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GUIDANCE, NAVIGATION AND CONTROL COMMAND MODULE FUNCTIONAL DESCRIPTION AND OPERATION USING FLIGHT PROGRAM COLOSSUS 2C

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MIT INSTRUMENTATION LABORATORY
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PREFACE

THE PURPOSE OF THIS DOCUMENT IS TWOFOLD. THE FIRST IS TO PROVIDE A FUNCTIONAL DESCRIPTION (OPERATIONALLY ORIENTED) OF THE CSM GNCS HARDWARE AND SOFTWARE AND THE INTERFACES WITH OTHER SPACECRAFT SYSTEMS. THE LEVEL OF DETAIL IS THAT REQUIRED TO IDENTIFY AND DEFINE TELEMETRY OUTPUTS. ALSO INCLUDED ARE FUNCTIONAL FLOW DIAGRAMS OF THE COLOSSUS PROGRAMS AND ROUTINES TOGETHER WITH LISTS OF VERBS, NOUNS, OPTION CODES, AND CHECKLIST CODES FOR THIS FLOW.

THE SECOND PURPOSE IS TO PROVIDE THE OPERATIONAL PROCEDURES FOR THIS HARDWARE AND SOFTWARE INCLUDING NOMINAL AIRBORNE CONDENSED CHECKLISTS, MALFUNCTION PROCEDURES, AND PROGRAM NOTES.

Wayne A. Siarnicki

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SECTION I

GENERAL DESCRIPTION OF THE GNCS

1.1 FUNCTIONAL DESCRIPTION

The guidance, navigation, and control system (GNCS) consists of the sensing, data processing, computational, control, and display devices necessary to accomplish spacecraft guidance, navigation, and control. The system's primary task is to obtain CSM orientation, position, and velocity data; and thereby, calculate any steering and thrust commands necessary to fulfill the flight objectives.

The system's navigation function consists of determining the location of the spacecraft and calculating pertinent trajectory information related to the present location and predicted locations so that the guidance function can be performed. Using a computerized dead reckoning process, the last known position of the spacecraft is updated to present position by keeping track of incremental changes in velocity and time. The predicted present position is revised whenever fix information from communications or optics is entered into the computation loop. The fix information is used to derive deviations of position and velocity which are added to the vehicle position and velocity estimates to form a new orbit estimate. This procedure is repeated for each navigation measurement until orbital uncertainties are reduced to an acceptable level.

The guidance function interrelates the navigation function to the flight control function. Navigation information is employed to determine what commands should be issued to maintain desired flight control. A velocity to be gained concept results from a comparison of the actual velocity and the velocity required. Steering equations are used which force the difference between the actual velocity and the velocity to be gained to zero by issuing the appropriate commands to the flight control subsystems. Thus, the GNCS is capable of performing an autopilot task or an augmentation task. In addition, a fully manual piloting task is available by the crew's use of navigational displays.

The functional subsystems contained within the GNCS are the inertial subsystem, optical subsystem, and computer subsystem. A radar transponder is provided on the CSM for use with the LM rendezvous radar subsystem. A VHF ranging system is also provided.

1.1.1 Inertial Subsystem Functions

The inertial subsystem (ISS) senses spacecraft acceleration and changes in attitude and provides incremental velocity and attitude data to the computer subsystem. The ISS sensor is the inertial measurement unit (IMU) which consists of a stable member mounted in a three-degree-of-freedom gimbal system. Three gyroscopes and three accelerometers are mounted on the stable member. Each gyroscope has a stabilization loop associated with it to maintain the stable member nonrotating with respect to inertial space. Thus, each stabilization loop maintains one axis of an orthogonal reference system; whereby, the spacecraft yaw, pitch, and roll orientation is definable. The stabilization loops measure the spacecraft orientation by producing signals proportional to the changing orientation of the gimbals relative to the stable member. The three accelerometers are pendulous mass unbalanced devices with each maintaining one axis of another orthogonal system parallel to the gyro orthogonal system. Hence, each accelerometer and its associated accelerometer loop permits measurement of changes in velocity along its axis relative to the inertial reference frame.

1.1.2 Optical Subsystem Functions

The optical subsystem (OSS) provides directional data of a selected target to the CMC. The OSS allows direct visual sightings to be made and precision measurements to be taken on celestial objects by means of the SCT and SXT. The angular data developed is transferred by the CDU into the CMC, which uses this data to calculate spacecraft position and trajectory. In addition, the results obtained are used to align the IMU to an inertial framework.

Establishment of a LOS to selected celestial targets generally requires use of the SCT and/or SXT together with spacecraft positioning controls. The astronaut changes spacecraft attitude to direct the optics field of view toward the celestial target area. Direct viewing through the wide 60 degree field of the SCT enables target search and recognition. The SXT is then used to take precise measurements.

After target acquisition, the optical angular measurements and the time of sighting are transferred to the CMC. Data pertaining to the location of targets and programs for navigational calculations stored in the CMC are then compared. The results of the comparisons are used to align the IMU and determine spacecraft position and trajectory.

In case of failure in the optics electronics, the astronaut can operate the SCT manually with a universal tool and read the angles off the SCT counters. In such emergencies, the astronaut will calculate, with possible assistance from the ground, a navigational fix to determine position and required velocity corrections.

. The OSS includes a sextant (SXT), a scanning telescope (SCT), two channels of the coupling data unit (CDU), and displays, controls, and other ancillary equipment.

The OSS performs three functions. It provides star sighting data for IMU alignment and midcourse navigational fixes; it provides landmark tracking data for orbit determination; and it provides LM tracking data for rendezvous.

1.1.3 Computer Subsystem Functions

The computer subsystem (CSS) performs data processing, storing and monitoring; maintains a time standard; performs computational programs; provides central control ability; and performs limited malfunction diagnosis. The subsystem consists of the CM guidance computer (CMC) and two display and keyboard (DSKY) assemblies.

The DSKY is the interface device between the astronaut and the CMC. It permits the astronaut to enter data into the CMC and to receive data from the CMC.

The CMC processes data from the astronaut and the other spacecraft subsystems to solve navigation and guidance equations. The computer performs a control function by issuing command pulses to the ISS and flight control subsystems. Malfunction diagnosis is performed by monitoring certain operational discretes and issuing appropriate discretes to the caution/warning subsystem when an irregularity occurs. The CMC also supplies timing signals to synchronize and control GNCS operations.

1.2 GNCS COMPONENTS

The components of the GNCS and their major functional interfaces are illustrated in Fig. 1-1. The sensors of the system are the IMU, SXT, and SCT. The CMC is the interface component between the subsystems. The communication link between the astronaut and the CMC is the DSKY which permits loading of data by a keyboard into the CMC and provides information to the astronaut from the CMC by its displays.

The OSS is manually controlled by the astronaut or automatically by the CMC. Optical data is entered into the CMC through the optical CDU's.

The coupling data unit (CDU) is an interface device between the CMC and the ISS and between the CMC and the OSS. Its primary function is to convert analog data to digital data and digital data to analog data. Three channels of the CDU are contained in the ISS and two channels in the OSS.

Support electronics are contained in the PIP electronics assembly (PEA) and power and servo assembly (PSA). The PEA supplies inputs to and processes outputs of the IMU. The majority of ISS and OSS power supplies are contained in the PSA which also contains such support items as the moding relays and the stabilization loop servo amplifiers.

The GNCS is controlled mainly from the two DSKY's and from the GNCS indicator control panel located in the lower equipment bay. Fig. 1-2 shows the indicator control panel and provides a brief description of the function of the controls.

