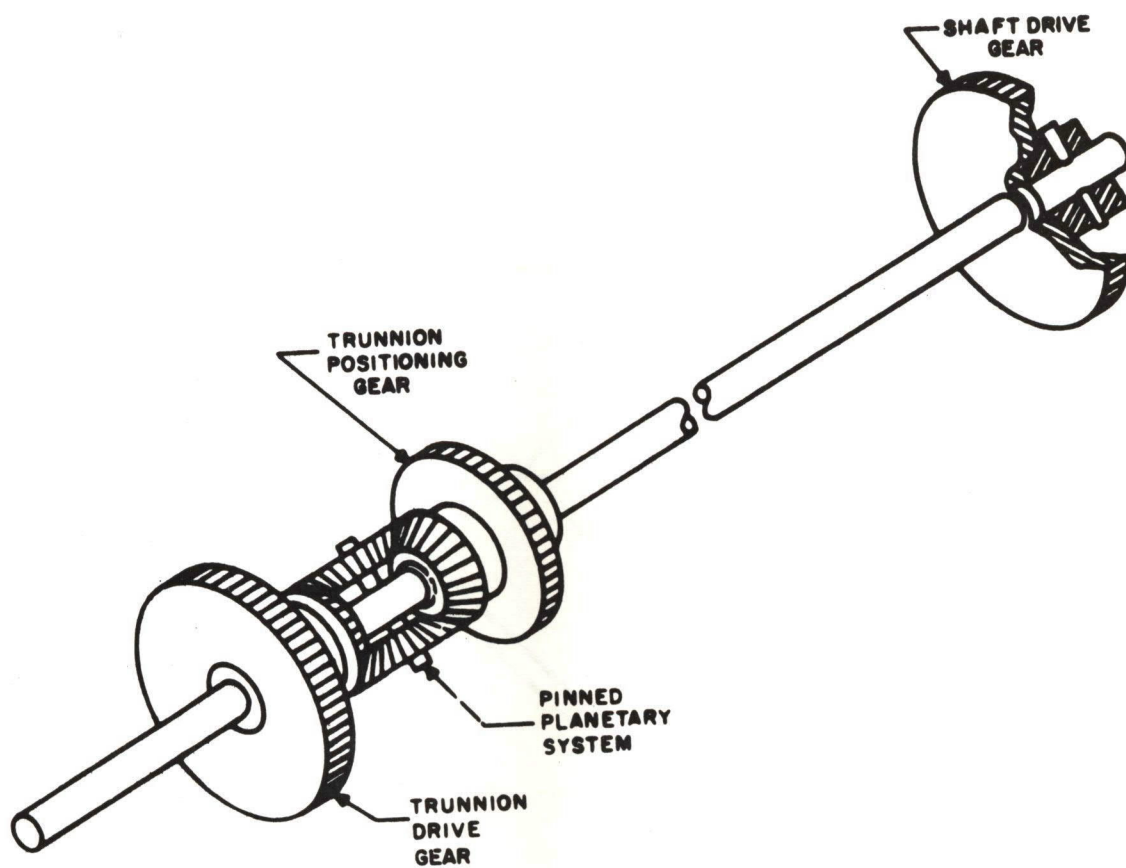
SCT Optical Schematic



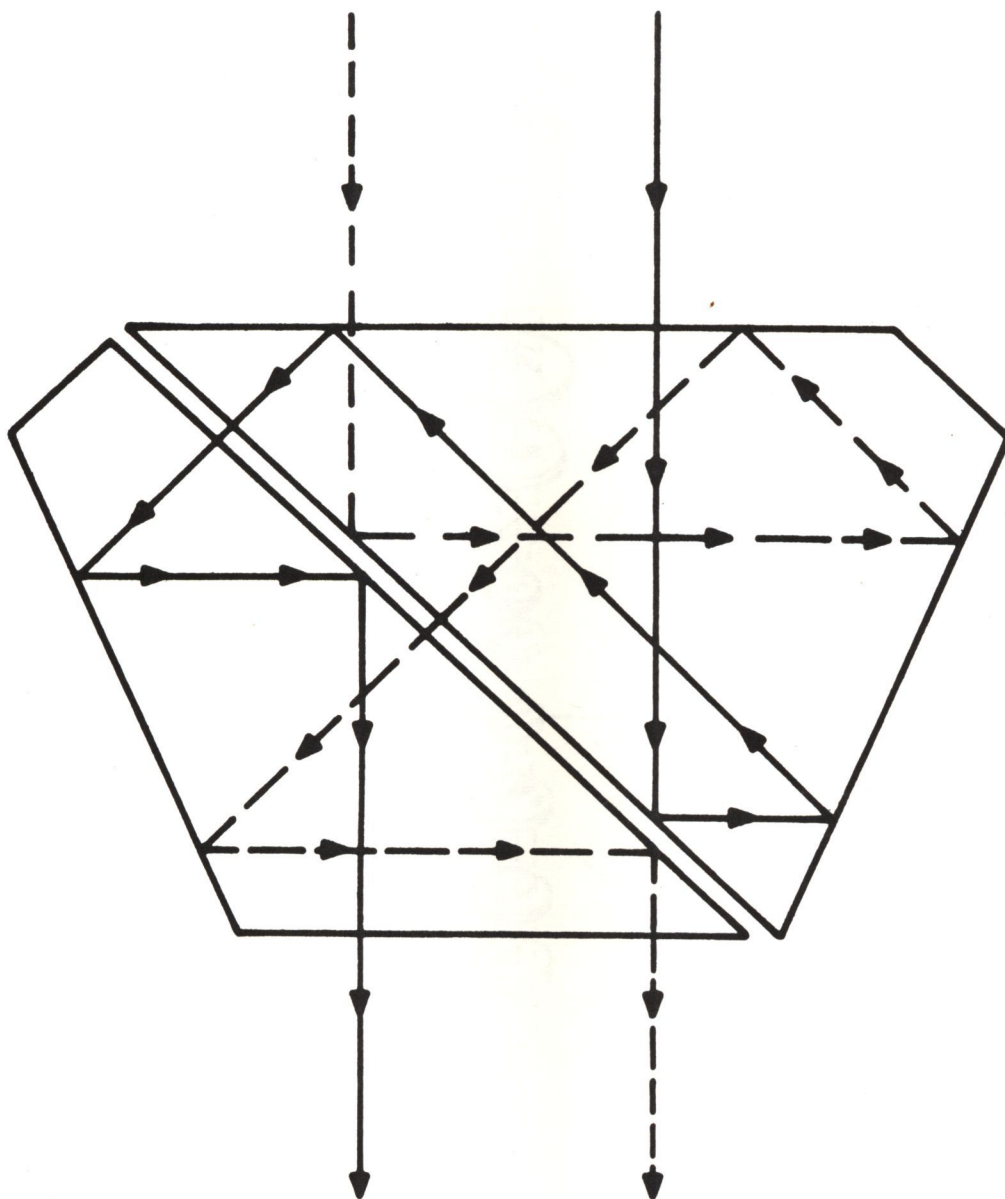
Double Dove Prism



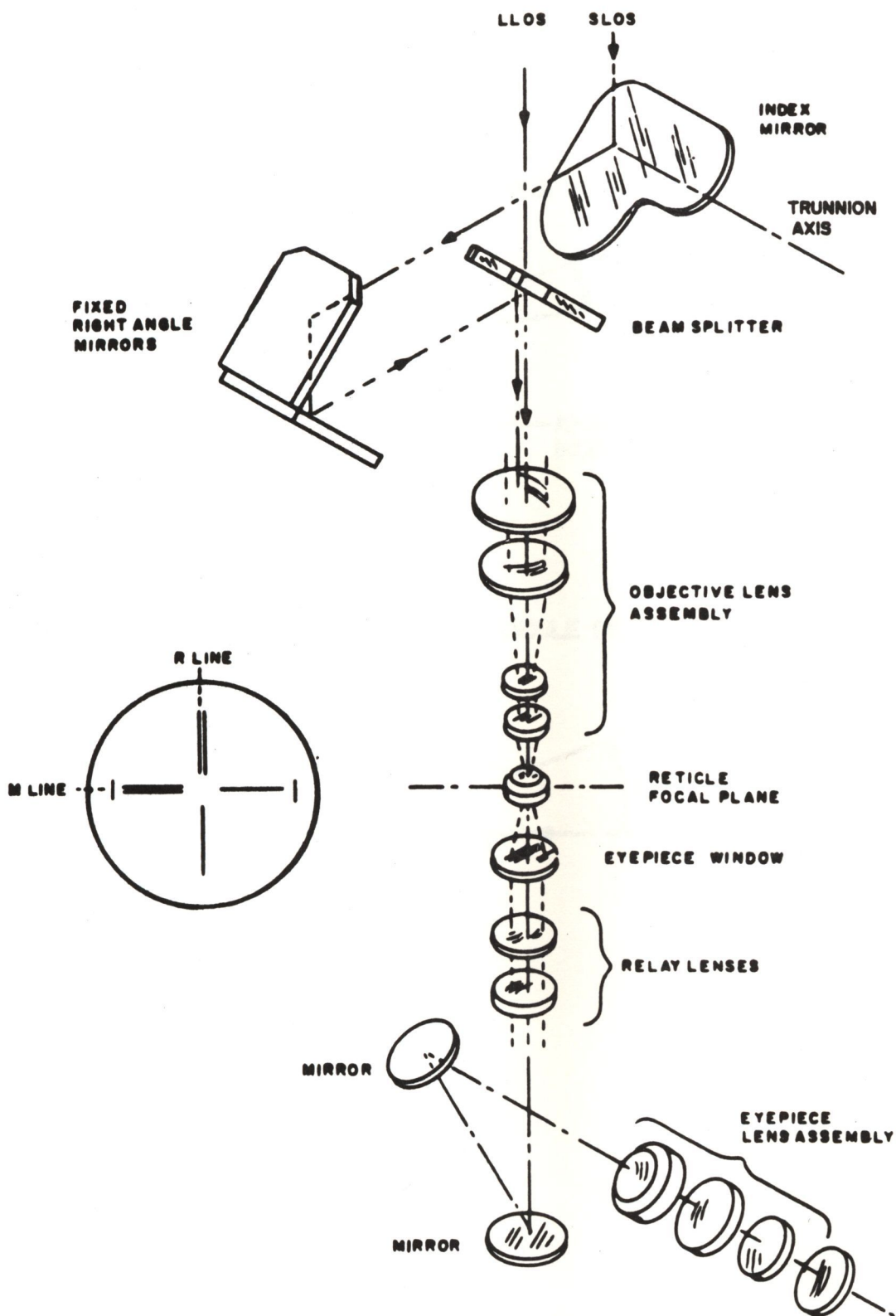