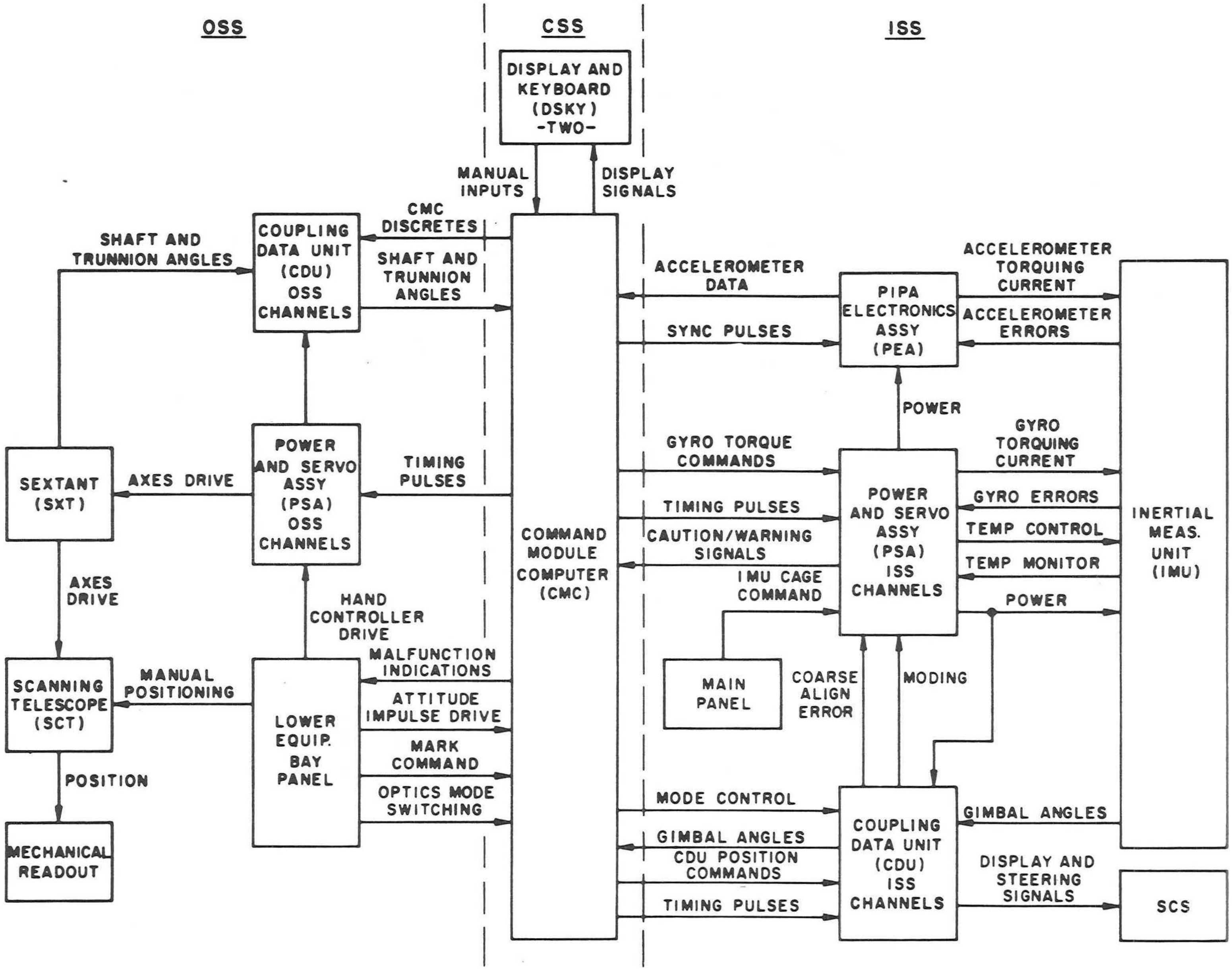


Fig. 1-1. GNCS Components Interface Diagram

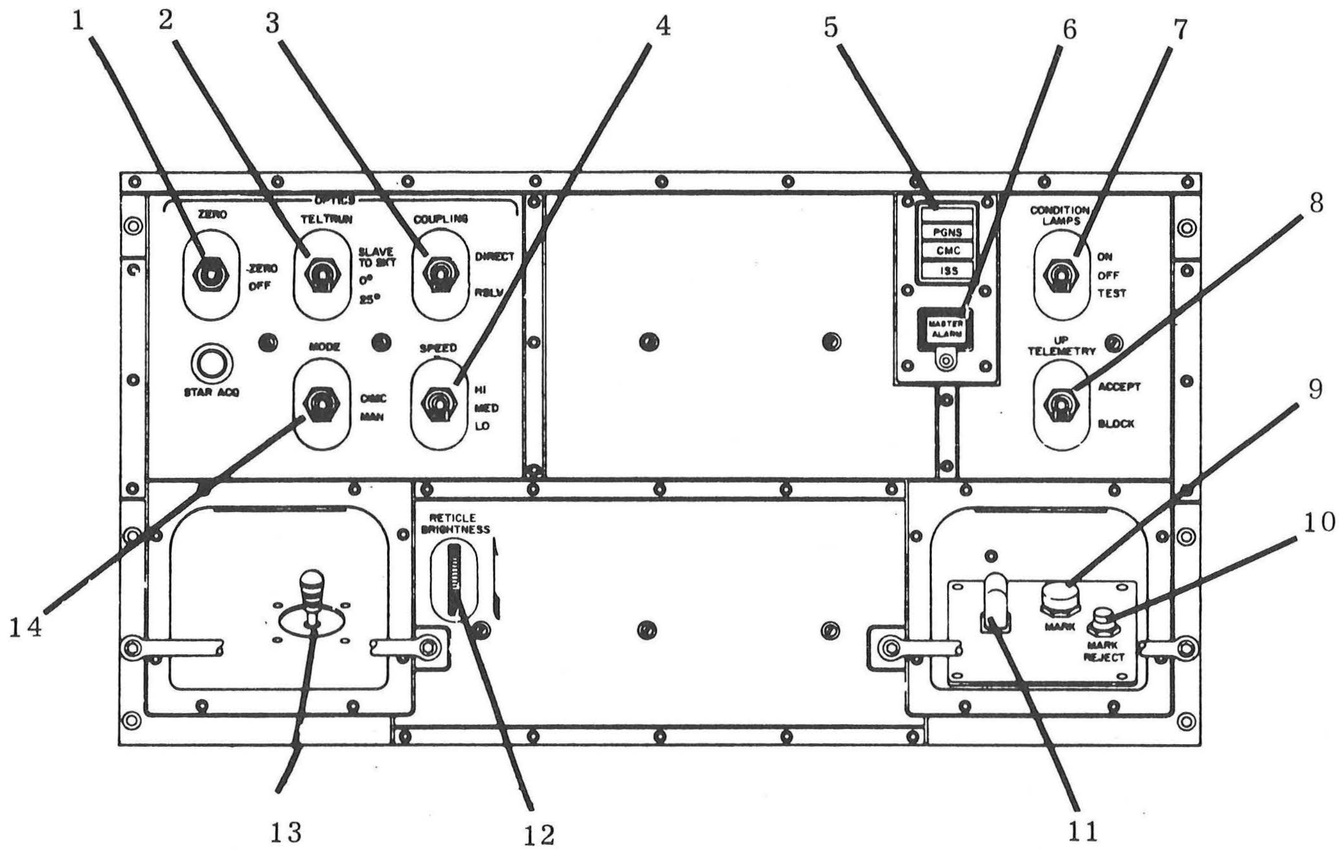


Fig. 1-2. GNCS Indicator Control Panel (Sheet 1 of 2)

Index	Name	Function
1	OPTICS ZERO switch	Selects optics zero mode
2	OPTICS TEL TRUN switch	Selects mode of operation for telescope trunnion drive
3	OPTICS COUPLING switch	Selects direct or resolved optics hand controller coupling
4	OPTICS SPEED switch	Selects optics drive speed
5	Caution/warning indicators	Indicates malfunctions in GNCS
6	MASTER ALARM indicator/ pushbutton	Provides master alarm indication and reset capability in the LEB
7	CONDITION LAMPS switch	Enables lighting and performs testing of the condition lamps
8	UP TELEMETRY switch	Blocks or enables receipt of up telemetry data by the CMC
9	MARK pushbutton	Used to make optics marks
10	MARK REJECT pushbutton	Used to reject bad optics mark
11	Minimum impulse control	Provides for minimum impulse attitude control during optics tracking
12	RETICLE BRIGHTNESS control	Controls brightness of optics reticles
13	Optics hand controller	Provides for manual control of optics movement
14	OPTICS MODE switch	Selects CMC or manual optics mode, if ZERO switch is OFF

Fig. 1-2. GNCS Indicator Control Panel (Sheet 2 of 2)

SECTION II

DETAILED DESCRIPTION OF THE GNCS

2.1 INERTIAL SUBSYSTEM

During thrusting phases the inertial subsystem (ISS) provides attitude references, processes steering commands from the CMC to the flight control system, and provides the velocity increment signals which are counted by the CMC and used for thrust termination. During nonthrusting phases the ISS is used to hold or control changes in spacecraft attitude at the direction of the astronaut or the CMC. To accomplish these tasks, the IMU stable member must maintain a predetermined inertial reference system. Thus, each time the ISS is energized the stable member must be aligned. Since use of the ISS during nonthrusting phases is optional within the limitations of available electrical power, the system may be reenergized several times during a flight and require realignment.

Before launch the IMU stable member is aligned to and held to a predetermined orientation with respect to an earth referenced coordinate system. Immediately after lift-off, the IMU is released to an inertial reference which provides a starting point from which to measure velocity, position, and attitude. During flight the established inertial reference system is accurately aligned by sightings of the OSS on celestial objects. This fine alignment procedure, using the OSS, is the prime method used throughout the flight for establishment of the inertial reference system. Once the IMU is aligned, the stable member remains essentially in a fixed spatial orientation and rotational motion of the spacecraft is sensed by resolvers mounted on the gimbal axes.

2.1.1 ISS Theory of Operation

Operational tasks of the ISS are implemented by combinations of functional loops (see Fig. 2-1). The three stabilization loops hold the stable platform at a fixed orientation which permits acceleration measurement by the three acceleration loops. In addition, each gimbal movement about the stable member changes the phase and amplitude of the associated resolver output to convey attitude information. The CDU loops provide data conversion and interface capability between the CMC, the stabilization loops, and displays. To align the IMU stable member, the CMC provides coarse alignment signals into the CDU loops and fine alignment signals into the gyro torquing electronics.

2.1.1.1 Stabilization Loops

The stabilization loops block of Fig. 2-1 represents three loops that maintain the IMU stable member at the spatial orientation to which it was aligned; and thereby, isolate the stable member from roll, pitch, and yaw motions of the vehicle. The CMC retains in memory a record of the reference coordinate system established by the stable member. Hence, when movement of the spacecraft produces IMU gimbal movement about the stable member, representative electrical signals of this movement are transmitted from the 1X and 16X gimbal resolvers (see Fig. 2-2).

A block diagram of the stabilization loops is shown in Fig. 2-3. Motion of the spacecraft produces a torque on the stable member tending to move it from its inertially fixed orientation. Each IMU IRIG (inertial reference integrating gyro) senses a component of this torque about its input axis and produces an error signal. Since the Y-gyro is mounted with its axis parallel

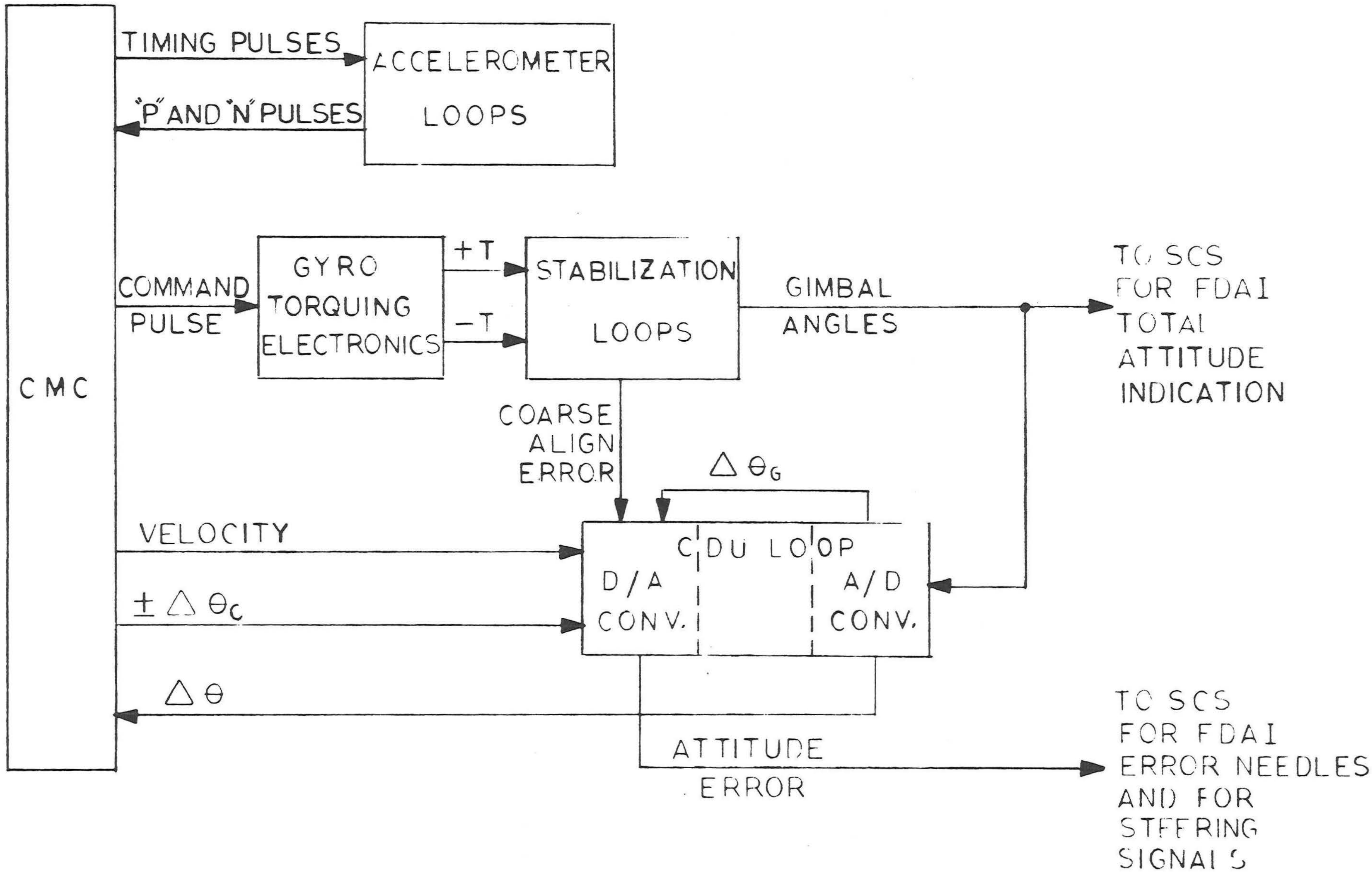


Fig. 2-1. ISS Functional Block Diagram

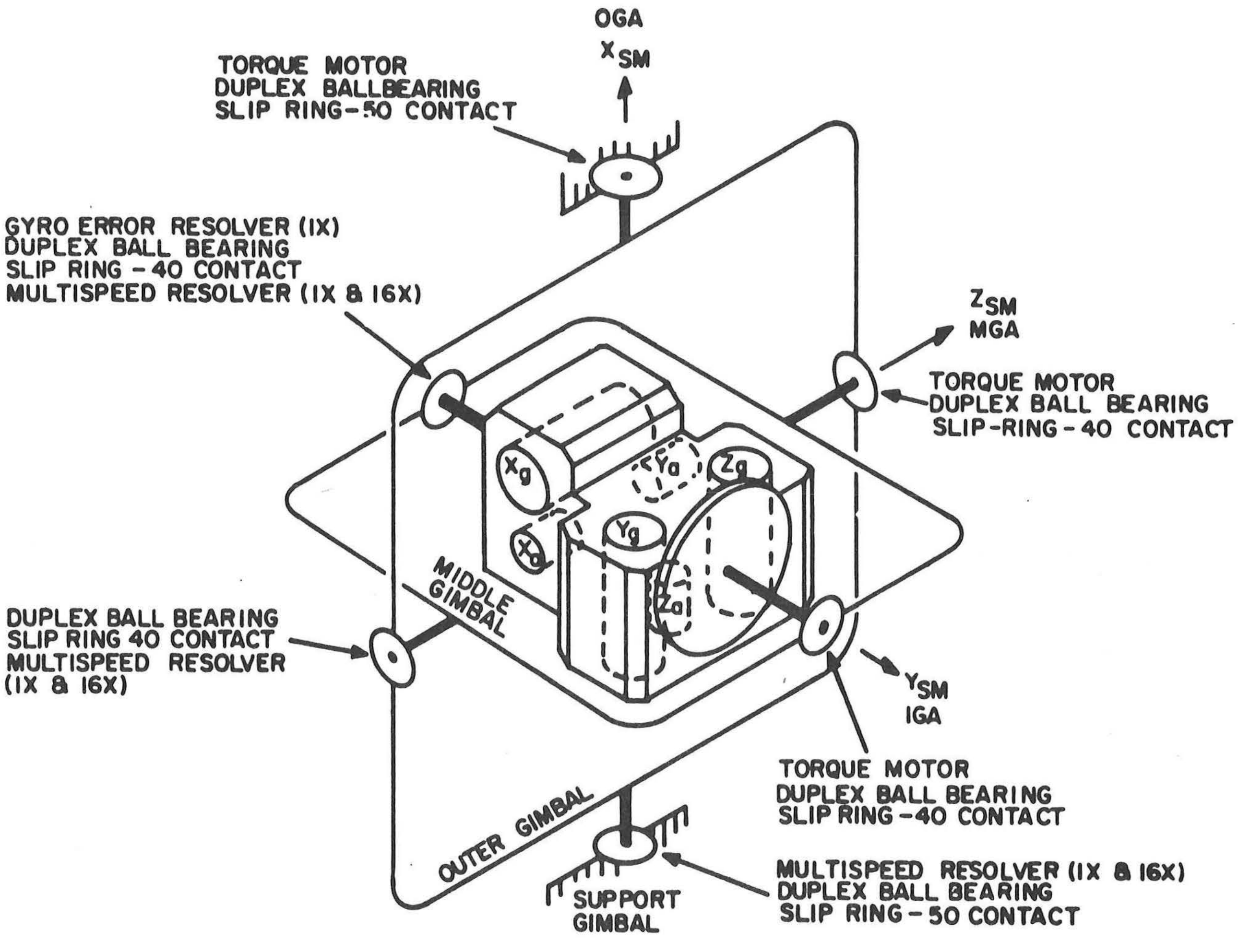


Fig. 2-2. IMU Gimbal Assembly and Gimbal Axes.

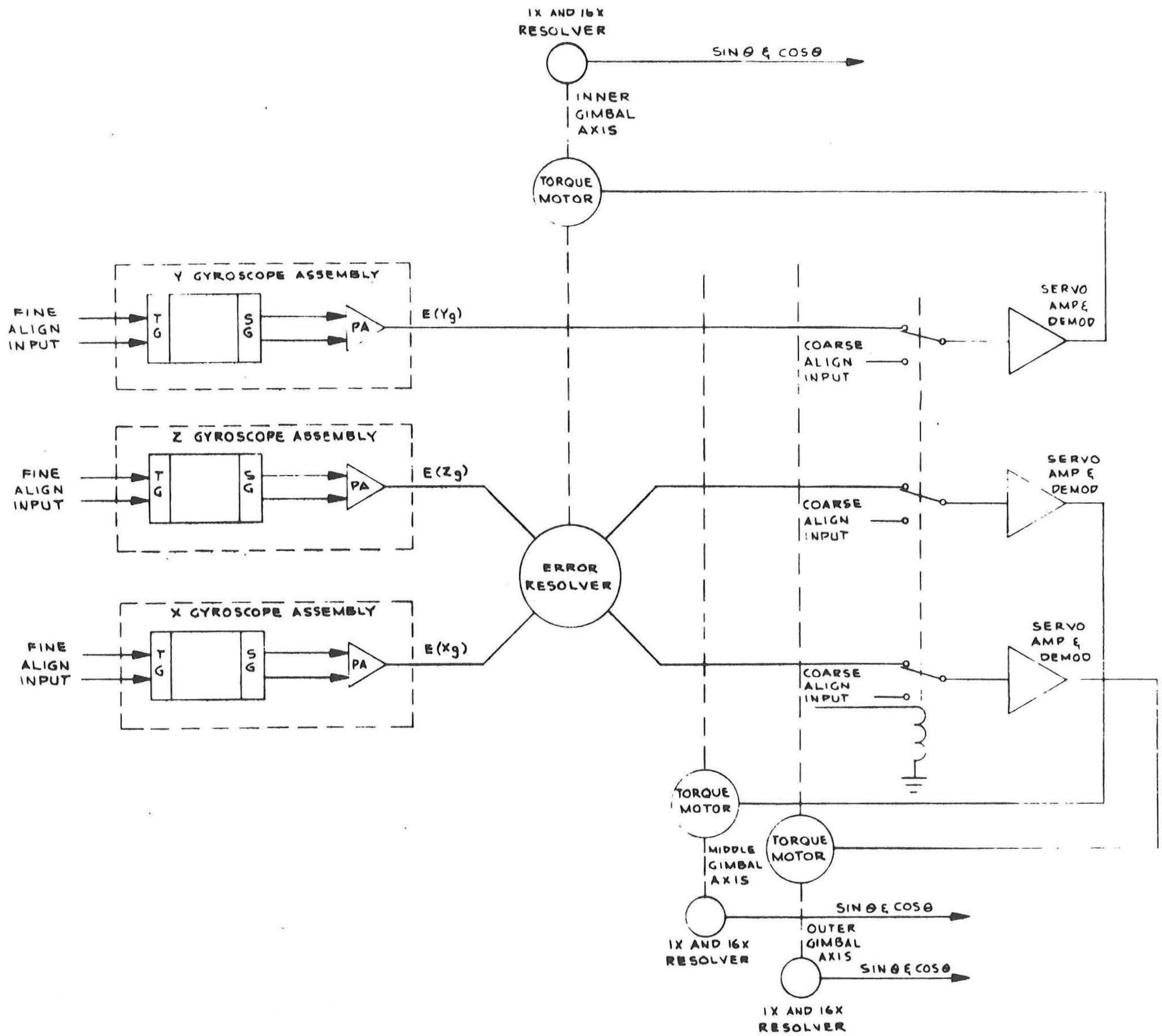


Fig. 2-3. Stabilization Loops Functional Block Diagram.

to the inner gimbal axis, it detects the full component of torque about the inner gimbal axis represented by signal $E(Y_g)$. However, movement of the stable member about the inner gimbal axis changes the relationship of the X and Z gyro input axes to the middle and outer gimbal axes. Hence, the detected $E(X_g)$ and $E(Z_g)$ values must be first resolved into their correct representative value of gimbal axes displacement. The three resultant signals $E(Y_g)$, resolved $E(X_g)$, and resolved $E(Z_g)$ are amplified and provide drive to the torque motors for counteracting the components of torque.

The 1X and 16X resolver outputs are transmitted to the CDU and the stabilization and control system (SCS). Each resolver has a sine and cosine output by an 800 cps suppressed carrier voltage analog. The outputs to the CDU are converted to digital representations that are sent incrementally to the CMC so that it is continuously aware of the present gimbal angle displacements. The output to the SCS provides a total attitude display on the flight director's attitude indicator (FDAI).

2.1.1.2 Analog-to-Digital Conversion

Analog-to-digital (A/D) conversion is accomplished by resolving an unknown gimbal angle θ about a preselected angle ψ by the expression:

$$\sin(\theta - \psi) = \sin\theta \cos\psi - \cos\theta \sin\psi$$

When the equation goes to zero, $\theta = \psi$ and as a consequence ψ is a representative value of θ. The value ψ is sequentially selected in incremental steps within a binary counter. A value for θ is obtained by the CMC accumulating the number of binary steps required to null $\sin(\theta - \psi)$.

An analog-to-digital circuit is associated with each of the three gimbals (two A/D are also associated with the optical subsystem). Figure 2-4 illustrates

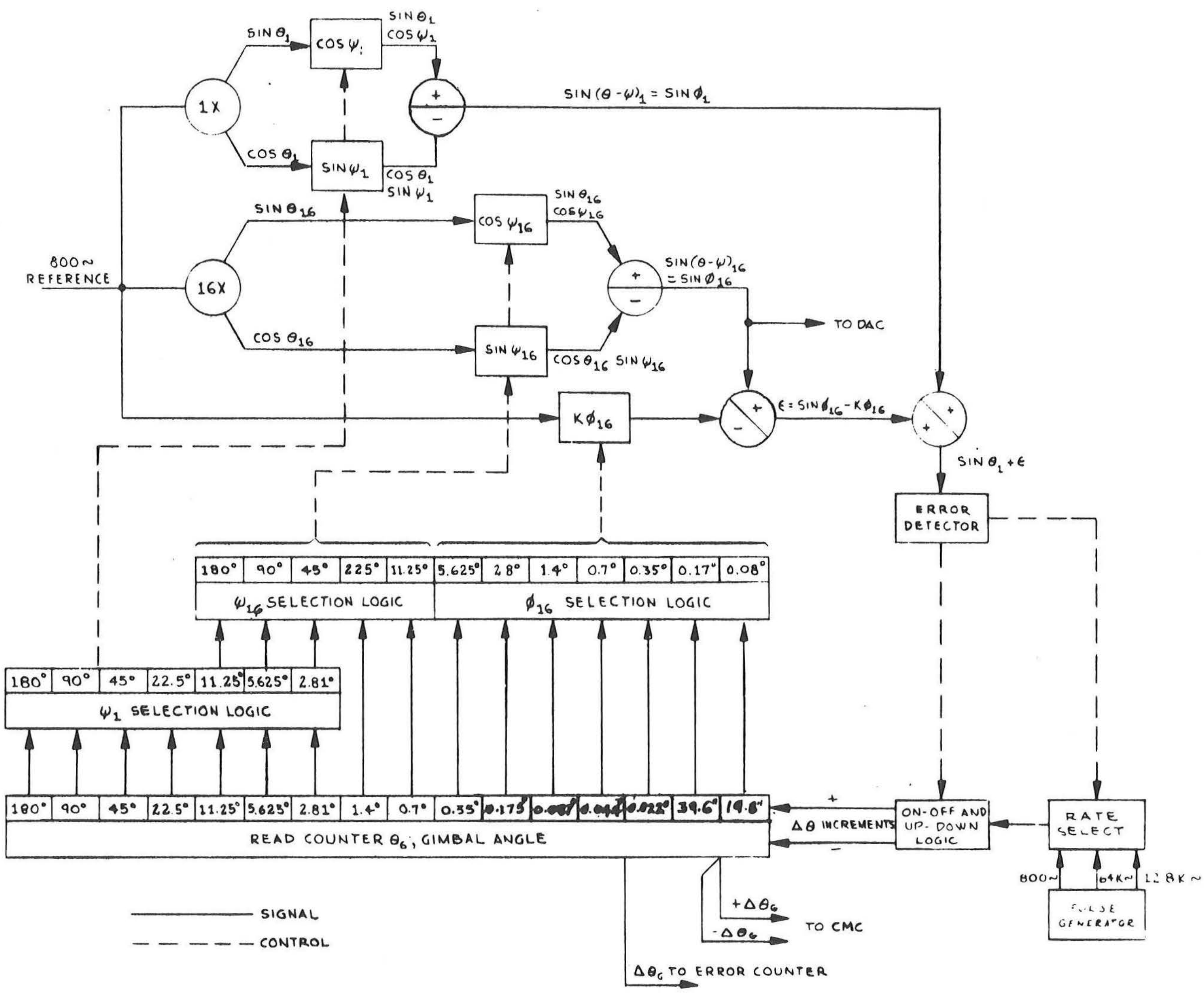


Fig. 2-4. Analog-to-Digital Conversion Functional Block Diagram.