SCT Gearing



Differential Gear Assembly

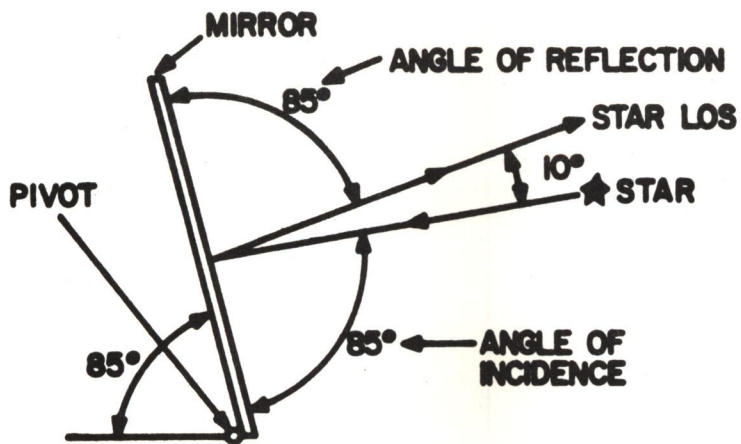


Pechan Prism

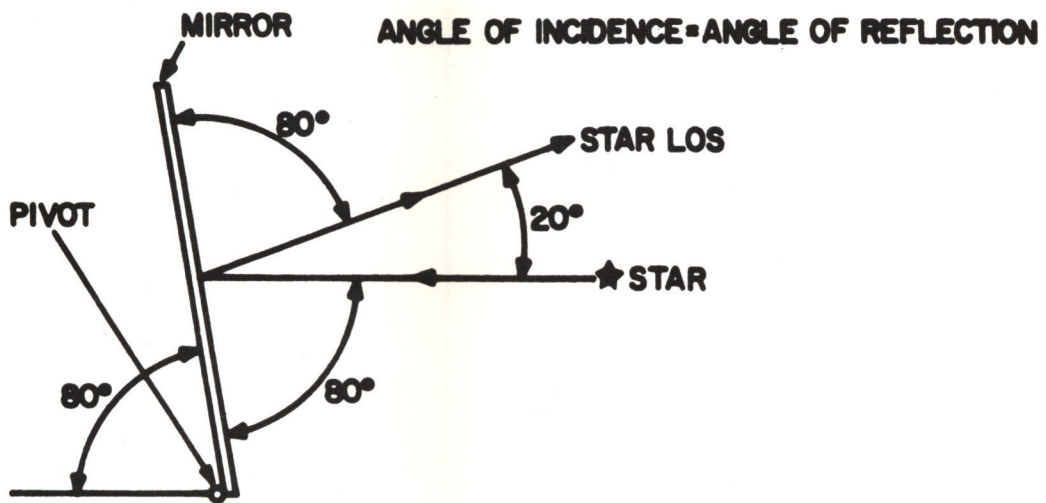


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SXT Optical Schematic



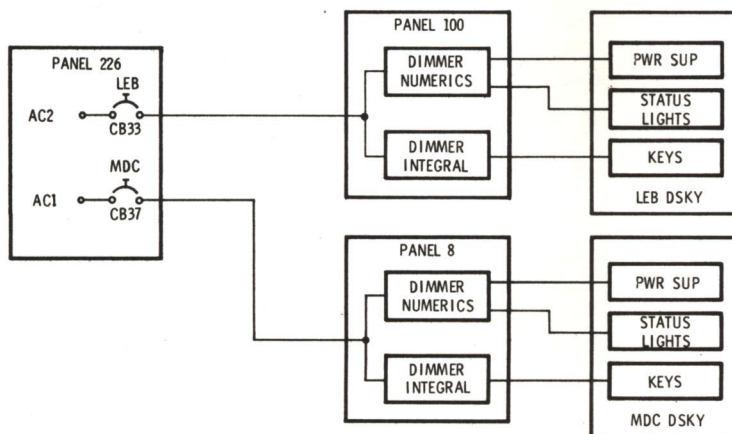
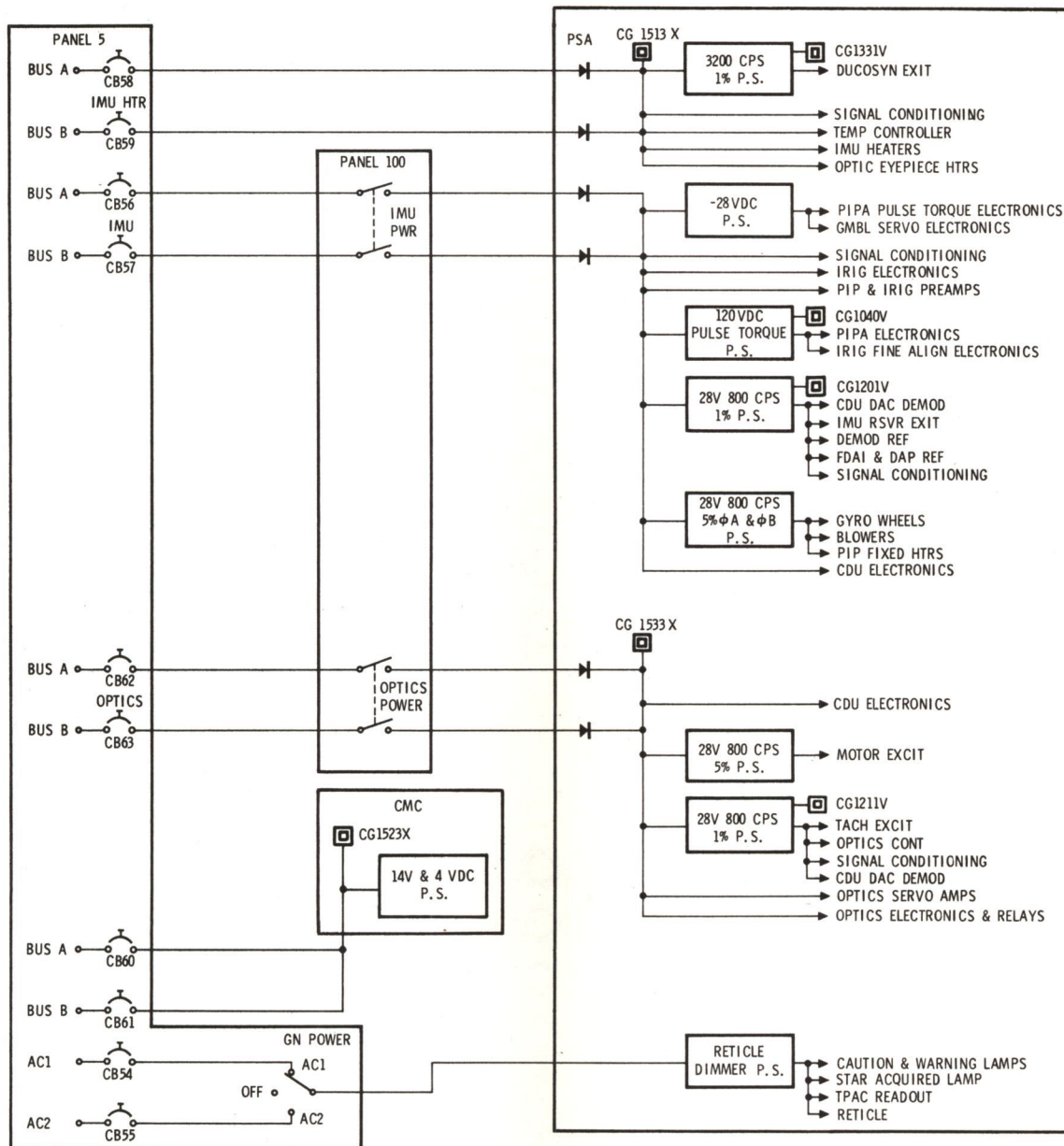
(A)