a functional block diagram of one of these circuits. The CDU receives sin θ and cos θ signals from the 1X and 16X resolvers. The θ_G information is contained in the amplitude of the sin θ and cos θ signals and their phase with respect to the 800 cycle reference. The value of ψ is accumulated in a 16-stage counter called the read counter. A binary one value contained in a stage of the counter energizes transistor switches that accumulate, by means of ladder networks (voltage dividers) and summing networks, analog attenuation values for nulling the input resolver voltages and the 800 cycle reference. As long as the equation is not nulled, the phase and amplitude of the difference signal out of the error detector circuit produces a count up or count down signal for incrementing the read counter. The amplitude of the error signal (sin $\theta_1 + \epsilon$) determines the rate (either 800 pps, 6.4 kpps, or 12.8 kpps) at which the digital pulses, equivalent to 19.8 arc seconds of gimbal displacement, are generated. The phase of the error signal determines a count-up or count-down condition. By counting the number of steps until a null takes place, the CMC obtains a digital representation of the gimbal angle. The $\Delta\theta_G$ counts to the CMC gimbal angle register are the output of the least significant stage of the read counter and are each equivalent to 39.6 arc seconds of gimbal angle change.

The functional nulling takes place in two loops, coarse and fine nulling. When ψ is within 22.5° of θ, a nulling ladder from 0 to 22.5° in steps of 2.81° is used to provide a coarse null for sin ϕ_1. The fine null is utilized to repeat the gimbal angle within approximately 1 bit (19.8 arc seconds). An overlapping between the coarse and fine nulling circuitry provides a smooth transition. Thus, the ψ selection logic for both loops is selected simultaneously with 180 electrical degrees of the 16X resolver rotation being equal to 11.25 degrees of the 1X resolver angle. The ψ_{16} selection logic develops a linear approximation of the gimbal angle within ± 11.25° of the fine null. The phase and amplitude of the sin $\theta_1 + \epsilon$ signal develops a complete count-down or count-up for a value $K\phi_{16}$ to obtain a null. Subsequent changes in gimbal angle continue the process and produce incremental pulses to the CMC so that the computer is continuously aware of the gimbal angle.

2.1.1.3 Digital-to-Analog Conversion

Digital-to-analog conversion (DAC) is used to provide attitude error information to the FDAI and coarse align error information to the gimbal servo amplifiers. Five DAC loops exist and their function is dependent upon the ISS mode of operation. Three of these loops are associated with the IMU gimbal angles and the other two are part of the optical subsystem.

A block diagram of a typical DAC loop is shown in Fig. 2-5. Assuming that the loop is one of the three associated with gimbal angles, the pulses entered into the error counter from the CMC provide a binary-coded representation of a desired gimbal angle change ($\Delta \theta_c$). Each pulse is equivalent to 158 arc seconds of gimbal angle displacement. The binary stages of the counter activate transistor switches in the voltage ladder decoder. The switches set a voltage divider into a configuration which provides a voltage output with an amplitude proportional to the binary count of the error counter. This output voltage is an 800 cps signal with its phase determined by whether a positive or negative value has been entered into the error counter. It serves as an input into the servo amplifier demodulator (see Fig. 2-3) or an attitude error display signal.

During coarse alignment, the read counter provides count-down pulses into the error counter as the value within the read counter accumulates

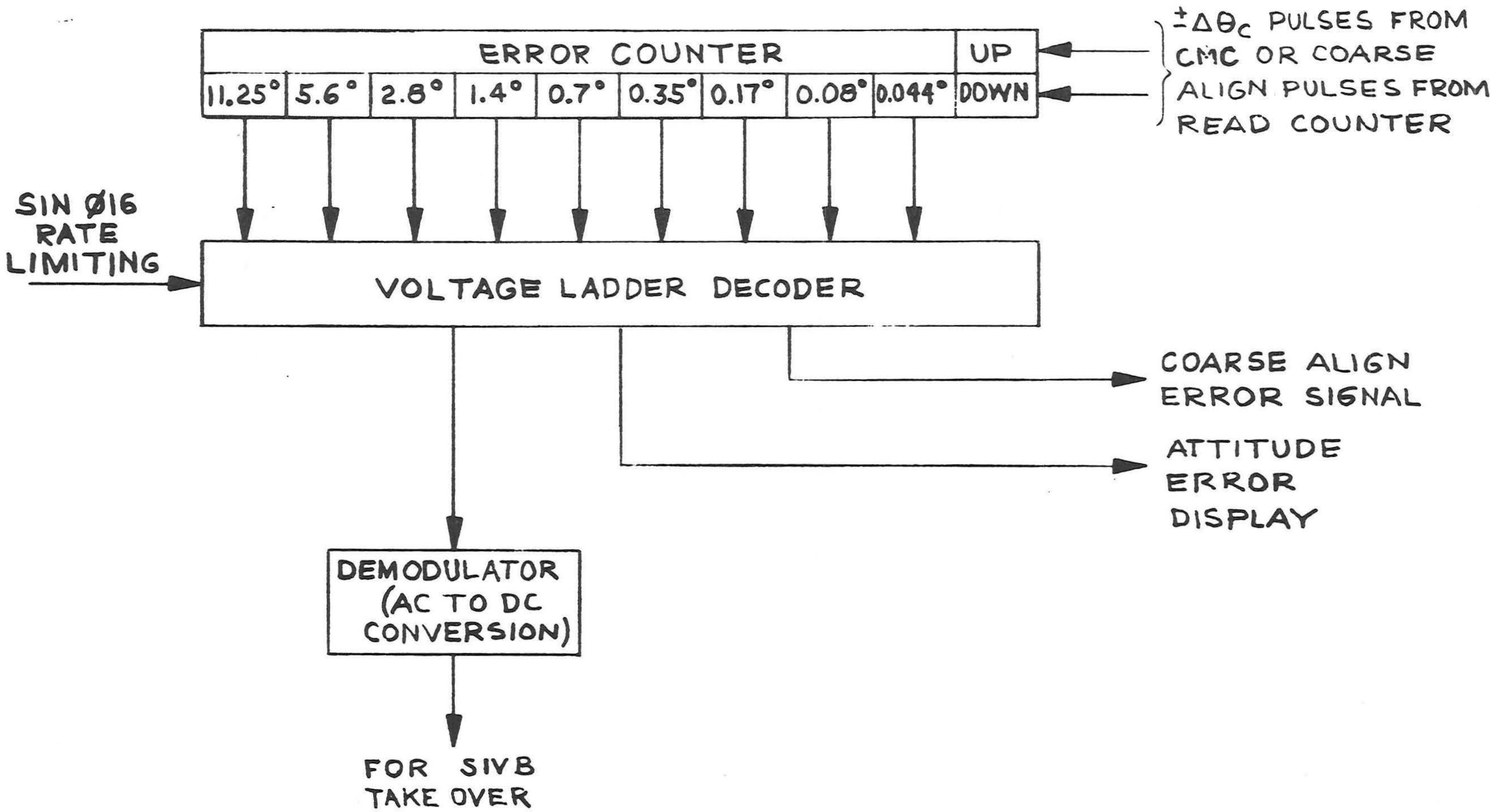


Fig. 2-5. Digital-to-Analog Conversion Functional Block Diagram

changing gimbal angle ($\Delta\theta_G$) due to coarse repositioning of the gimbal. These pulses are accepted from the third stage of the read counter for decrementing the error counter. The error counter tends to null as θ_G approaches θ_c. Rate limiting pulses are also received from the analog-to-digital conversion circuit to be summed with the voltage ladder decoder output and limit gimbal driving rate. A signal out of phase with the ladder voltage and with an amplitude proportional to the difference between the gimbal angle and the angle in the read counter provides gimbal rate limiting.

If attitude error is to be displayed, the error counter accumulates the $\Delta\theta$ pulses from the CMC and maintains this accumulative value until the CMC counts the binary-value down. Thus, three separate signals from the three digital-to-analog conversion circuits are available to the FDAI attitude error needles. Each signal is a ± 5.06 volts rms maximum, 800 cps suppressed carrier voltage analog of each axis at a scaling of 3.3 degrees per volt.

2.1.1.4 Gyro Torquing Electronics

The gyro torquing electronics (see Fig. 2-1) is used only during the fine alignment mode. It permits the stable member to be aligned within 65 seconds of arc to a coordinate frame determined by optical measurements. Control is maintained by the CMC which computes the difference between the angle of the gimbals at an instant of time and the desired gimbal angles. This difference is transposed into a number of pulses, each equivalent to 0.618 arc seconds, necessary to drive the gimbal through this difference angle.

Figure 2-6 illustrates a block diagram of the gyro torquing electronics. The gyros are torqued on a time shared basis. The CMC sends to the fine