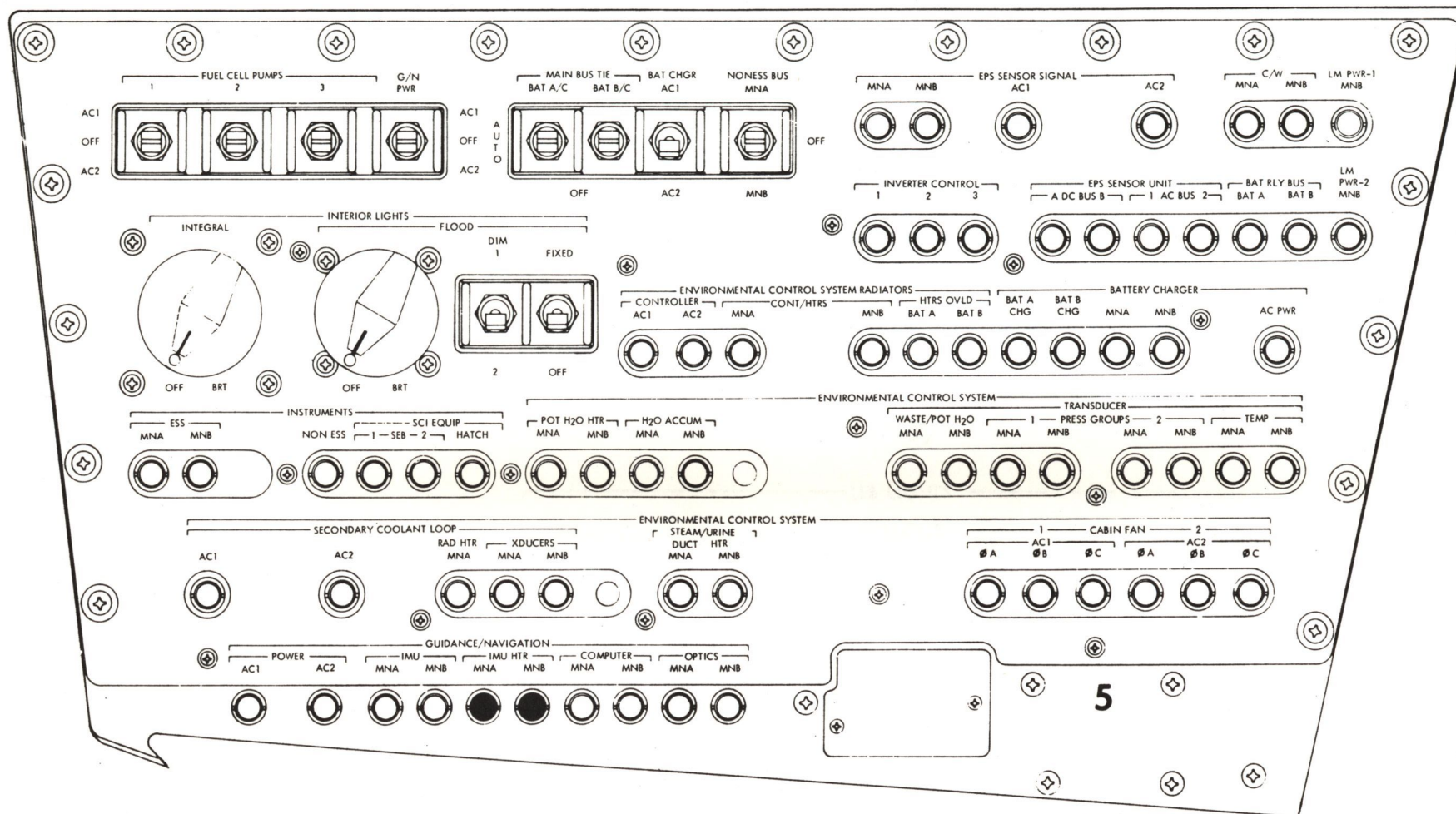
(B)