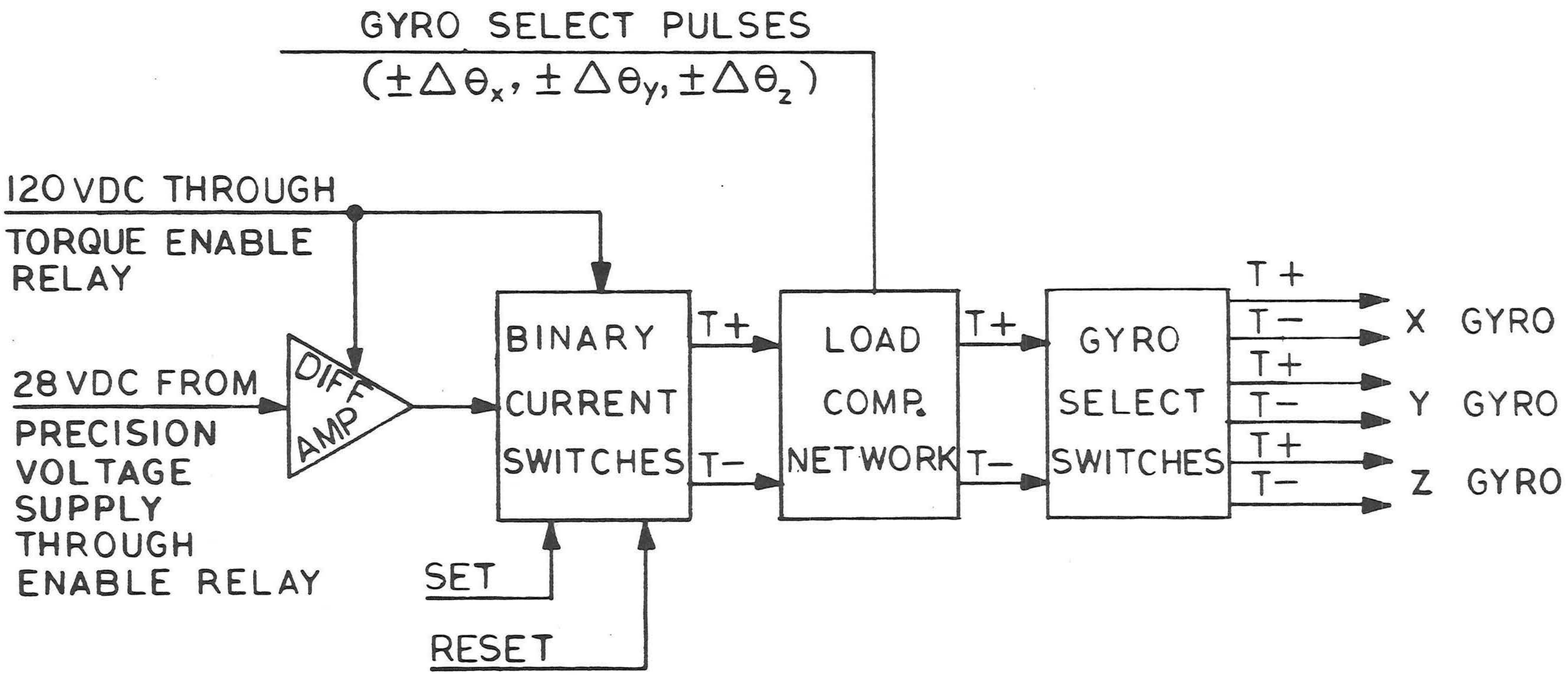


Fig. 2-6. Gyro Torquing Loop Functional Block Diagram

align electronics four types of pulses: torque enable pulses, gyro select pulses, torque set pulses, and torque reset pulses. The torque enable pulse train is first sent to a relay driver to activate the circuit. The CMC then sends gyro select pulses ($+\Delta\theta x$ or $-\Delta\theta x$, $+\Delta\theta y$ or $-\Delta\theta y$, and $+\Delta\theta z$ or $-\Delta\theta z$) which select a particular gyro and the direction it is to be torqued by means of a transistor switch network that 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 coil. The amount of current flow (T+ or T-) through the torque ducosyn coils is precisely controlled at a fixed value by the precision power supply and regulating differential amplifier. The duration of application is controlled by the length of time that set pulses are applied. The ducosyn winding appears to the circuit as a pure resistive load due to the effect of the load compensation network.

2.1.1.5 Accelerometer Loops

The accelerometer loops block of Fig. 2-1 consists of three loops. Each loop measures a component of linear acceleration felt by the stable member along the axis of the accelerometer within the loop. Since the axes of the three accelerometers or PIP (pulsed integrating pendulum) are mutually perpendicular and parallel to the gyro axes, the three measured components of acceleration are representative of the acceleration on the stable member (Fig. 2-7).

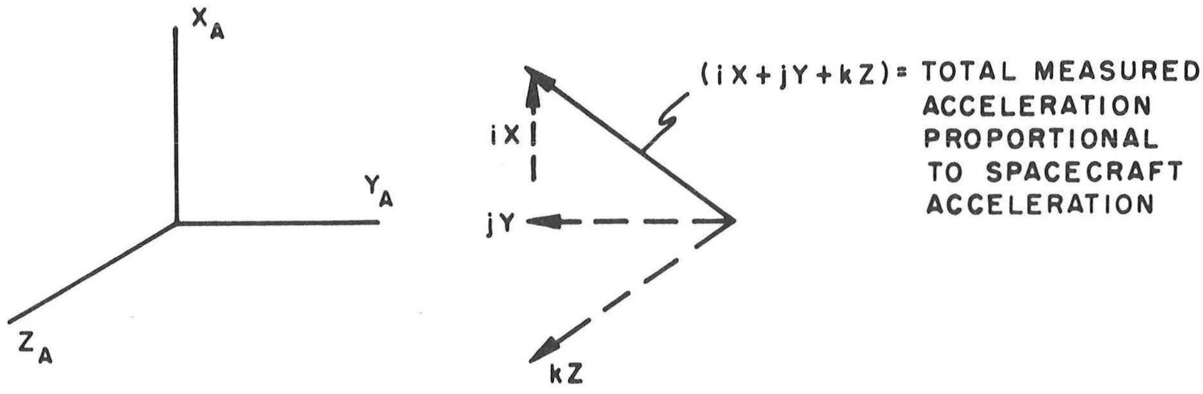


Fig. 2-7. Acceleration Detected on Stable Member

A block diagram of a typical acceleration loop is shown in Fig. 2-8. The accelerometer pendulum is maintained in oscillatory motion about its null point. That is, with no spacecraft thrusting a constant input to the torque ducosyn (TD) will hold the pendulum cycle constant. The signal ducosyn (SD) output phase changes as the pendulum passes through its null and the clock pulses from the CMC interrogate the ac differential amplifier output to determine the phasing. The frequency of the clock pulses is 3200 pps and with no acceleration acting on the stable member, the frequency of the accelerometer pendulum is 533-1/3 pps, which approaches its natural frequency. Hence, a complete pendulum cycle occurs during six clock pulses. The binary current switches use the TM+ and TM- set pulse outputs to generate accelerometer torquing current. The TM+ set pulse occurring for three clock pulses and the TM- set pulse for the next three clock pulses. A TM+ set condition produces a plus torque condition and a TM- set condition produces a minus torque condition to the accelerometer TD maintaining the pendulum at 533-1/3 pps.

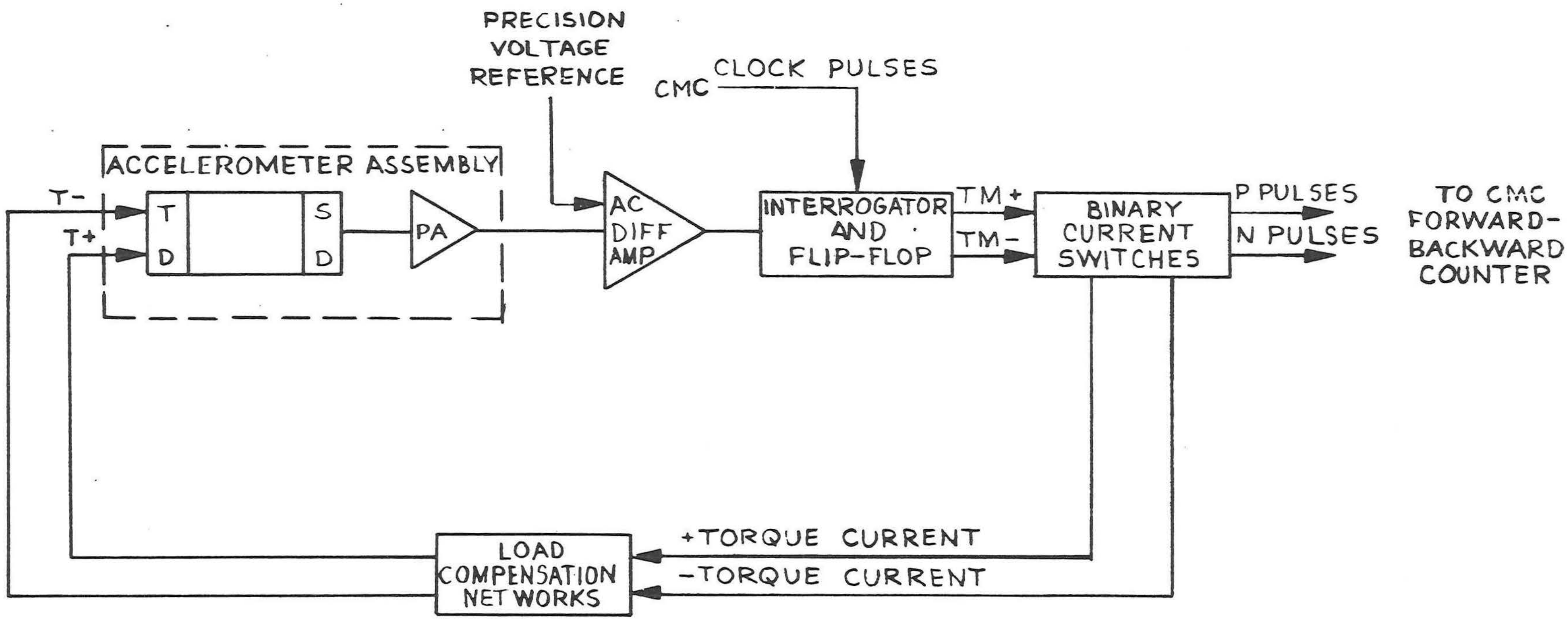


Fig. 2-8. Typical Accelerometer Loop Functional Block Diagram.

To regulate the balance of the plus and minus torques, the load compensation networks compensate for the inductive load of the accelerometer generator ducosyns. Thus, the generator coils appear as pure resistive load to the binary current switches. Therefore, as long as no acceleration acts on the loop, three P pulses and three N pulses are generated to the CMC forward-backward counter causing a count up of three and then a count down of three. The CMC, in effect, is then recognizing a condition of no acceleration.

When an acceleration acts on the stable member, the equilibrium of the loop is interrupted. Each accelerometer feels a linear component of this acceleration as an additional torque that aids or opposes the torque generator forces. Because the torque current from the binary current switches is constant, a longer application of plus or minus current application is necessary to keep the pendulum in its oscillatory motion. The change in time required for the float to be torqued back through null, results in an unequal number of P and N pulses sent to the CMC. The CMC synchronizes its sampling of each of the three forward-backward counters to once every 1/533-1/3 seconds which is equivalent to a pendulum period. Thus, the difference of the accumulative count of P and N pulses $[\Sigma(P) - \Sigma(N)]$, is proportional by a constant (K) to the magnitude of a component of acceleration. Since the CMC performs its calculations with discrete values, the formula $a = (dv/dt)$ becomes $a = (\Delta V/\Delta t)$ [that is, $\Delta V = a\Delta t$]. Hence, the CMC calculations for solution of a change in velocity (ΔV) can be summarized as follows:

$$\Delta V = K[\Sigma(P) - \Sigma(N)]\,\Delta t$$

2.1.2 ISS Modes of Operation

The ISS modes of operation are normally initiated automatically by the CMC or by the astronaut selecting a CMC program through the DSKY. Mode control is regulated by the issuance of CMC discretes to the CDU.

The ISS is in a standby state when the IMU HTR circuit breaker is closed and either the IMU circuit breaker is open or the G/N POWER, IMU switch is off. During the standby state, +27.5 dc prime power is supplied only to the IMU heater circuit. The remaining portions of the ISS are deenergized.

2.1.2.1 IMU Turn On

The IMU turn on mode is entered only if the IMU circuit breaker is closed and the G/N POWER, IMU switch is set to the on position. This mode drives the IMU gimbals to their zero position and holds them there. It also clears the CMC gimbal angle registers and the ICDU read counters. By establishing this zero reference coincident with the spacecraft attitude, the CMC knows the gimbal angles and is prepared to obtain incremental changes in gimbal orientation from the read counters in any subsequent mode.