Motion of Indexing Mirror

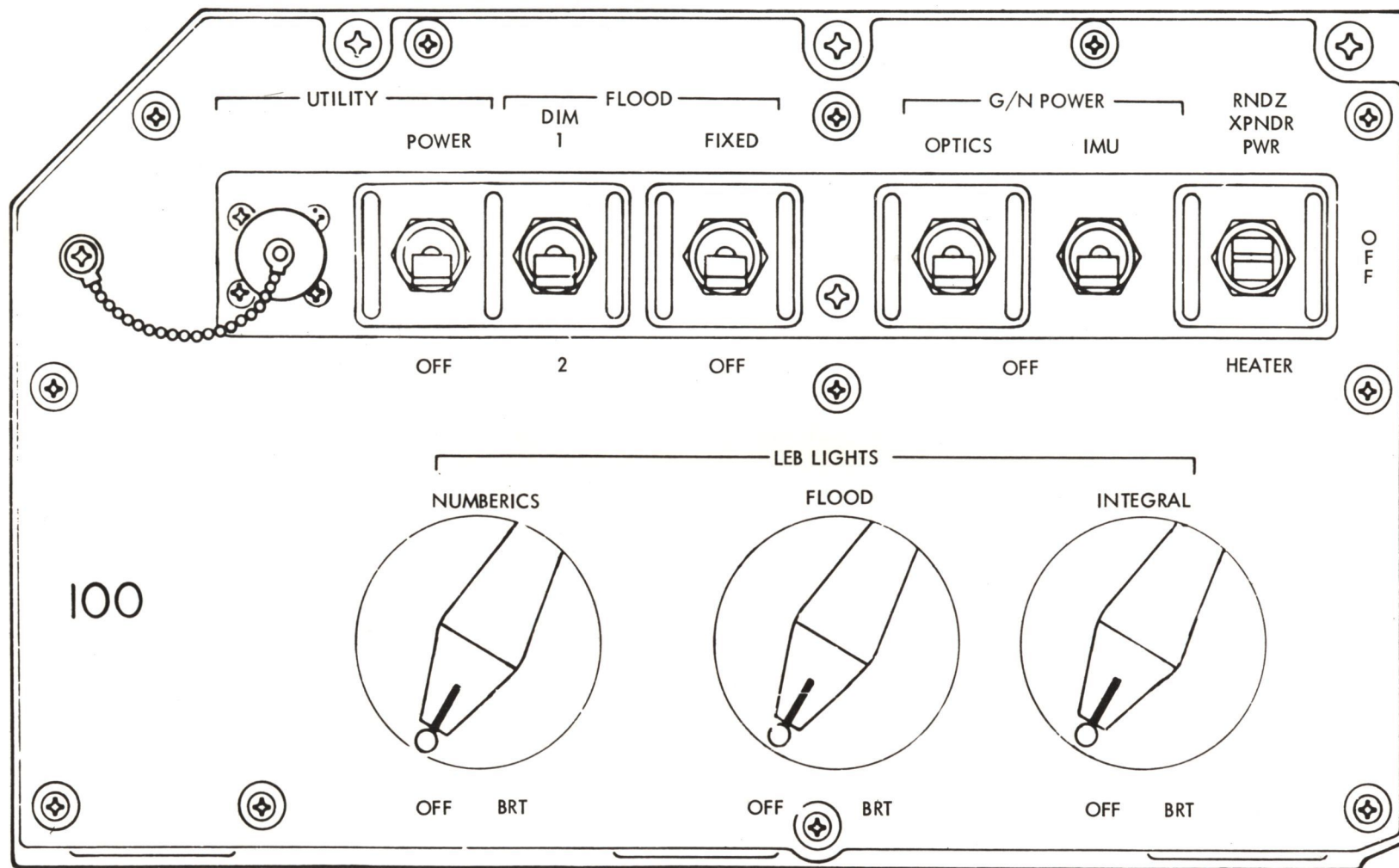
GNC POWER DISTRIBUTION



CG 1040V - 120 VDC PIPA SUPPLY DC LEVEL
 CG 1201V - IMU 28V .8 KC 1 PCT 0° RMS
 CG 1211V - OPTICS 28V .8 KC 1 PCT 0° RMS
 CG 1331V - 3.2 KC 28V SUPPLY
 CG 1513X - IMU +28 VDC STANDBY
 CG 1523X - +28 VDC CMC OPERATE
 CG 1533X - +28 VDC OPTICS OPERATE



CSM 103

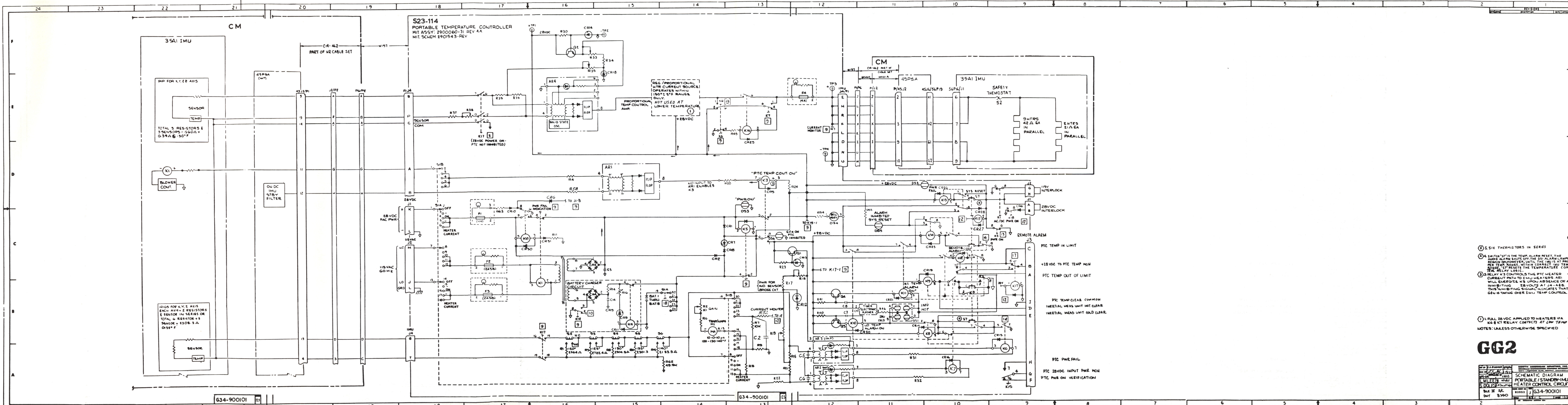




- ② 3. 3/C 10B & 3UBS
2. 4 DENOTES CABLE INFO
- | | | | | |
|-----|----|----|----|----|
| 57A | 2A | 2B | 2C | 2D |
| 59 | 6 | 4 | 2 | 0 |
- ① 1. K6T ENERGIZED BY C34-39T LOCAL DEADFACE COMMAND (54) OR BY 3/C DEADFACE COMMAND.
SEE G65 FOR TYP CONTROL CIRCUIT
- NOTES: UNLESS OTHERWISE SPECIFIED

GG1

NO BY	F.COMP	3-148	NORTH AMERICAN AVIATION, INC. OFFICE AND INFORMATION SYSTEMS DIVISION 1816 LAWRENCE BLVD. GUNWY, CALIFORNIA		
DATE BY	R.C.M.	7/1/70			
APPROVED BY			G & N COMMANDS & 1MU HTR BLOCK DIAG.		
6095-56	X3593				
L.M. LEE	7/2/68				
S. DOLES	7/2/68				
BLK II S/C					
DNY B2A0					
DATE DUE		NO	G34-900101		
03953		J			
SCALE		REV	SHEET 13 L		

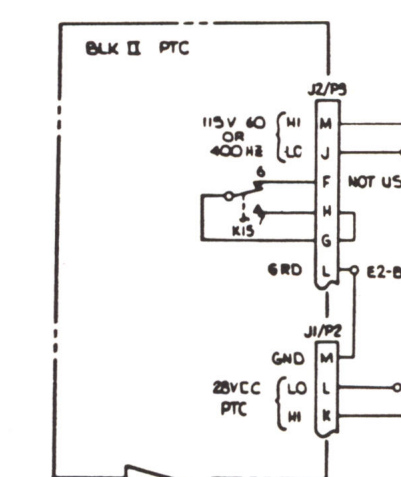
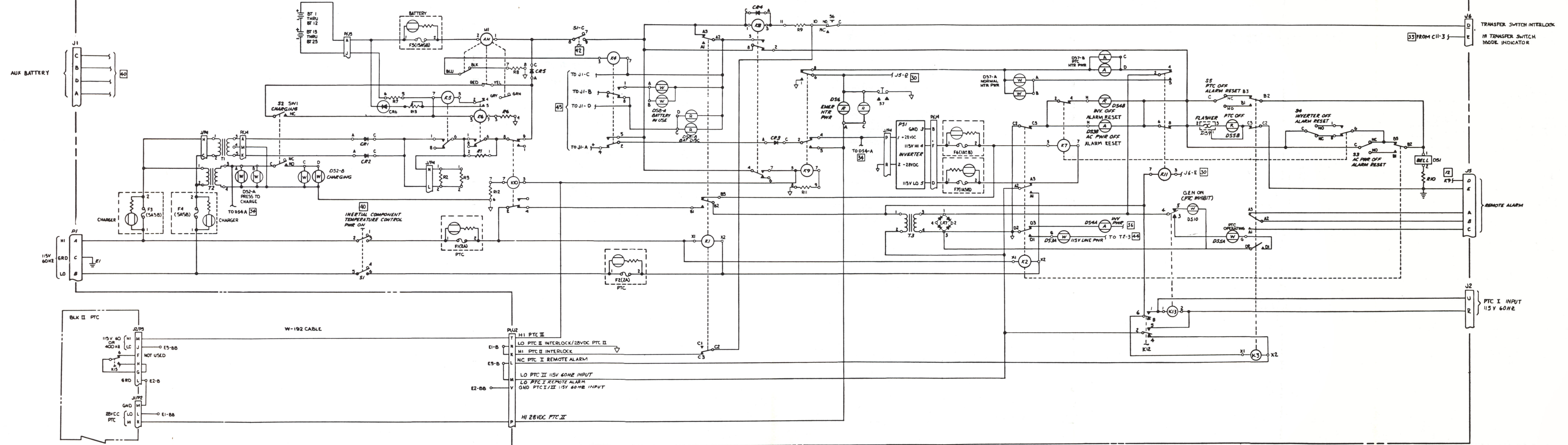