Figure 2-9 illustrates the circuit configuration for one of the three gimbals during the turn on mode. Application of ISS operating power, through deenergized ISS turn on relay, energizes the IMU cage relays which in turn energizes the coarse align relays. In addition, the initial application of power routes to the computer an ISS turn on delay request discrete which provides a 90-second period for mode completion, which permits the gyro wheels to run up to full speed. Upon reception of this delay request, the CMC issues the coarse align enable and CDU zero discretes. The coarse align enable discrete provides a redundant

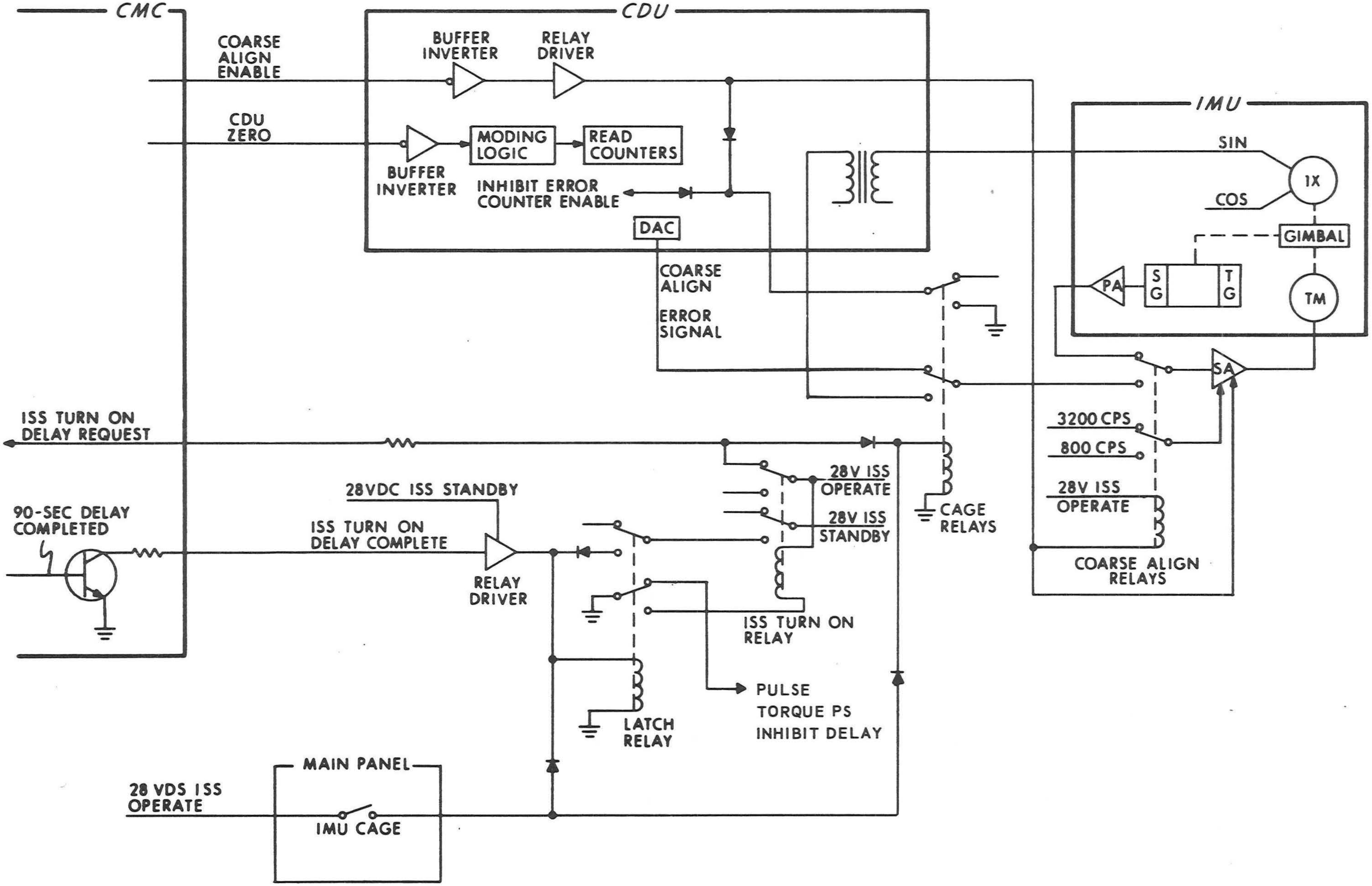


Fig. 2-9. IMU Turn On Mode

means of energizing the coarse align relays. The CDU zero discrete clears the three read counters, clears the CMC gimbal angle registers, and inhibits any incrementing pulses to the read counter.

The relay configuration is such that an 800 cps reference is applied to the gimbal servo amplifier enabling the 800 cps sin θ signal from the 1X resolver to be converted to a dc drive signal. The gimbal torque motor drives the gimbal to its zero position where the sin θ value is now zero.

After the 90-second delay is completed, the CMC issues the delay complete discrete. This discrete causes the latch relay to be energized. This energizes the ISS turn on relay which removes the turn on delay discrete to the CMC and deenergizes the cage relay. The CMC can then remove both the CDU zero discrete and the coarse align discrete allowing the ISS to go into the inertial reference mode or it can remove the CDU zero discrete and issue an error counter enable discrete (while maintaining the coarse align discrete) allowing the ISS to go into the coarse align mode. The latch and turn on relays are kept energized by 28 vdc ISS standby power applied serially through both relays to the latch relay coil.

2.1.2.2 ISS CDU Zero

The purpose of the ISS CDU zero mode is to clear and inhibit the three ISS CDU read counters. The mode is initiated by a CDU zero discrete from the CMC. This discrete clears the read counters, clears the CMC gimbal angle registers, and inhibits any incrementing pulses to the read counter. The discrete remains present for as long as the read counters are to be held at zero.

2.1.2.3 IMU Cage

The IMU cage mode is an emergency mode used during CMC failure or to stop a tumbling platform. It drives the gimbals to a known reference with respect to the spacecraft axes. When the IMU CAGE switch is set to the on position, the IMU cage relay and the coarse align relay are energized to feed the sin θ signal from the 1X resolver into the gimbal servo amplifier (see Fig. 2-9). The switch is held until the gimbals settle at the zero position (five seconds maximum). The gimbal position is observed on the FDAI. When the IMU CAGE switch is positioned off, the CMC allows the read counters to zero and then places the ISS in an attitude control mode. During the read counter settling period, the IMU cage discrete is present and the NO ATT lamp on the DSKY is lighted. Setting the switch off releases the IMU to inertially stabilize at an attitude within 1 degree of the attitude at the time that the switch is set to the off position.

The IMU cage mode may also be used to establish an inertial reference while the CMC is deenergized or in a standby state. However, the IMU cage mode is an emergency backup mode and should not be employed unnecessarily at any time, because of the lack of CDU rate limiting which could cause gimbal rates sufficient to drive the gyros into their rotational and radial stops. Such action could cause gyro bias shift.

2.1.2.4 Coarse Align

The coarse align mode is entered when the CMC has issued the ISS error counter enable and coarse align discretes. The purpose of this mode is to change IMU gimbal orientation according to CMC computations to provide a more desirable orientation for inertial measurement.

When the mode is entered by issuance of the discretes, the CDU read counters are in the process of repeating gimbal angles and supplying this information as $\Delta\theta_G$ pulses to the CMC (see Fig. 2-10). By incremental storing up-and-down counts in the gimbal angle registers, the CMC is aware of total gimbal angles and calculates the necessary change in angles to bring the gimbals to the desired orientation. Hence, the CMC computes the number of pulses that must be entered into each error counter to produce the desired analog drive signal.

The coarse align enable discrete energizes the coarse align relays to disengage the fine align electronics and produce an input into the servo amplifier from the digital-to-analog conversion circuit where the error counter has been enabled by the error counter enable discrete. The CMC sends bursts of pulses ($\pm\Delta\dot{\theta}_c$) at 3200 pps to the DAC with each pulse equivalent to a desired angle change of 158.2 arc seconds on the IMU 1X resolver. Suppose for example, the CMC desires an 11.25 degree change in a gimbal angle with respect to the spacecraft. Since 11.25 degrees is equivalent to 40,500 arc seconds, the CMC sends a burst of 256 pulses (40,500 ÷ 158.2) to the DAC. The value in the DAC error counter is converted to an analog value for servo amplifier input. The resulting torque motor drive moves the gimbal to produce a new resolver angle in the read counter which transmits the incremental change to the CMC and the error counter. The pulses sent to the error counter subtract from the original binary value so that the error counter ultimately contains a zero value when the gimbal has moved to the commanded position.

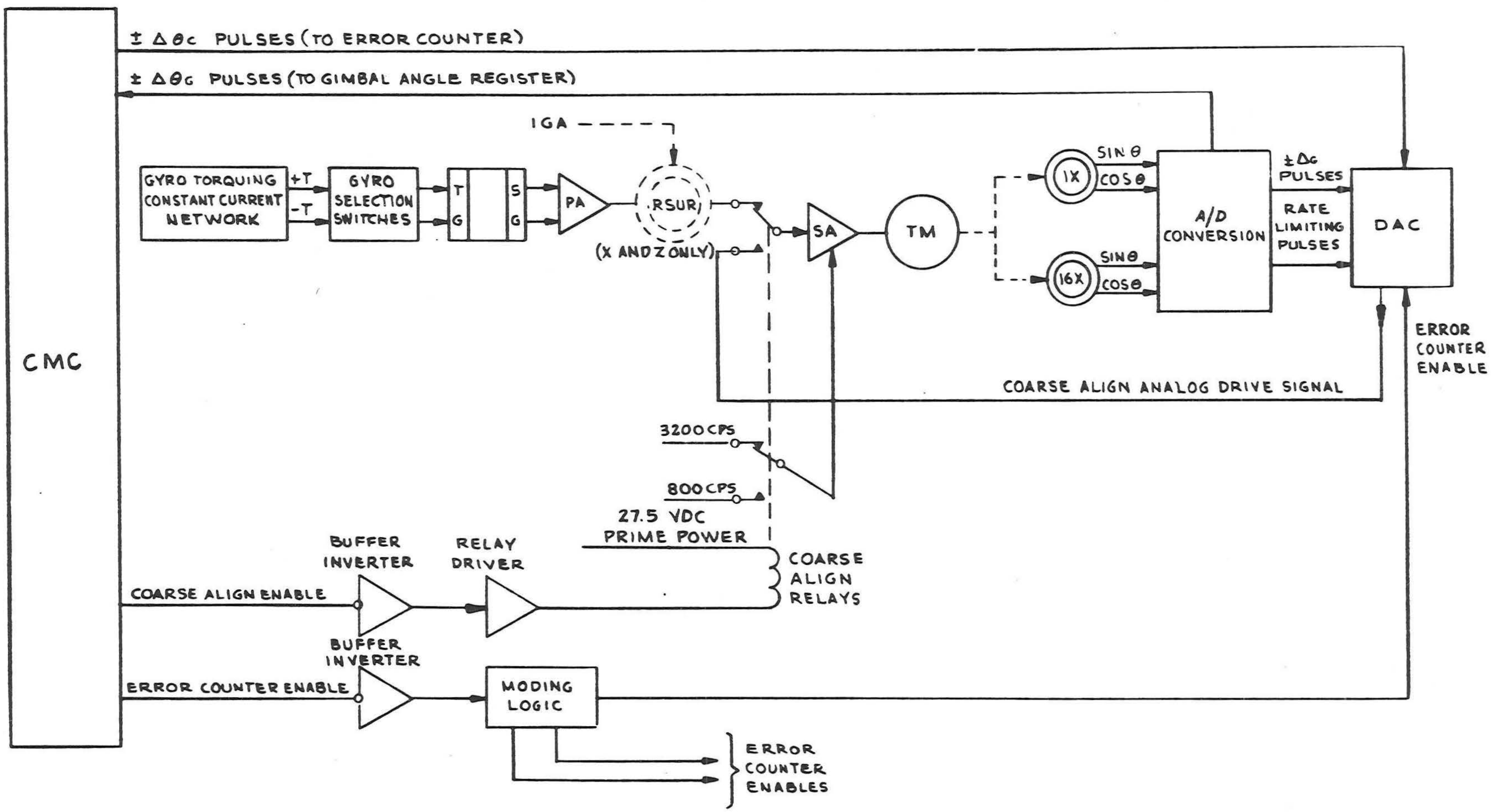


Fig. 2-10. Coarse Align Mode.

To prevent damage to the gyros and to assure that the read counter tracks the gimbal angle accurately, the rate of gimbal drive is limited. A fine error signal performs rate limiting by being mixed with the decoded error counter output. This 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 and the angle in the read counter. During the coarse align mode, the read counter is limited to a high counting speed of 6.4 kpps and a low counting speed of 800 pps. If the gimbals are moving at a faster rate than that which the read counter is counting, the fine error signal increases, 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 read counter is counting, the fine error signal decreases, causing the gimbal servo amplifier to apply an accelerating torque to the gimbals. The gimbal drive rate is limited to either 35.5°/second (at the 6.4 kpps counting rate) or 4.5°/second (at the 800 cps counting rate).

2.1.2.5 Thrust Vector Control

During the thrust vector control mode, the CMC controls the SPS engine gimbals by sending steering control signals to the SPS engine gimbal amplifiers through the optics CDU. The thrust vector control mode is initiated by setting the SC CONT switch to CMC and setting either of the ΔV THRUST NORMAL switches to NORMAL. The closure of the ΔV THRUST NORMAL switch enables the CMC thrust on discrete to energize the engine solenoids. In the CMC position, the SC CONT switch routes a +28 vdc discrete to the optics CDU where it arms a set of relays which, when energized, connect the dc outputs of the optics CDU DAC's to the SPS engine gimbal amplifiers. The +28 vdc discrete is also routed to the CMC. Receipt of this discrete by the CMC enables the CMC to issue the thrust vector control discrete. The thrust vector control discrete energizes the previously armed control relays which connect the optics CDU DAC dc outputs to the SPS engine gimbal amplifiers. The CMC issues the optics DAC enable discrete 60 milliseconds after the thrust vector control discrete. With the optics error counters enabled and the optics CDU DAC dc outputs connected to the SPS engine gimbal amplifiers, 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 DAC's 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 GNCS 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 removes the optics DAC enable discrete which inhibits and clears the error counters. The CMC then issues the thrust vector control discrete.

2.1.2.6 Inertial Reference

The ISS is in the inertial reference mode during any operating period in which the CMC does not issue moding commands. The inertial reference mode provides a fixed coordinate reference system for attitude and velocity measurements.

During this mode, the stable member is held at a fixed orientation by the stabilization loops (see Fig. 2-11). The fine align electronics are inhibited because the fine align command pulses are not present and the error counters are cleared and inhibited. The read counters provide the CMC with changes in gimbal angles with respect to the stable member and the binary current switches provide the CMC with changes in acceleration with respect to the stable member. The six signals from the 1X gimbal resolvers (sine and cosine windings) are sent to the FDAI total attitude display.

2.1.2.7 Fine Align

The fine align mode precisely repositions the stable member to a coordinate frame determined by optical measurements. It is essentially a gyro torquing submode of the inertial reference mode. Command discretes are not issued, but this submode is entered by the CMC activation of the fine align electronics during the inertial reference mode. Upon deactivation, the ISS returns to the inertial reference mode.

Figure 2-11 illustrates the operating configuration of the fine align mode. The error counter is cleared and inhibited. The read counter continues to supply gimbal angle data to the CMC. Line-of-sight data from the OSS is transformed by the CMC into stable member coordinates. From the difference between the actual gimbal angle and the desired gimbal angle, the

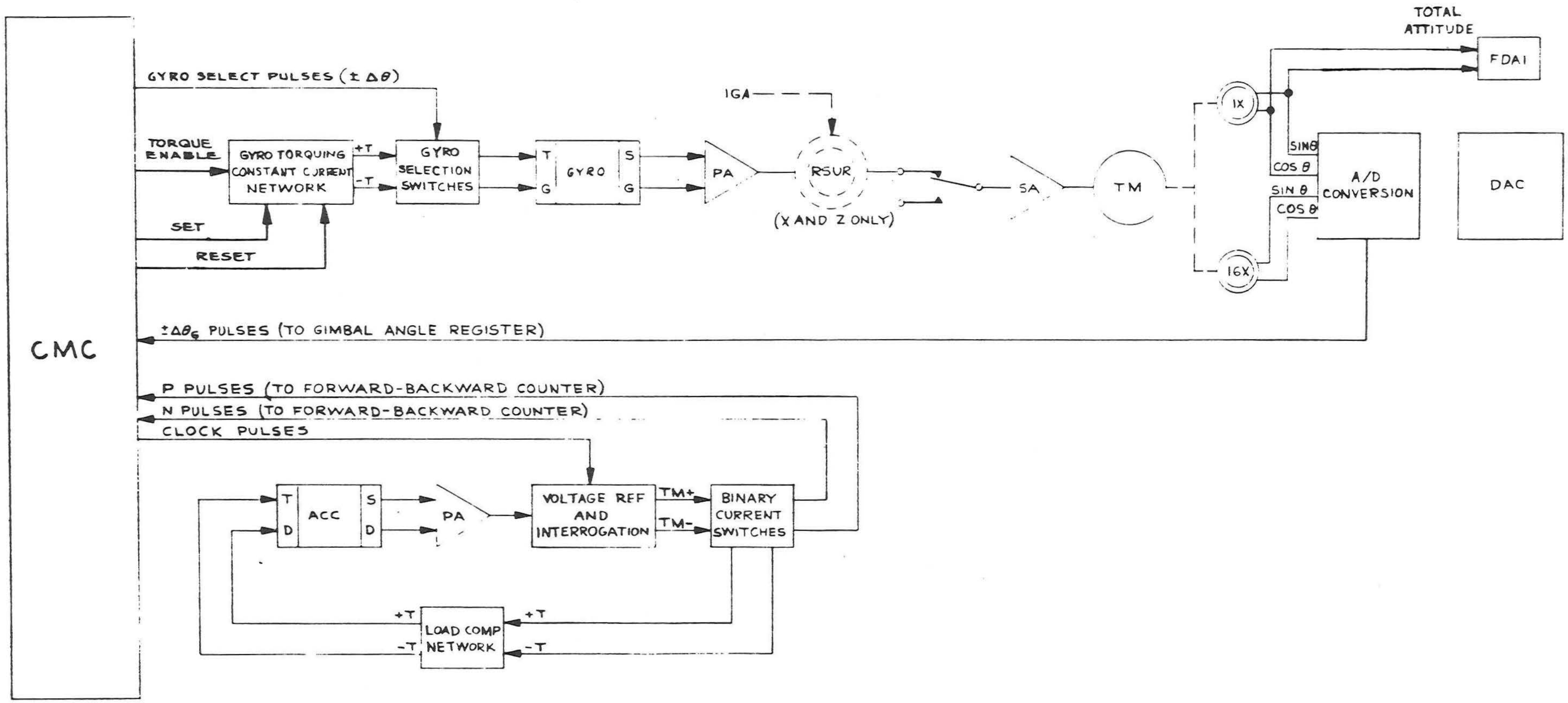


Fig. 2-11. Inertial Reference Mode.

CMC computes the angular rotation about each stable member axis necessary to change the stable member to the desired coordinate frame. Thus, the difference (θ_G - θ_c) determines the necessary number of set pulses to be sent from the CMC to the torquing electronics. The pulses are generated by the CMC in bursts at a bit rate of 3200 pps. Each pulse is equivalent to 0.618 arc seconds of gimbal displacement. The CMC simultaneously supplies a torque enable command to the IMU, selects the gyro to be torqued, and gates the required number of pulses through the fine align electronics to each gyro. The number of set pulses to each gyro determine the duration of a constant current that is applied to the torque generator coil which results in a repositioning of the gimbal to the desired angle. Upon completion of torquing, stable member orientation can be checked with another set of star sightings.

2.1.2.8 Display Attitude Error

The ISS is in the display attitude error mode during the CMC autopilot program. The mode permits attitude error display on the FDAI and changes in attitude and velocity to be supplied to the CMC. The ISS enters this mode of operation whenever the error counter enable discrete is the only mode command discrete issued by the CMC. (See Fig. 2-12.)

The CMC through its autopilot program controls maneuvering and thrusting of the spacecraft by issuing commands to the stabilization control system (SCS). During the display attitude error mode, the error counter is enabled and the read counter continues to supply actual attitude information to the CMC. The autopilot program computes desired attitude associated with the present time and position of the spacecraft. The difference between actual attitude and desired attitude (in each reference axis) is an attitude error. The CMC transmits (θ_G - θ_c) pulses that are representative of

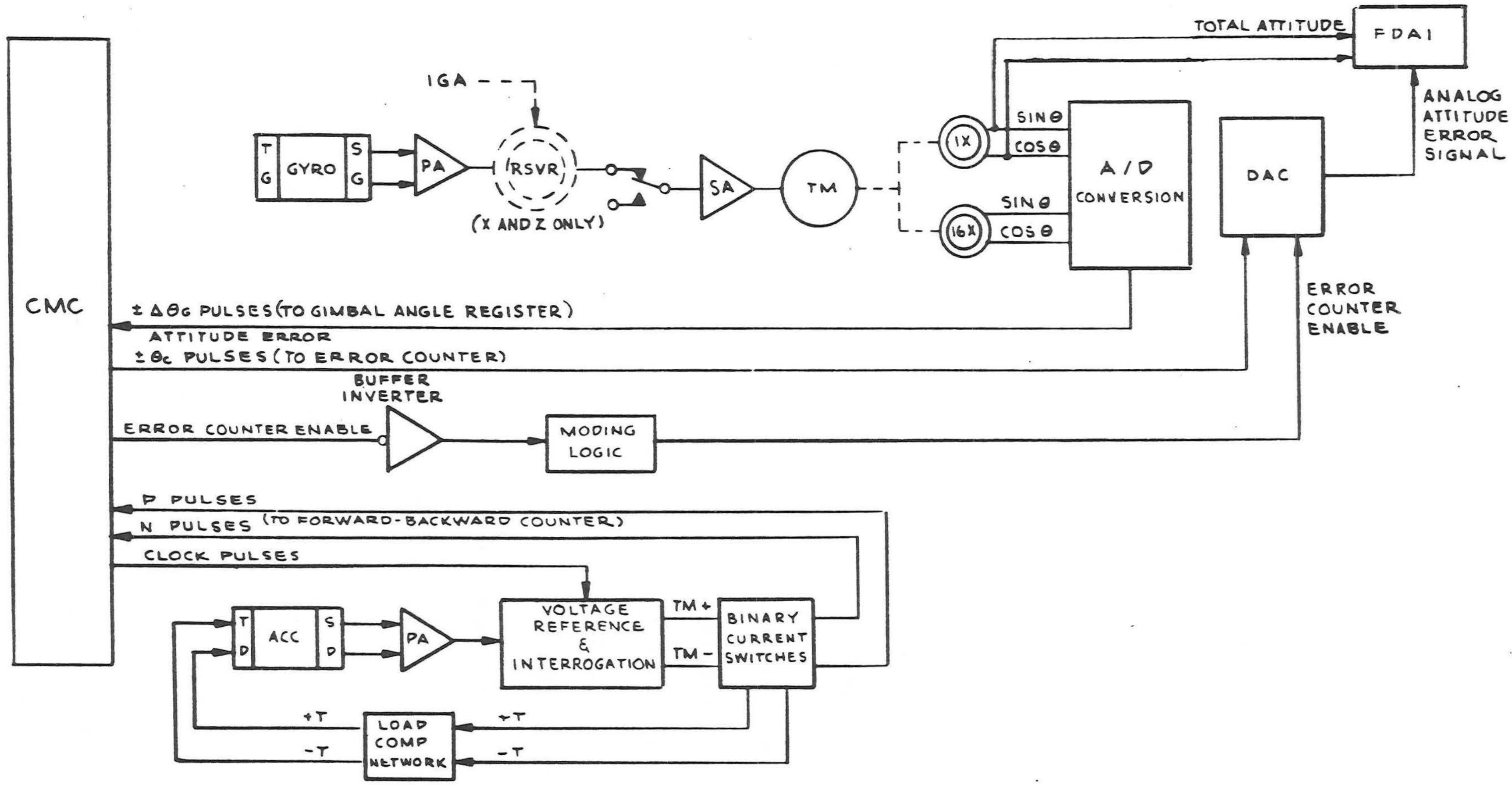


Fig. 2-12. Display Attitude Error Mode.

attitude errors into each error counter. These pulses are generated at a bit rate of 3200 pps with each pulse equivalent to 158.2 arc seconds of error, except for roll axis during boost monitor and entry for which the scaling is 632.8 arc seconds per pulse. The output of each error counter is developed into an analog error signal and fed to the FDAI. The error counter is incremented or decremented only from the CMC as the digital feedback from the read counter to the error counter is disabled.