- ① SIX THERMISTORS IN SERIES
 - ② SWITCH 'ST' IS THE TEMP. ALARM RESET. THE ALARM SHUTS OFF THE IMU'S AT PROPER TEMP. RANGE. WITHIN CORRECT IMU TEMP. RANGE 'ST' RESETS THE TEMPERATURE CONTROL RELAY LOGIC.
 - ③ RELAY K3 CONTROLS THE PTC HEATER CURRENT PATH TO IMU HEATERS. ARI WILL ENERGIZE K3 UPON ABSENCE OF AN INHIBITING 28VDC AT J4-A-B. THIS INHIBITING SIGNAL INDICATES THAT GEN IS TAKING OVER IMU TEMP CONTROL.
 - ④ FULL 28VDC APPLIED TO HEATERS VIA K6 & K7 RELAY CONTACTS AT LOW TEMP
- NOTES: UNLESS OTHERWISE SPECIFIED

GG2

DATE	10-1-68	BY	W. J. B.
REV	1	BY	W. J. B.
SCHEMATIC DIAGRAM			
PORTABLE/STAND-IMU			
HEATER CONTROL CIRCUITS			
FILE NO.	634-900101	DATE	10-1-68

S23-100
ELECT BATTERY POWER PACK BLK II
SCHEM: 190001-01
ASSY: 190001-01-01-REV AD



GUIDANCE AND NAVIGATION SYSTEM FUNCTIONAL VERIFICATION

SCOPE FOR OCP-P-6504

Description

Power is supplied to the guidance and navigation (G&N) system. Stimuli from the appropriate ACE station and the command module is injected into various control loops. System responses are monitored and recorded in the command module and at the ACE checkout consoles. These recorded reactions are reduced for analysis.

Objectives

1. To demonstrate the proper functional operation of the G&N system within the spacecraft.
2. To verify the operational compatibility of the G&N system with the EPS, ECS, caution warning system, and pulse code modulator (PCM).

Prerequisites

Applicable sections of the following OCP's will have been completed:

OCP-P-1013	Prepower Application Test
OCP-P-10060	Test Configuration Checklist, Crew Compartment Controls
OCP-P-10030	Test Configuration Checklist, Vehicle and GSE Pretest Cables and Hardline Configuration
OCP-P-10058	Test Configuration Checklist, GSE Pretest

Sequencing

01. Activation of Support Subsystems and Support GSE (EPS, C.I., ECS)
02. G&N activation: The G&N is placed into the standby mode of operation. The command module computer (CMC) is initialized and voltages are verified. Inertial measurement unit (IMU) standby power supplies are verified.

3. G&N panel brightness controls, lamps, and minimum impulse and mark reject tests: All G&N displays, such as warning lamps (including caution/warning master alarm), condition lamps, and CMC alarm lamps are tested.

The illumination of the optics reticles and telescope panel angle counters are tested for required lighting and minimum impulse. The hand controller is verified for proper operation.

4. CMC operational test: The basic functional capabilities of the computer are verified using test routines initiated by the command module display and keyboard (DSKY) entries. DSKY lamps, alarms (including caution/warning system interfaces), and interrupt responses are observed in the command module and ACE control station. The CMC clock frequency is verified.
5. Voltage margin test: The voltage margin test checks the voltage fail circuitry. By stressing the micro logic, information is obtained which assures reliability of the CMC.
6. Power-on operational test: Operating power is applied to the IMU, and optics discretes and voltages are monitored. Outputs of all power supplies are recorded and verified.
7. G&N operational test: The G&N operational test routine is entered. The gravity vector and the horizontal component of earth rate are calculated. This is a cross check of G&N system operations.
8. Gimbal friction test: The three gimbal axes are separately torqued, in both a positive and negative direction, to check for any indication of excessive friction in the gimbal system.
9. Semi-automatic mode control test: This test verifies the ability of the CMC to command various platform angles. The gimbal lock indication is verified, and the optical and inertial coupling display unit (CDU) drive rates are checked.
10. Zero optics test: The zero optics test demonstrates the optics time to zero and CDU zeroing accuracy.
11. Optics slew rate test: This test demonstrates the slewing performance of the optics servo loop at high, medium, and low speeds. The optics are driven for a time interval and then the angle is divided by the time interval to determine the slew rate parameter.

12. Optics coordinate transformation control test: The functional operation of the optics resolved mode is demonstrated, including the control stick resolution and slewing performance.
13. Optics positional accuracy test: The image resolution of the sextant and scanning telescope are verified, and the trunnion (SXT) positional accuracy is checked. Parallelism of the sextant line of sight and the scanning telescope line of sight are verified and the ability to drive the optics to a known angle by CMC control is checked. Manual drive of the optics with the universal tool will be demonstrated.
14. Stabilization loop step response test: A step input is separately applied to each of the IMU stabilization loops. Stabilization loop response time and number of overshoots are verified.
15. IRIG scale factor test: The IRIG scale factor test routine is selected. Each IRIG is torqued in a positive and negative direction. The average torquing scale factor is then calculated.
16. IMU performance test: The PIPA bias and scale factors are determined. The drift coefficients are calculated for each IRIG.
17. Fine alignment test. The alignment between the SXT-navigation base and IMU is verified.
18. Gyrocompassing test: The ability of the stable members to maintain a local vertical attitude and an azimuth reference is verified.
19. G/N deactivation proper system power down
20. Deactivation of support subsystems and support GSE (EPS, C.I., ECS)
21. Short G/N activation: System reactivation after sequences 2, 6, and 7 if necessary.

Test Support Requirements

1. Documents

OCP-P-1115	Electrical Power Functional Checkout
OCP-P-1237	EPS, C&I, ECS Cooling Turn-on Procedure
OCP-P-10060	Test Configuration Checklist, Crew Compartment Controls
OCP-P-10030	Test Configuration Checklist, Vehicle and GSE Cables and Hardline Configuration
OCP-P-10058	GSE Pretest Test Configuration
MA0308-0107	Mechanical Installation Specification for Apollo Guidance Equipment
MA0610-018	Contamination Control, Apollo Command Module and Service Module
SID 65-1642	Apollo Command Module/Service Module Measurements, Requirements for Block II
MA0201-5528	Post-Installation Checkout Process Specification for the Apollo Guidance and Navigation System, Block II (SC 101 and Subsequent)
MA0201-5036	Installation and Alignment of Optical Target GSE SC 101, Block II Acceptance Data Package
MA0201-5117	ACE Programming Requirements, SC 101
PS2015000	Master End Item Specification, Part II, Product Configuration and Acceptance Test Requirements, G&N Spacecraft Equip- ment, Command Module, Block II Installation
V36-976018	Design Layout, Main Controls and Displays
V36-945043	Guidance and Navigation System Schematic Diagram
V36-421300	Wire List, Cable Assembly CM Harness
V34-900101	Functional Integrated System Schematics
V36-724001	Equipment Installation, Block II Guidance and Navigation, Lower Equipment Bay

2. Equipment

A23-114	Portable temperature controller
A23-097	G&N installation and qualification fixture
A23-196	Portable light assembly (to backlight optics)
A23-304	Power servo assembly adapter module
A23-200	Retro-reflecting prism
A14-135	Optics support fixture
C14-462	Cable set, portable G&N system
C14-418	SC ground power supply
C14-418-101	Ground power console
C14-240-301	ACE-SC service equipment adapter
C34-391	Carry-on cable set (ACE)
C14-484-301	ACE external signal conditioner
C14-241	External digital test command unit
C14-232	ACE data interleaving system
C14-207	Digital test command system (carry-off)
C14-208	Digital test monitoring system (carry-off)
C14-467	Breakout box test CM-SM adapter
C14-391	Electrical cable set (carry-off)
A14-298 or SK1312	Inverter substitute
C14-473	Electrical cable set
S14-053	ECS water-glycol trim unit system
A34-243	Umbilical disconnect
S14-019	Water-glycol service set
C14-262	ACE power supply, dc
C14-651	Power distribution unit, Myers 11678

SL4-082 (SL4-014)	Fluid distribution system
SL4-121	Water glycol refrigeration unit
C34-561	External ACE J-box
A23-166	SCT/SXT lens cover
H23-207	Lifting fixture qualification/aximuth reference
H.P.5245L	Eput counter
H.P.526A	Plug-in
SMD9-17166	Cable set
SMD9-17167	Cable set
SMD9-17003	Breakout box
DKM-3 (A23-079)	Theodolites (2) Volt ohmmeter Test leads Calculator (Friden) Movable optics target SCT resolution chart Leeds and Northrup 8693 temperature potentiometer, Universal tool

3. Data

Real-time recorded data and visual displays in the ACE control room are recorded in the OCP.

Downlink playback data are utilized when required for special analysis.

SC IOI PGNC S A/B TLM LIST

MEASUREMENT NUMBER	MEASUREMENT DESCRIPTION	DATA RANGE	CHANNEL CODE
CG000IV	Computer Digital Data 40 Bits		5I DS I
CGI040V	+120 VDC PIPA Supply DC Level	+85 to +135 VDC	10A83
CGI110V	2.5 VDC TM Bias	0 to +5 VDC	10A138
CGI20IV	IMU 28 V .8 KC I PCT 0 Deg. Sup. Rms.	0 to 31.1 VRMS	10A91
CGI21IV	OPTX 28V .8 KC I PCT 0 Deg. Rms.	0 to 31.1 VRMS	10A146
CGI33IV	3.2 KC 28 V Supply	0 to 31.1 VRMS	10A85
CGI513X	+28 VDC Standby	Off or Standby	11E15-2
CGI523X	+28 V CMC Operate	Off or Oper.	11E15-3
CGI533X	OPTX Operate +28 VDC	Off or Oper.	11E15-4
CG2112V	IG IX Resolver Output Sin	0 to 360 Deg.	11A54
CG2113V	IG IX Resolver Output COS	0 to 360 Deg.	11A59
CG2117V	IGA Servo Error in Phase	-3.0 to +3.0 VRMS	12A2
CG2142V	MG IX Resolver Output Sin	0 to 360 Deg.	11A60
CG2143V	MG IX Resolver Output COS	0 to 360 Deg.	11A61
CG2147V	MGA Servo Error in Phase	-3.0 to +3.0 VRMS	12A1
CG2172V	OG IX Resolver Output SIN	0 to 360 Deg.	11A62
CG2173V	OG IX Resolver Output COS	0 to 360 Deg.	11A63
CG2177V	OGA Servo Error in Phase	-3.0 to +3.0 VRMS	12A3
CG2219V	Pitch Att. Error - CDU DAC Out	-16.9 to +16.9 Deg.	11A64
CG2249V	Yaw Att. Error-CDU DAC Out	-16.9 to +16.9 Deg.	11A65
CG2279V	Roll Att. Error - CDU DAC Out	-16.9 to +16.9 Deg.	11A16
CG2300T	PIPA Temperature	+120 to +140 Deg. F	10A96
CG2301T	I RIG Temperature	+123 to +143 Deg. F	10A1
CG2302X	IMU Heater Current	On or Off	10A5
CG2303X	IMU Blower Current	On or Off	10A7

<u>MEASUREMENT NUMBER</u>	<u>MEASUREMENT DESCRIPTION</u>	<u>DATA RANGE</u>	<u>CHANNEL CODE</u>
CG301IV	Trunnion CDU Fine Error	-1.2 to +1.2 VRMS	IIA171
CG302IV	Shaft CDU Fine Error	-1.2 to +1.2 VRMS	IIA180
CG3140V	SXT Shaft Tachometer Output	-0.5 to +0.5 VRMS	IIA172
CG3150V	SXT Trunnion Tachometer Output	-0.5 to +0.5 VRMS	IIA173
CG3160V	SCT Shaft Tachometer Output	-5.0 to +5.0 VRMS	IOA13
CG3170V	SCT Trunnion Tachometer Output	-5.0 to +5.0 VRMS	IOA14
CG372IV	Shaft CDU DAC Output	-10 to +10 VRMS	IIA52
CG3722V	Trunnion CDU DAC Output	-10 to +10 VRMS	IIA53
CG5040X	CMC Warning	Warn or Off	IIIE19-1

ACCEL	Accelerometer/Acceleration
ACS	Attitude Control Subsystem
AC	Alternating Current
A/C	RCS Quads A and C
A/D	Analog to Digital
ALT	Attitude
AMP	Amplifier
ARS	Attitude Reference Subsystem
ASCP	Attitude Set Control Panel
ATT	Attitude/Attenuation
ATT SET	Attitude Set
AUTO	Automatic
B/D	RCS Quads B and D
BMAG	Body Mounted Attitude Gyro
B.O.	Break Out Switch
bps	Bits Per Second
BUR	Backup Rate
BURR	Backup Rate Roll
BURP	Backup Rate Pitch
BURY	Backup Rate Yaw
CB	Circuit Breaker
CCW	Counterclockwise
C&D	Controls and Displays
CDH	Constant Delta Height
CDU	Coupling Data Unit
CFP	Concentric Flight Plan
CG	Center of Gravity
CHAN	Channel
CM	Command Module
CMC	Command Module Computer
CMD	Command
COAS	Crew Optical Alignment Sight
CONT	Control
CPS	Cycles Per Second
CSC	Cosecant Computing Amplifier

CSM	Command and Service Module
CSS	Computer Subsystem
CTE	Central Timing Equipment
CW	Clockwise/Continuous Wave
CW	Not Clockwise
C/W	Caution and Warning
D/A	Digital - to - Analog
DAC	Digital to Analog Converter
DAP	Digital Autopilot
DB or	
d.b.	Deadband
DECR	Decrease
DC	Direct Current
DEM0D	Demodulator
DSKY	Display and Keyboard
E	Elevation Angle
ECA	Electronic Control Assembly
ECO	Engine Combustion/Engine Cut OFF
EDA	Electronic Display Assembly
ELECT	Electronic
ELS	Earth Landing System
EMS	Entry Monitor System
ENC	Encode
ENG	Engine
ERR	Error
FCSD	Flight Crew Support Division (MSC)
FCSM	Flight Combustion Stability Monitor
FDAI	Flight Director Attitude Indicator
FUNCT	Functional
GA	Gyro Assembly
G&C	Guidance and Control
GET	Ground Elapse Time
G&N	Guidance and Navigation

GNCS	Guidance Navigation and Control System	MAN	Manual
GDC	Gyro Display Coupler	MAX	Maximum
GMBL	Gimbal	MDC	Main Display Console
GP/FPI	Gimbal Position and Fuel Pressure Indicator	MERU	Milli Earth Rate Unit
GPI	Gimbal Position Display	MESC	Mission Events Sequence Control
GSOP	Guidance System Operations Plan	MIN	Minimum
ha	Apogee Altitude	MGA	Middle Gimbal Angle
HI	High/Hello	MMH	Monomethylhydrozene
hp	Perigee Altitude	MNA	Main Buss A
HTRS	Heaters	MNB	Main Buss B
		MSB	Most Significant Bit
		MTVC	Manual Thrust Vector Control
ICDU	Inertial Coupling Data Unit	NAV	Navigation
IGA	Inner Gimbal Angle	NB	Navigation Base
IGN	Ignition	NORM	Normal
IND	Indicator	NRZ	Non-return to Zero
IMP	Impulse		
IMU	Inertial Measurement Unit	OCDU	Optics Coupling Data Unit
INCR	Increase	OGA	Outer Gimbal Angle
IRIG	Inertial Rate Integrating Gyro	OPT	Optics
ISS	Inertial Subsystem	OSS	Optics Subsystem
IU	Instrument Unit	ORDEAL	Orbit Rate Drive Electronics Apollo IM
		OXID	Oxidizer
KC	Kilo Cycles	P	Pitch Axis of Control/Program
		PA	Power Amplifier
LAT	Latitude	PB	Push Button
LEB	Lower Equipment Bay	PCM	Pulse Code Modulation
LES	Launch Escape System	PGNCS	Primary Guidance, Navigation and Control System
LET	Launch Escape Tower		
LM	Lunar Module	PH	Phase
LMK	Landmark	PIPA	Pulsed Integrating Pendulous Accelerometer
LOR	Lunar Orbit Rendezvous	PSA	Power Servo Assembly
LOS	Line of Sight	PPS	Pulse Per Second
LV	Launch Vehicle/Lift Vector	PTT	Push to Talk

PWR	Power
R	Roll Axis of Control/Routine or DSKY Display Register
RC	Rotation Control
RCS	Reaction Control System
REL	Release
REV	Reverse
RGA	Rate Gyro Assembly
RJD	Reaction Jet Driver
RJ/EC	Reaction Jet and Engine ON-OFF Control
RLVDT	Rotary Linear Variable Differential Transformer
RNG	Range
ROT	Rotation
RSI	Roll Stability Indicator
RTC	Real Time Commands
RUPT	Interrupt
S/C	Spacecraft
SCT	Scanning Telescope
SCS	Stabilization and Control System
SIG	Signal
SLOS	Star Line of Sight
SM	Service Module
SMJC	Service Module Jettison Controller
SMRD	Spin Motor Rotation Detector
SPS	Service Propulsion System/Samples per Second
STBY	Standby
SW	Switch
SXT	Sextant
SYNC	Synchronize
SYS	System
TC	Translation Control
TEC	Transearch Coast
TEMP	Temperature
TFL	Time - From - Launch

TIGN	Time of Ignition
TLC	Translunar Coast
TM	Telemetry
TPAC	Telescope Pointing Angle Counter
TFF	Time of Freefall
TPF	Transfer Phase Final
TPI	Transfer Phase Initiation
TTINT	Time to Intercept
TRNFR	Transfer
TTE	Time - to Events
TVC	Thrust Vector Control
TVSA	Thrust Vector Position Servo Amplifier
UDL	Up Data Link
UPTLM	Up-Link Telemetry
V	Velocity
VM	Velocity Measured
Vc	Circular Velocity
Vo	Initial Velocity at .05g
XLATION	Translation
XLUNAR	Translunar
ΔV	Differential Velocity
ϕ	Roll Control Axis Designation/Phase
ψ	Yaw Control Axis Designation
θ	Pitch Control Axis Designation