Changes in spacecraft orientation are sensed by the IMU stabilization loops which result in gimbal angle resolver outputs being transmitted to the DAC and to the FDAI for total attitude display.

2.1.2.9 Attitude Control

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

During attitude control, 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 discretes 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 to determine when to stop firing the RCS jets. The FDAI error counter is pulsed to zero, nulling the attitude error signal on the FDAI.

2.1.3 IMU Temperature Control

The IMU temperature control circuitry maintains the temperature of the stabilization gyros and accelerometers within their required temperature limits during both standby and operating modes of the IMU (see Fig. 2-13). Heat is supplied and removed to maintain the IMU heat balance with minimum power consumption. Heat is removed by convection, conduction, and radiation. The natural convection used during the IMU standby state changes to blower controlled, forced convection during IMU operating modes. The IMU internal pressure is maintained between 3.5 and 15 psia to enable the required forced convection. To aid in removing heat, a water-glycol solution at approximately 45.0 degrees Fahrenheit from the spacecraft coolant system passes through the coolant passages of the IMU support gimbal.

2.1.3.1 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 gyro end mount heaters, three gyro tapered mount heaters, two stable member

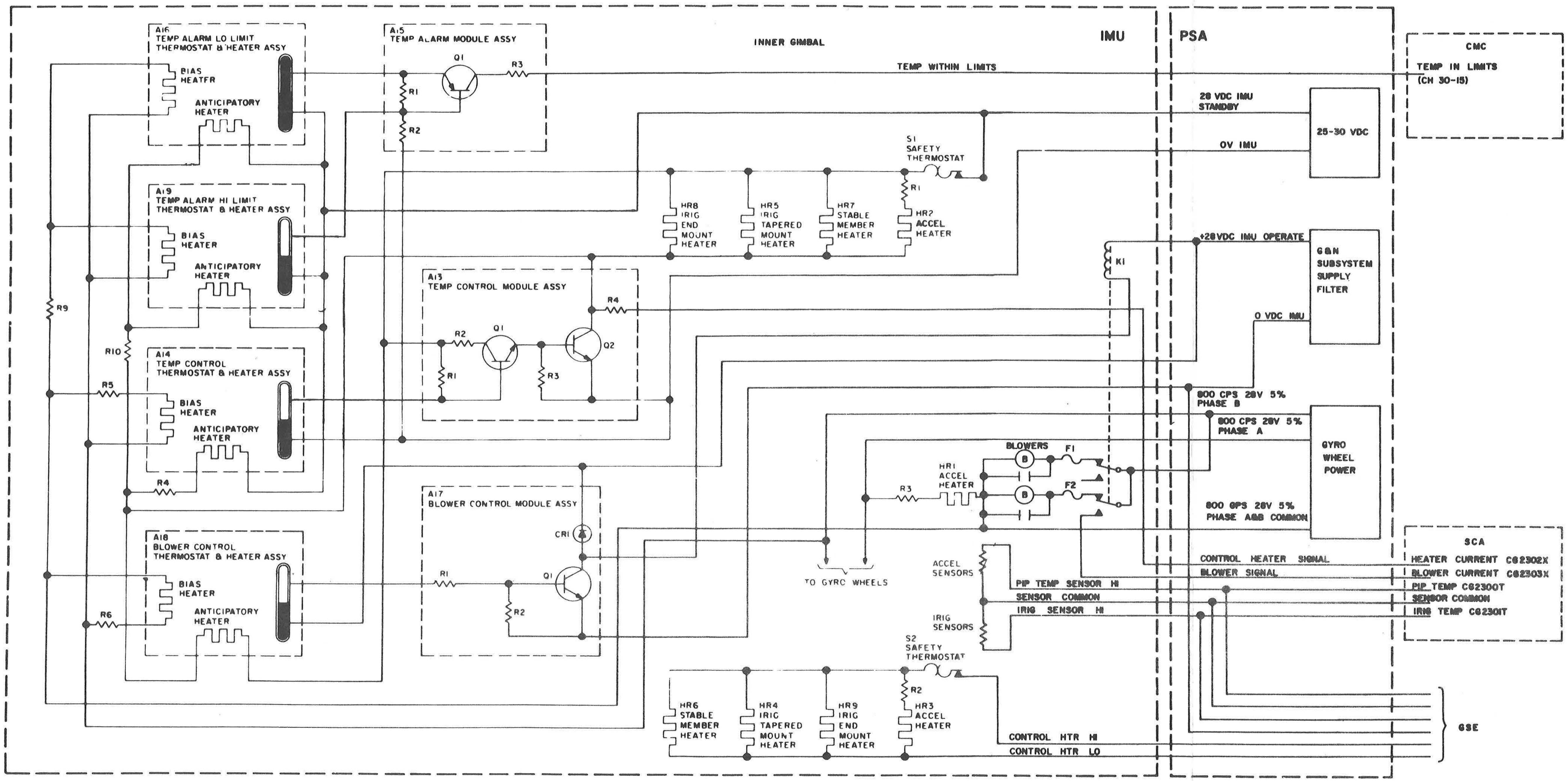


Fig. 2-13. IMU Temperature Control System

heaters, and three accelerometer heaters (see Fig. 2-13). 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 heater, all heaters are connected in parallel and are energized by 28 vdc through the switching action of Q2.

When the temperature falls below 130 (± 0. 2) degrees Fahrenheit, the thermostat opens and transistor Q1 conducts and drives transistor Q2 to conduct. When transistor Q2 conducts, current flows through the twelve heaters. Because of the large mass of the stable member, its temperature increases at a relatively slow rate as compared to the gyros. The anticipatory heater improves the response of the thermostat to insure that the magnitude of the temperature cycling of the gyros and accelerometers is as small as possible. When the temperature rises above 130 (± 0. 2) degrees, the thermostat closes and the base of Q1 is shorted to ground, cutting off Q1 and Q2. The temperature control circuit maintains the average gyro temperatures at 135 (± 1. 0) degrees and the average accelerometer temperatures at 130 (± 1. 0) degrees under normal ambient conditions.

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 and close at 137 (± 3. 0) degrees.

2. 1. 3. 2 <u>Blower Control Circuit</u>

The blowers maintain IMU heat balance by removing heat. They are supplied 28 vdc, 800 cps power, which is also supplied to the gyro wheels (see Fig. 2-13). Fused phase shift networks are associated with each blower so that excitation and control current can be supplied from the same source.

The contacts of the blower control thermostat close at 139 (±0.2) degrees and remain closed at higher temperatures. 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 is provided by the anticipatory heater to increase the temperature of the blower control thermostat to 139 degrees. 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 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.

2.1.3.3 Temperature Alarm Circuit

The temperature alarm circuit monitors the temperature control (see Fig. 2-13). If a high or low temperature is sensed by the temperature alarm thermostat located on the stable member, the temperature within limits discrete to the CMC and PSA is removed. When the temperature is within the normal range of 126.0 to 134.0° F, the low limit thermostat contacts are closed and the high limit contacts are open. Transistor Q1 is then properly biased for conduction through a grounding system in the CMC. At temperatures above 134.0 (±0.2) degrees, both the low limit and high limit thermostat contacts are closed. At temperatures below 126.0 (±0.2) degrees, both contacts are open. In either case, transistor Q1 is not able to conduct. Nonconduction of transistor Q1 signals the CMC of an alarm condition.

No differentiation is made by the CMC between a high or low temperature alarm. When the CMC senses a temperature alarm, it causes the TEMP lamps on the DSKY's and the PGNS lamps on the LEB panel and the main panel to light. When the PSA receives a temperature alarm, it sends the information to telemetry.

2.1.4 ISS Power Supplies

Four power supplies convert the +27.5 vdc prime power into the various voltages required by the ISS. The power supplies employed in the ISS are:

a. Pulse torque power supply

b. 800 cps power supply

c. -28 volt power supply

d. 3200 cps power supply

The power supplies are located in the PSA. Closing of IMU circuit breaker and the G&N POWER, IMU switch supplies the prime +28 vdc to these power supplies.

In addition to prime power, the ISS power supplies require clock pulses from the CMC for synchronization. The dc power supplies utilize multivibrators as ac sources for synchronization. If CMC clock pulses are lost, the multivibrators free run at a lower frequency.

2.1.4.1 Pulse Torque Power Supply

The pulse torque power supply provides +120 vdc to the three binary current switches and three dc differential amplifiers in the accelerometer loops and the binary current switch and dc differential amplifier in the stabilization loop fine align electronics. It also supplies three 28 vdc outputs to the accelerometer loop precision voltage reference, and +20 vdc and -20 vdc to the differential amplifiers, integrators, and binary current switches in the accelerometer loops.

The -20 vdc output is derived from the -28 vdc power supply by using a zenor diode as a voltage divider and regulator. (See Fig. 2-14.) The output is regulated at -20 (±0.8) vdc. The +20 vdc is derived from +27.5 vdc prime power by the use of a transistor series regulator which maintains the output at +20 (±0.55) vdc.

A synchronizing frequency of 12.8 kpps originates from the CMC and after being amplified and inverted is applied to a multivibrator-chopper causing it to be synchronized at 6,400 cps. A transistorized time delay circuit is incorporated into the emitter circuits of the multivibrator to provide a turn on delay of approximately 350 milliseconds. During the 90-second IMU turn on mode, 0 vdc is applied through the turn on circuits to the time delay circuit which inhibits the +120 vdc and +28 vdc outputs.

The multivibrator output is applied to the primary of a transformer which has prime power applied to its center tap. The secondary of the transformer is coupled to a two stage push-pull power amplifier which operates from prime power. Each of the rectifier regulators obtains full wave rectification. The precision voltage reference time delay circuit inhibits the operation of the regulators to provide a 6 to 8 second delay in the 28 vdc outputs.

2.1.4.2 800 cps Power Supply

The 800 cps power supply provides 800 cps, 0 phase power for IMU gimbal resolver excitation, gimbal servo amplifier demodulator reference, and FDAI and autopilot reference. The two 5-percent outputs provide gyro wheel excitation, IMU blower excitation, and accelerometer fixed heat power.

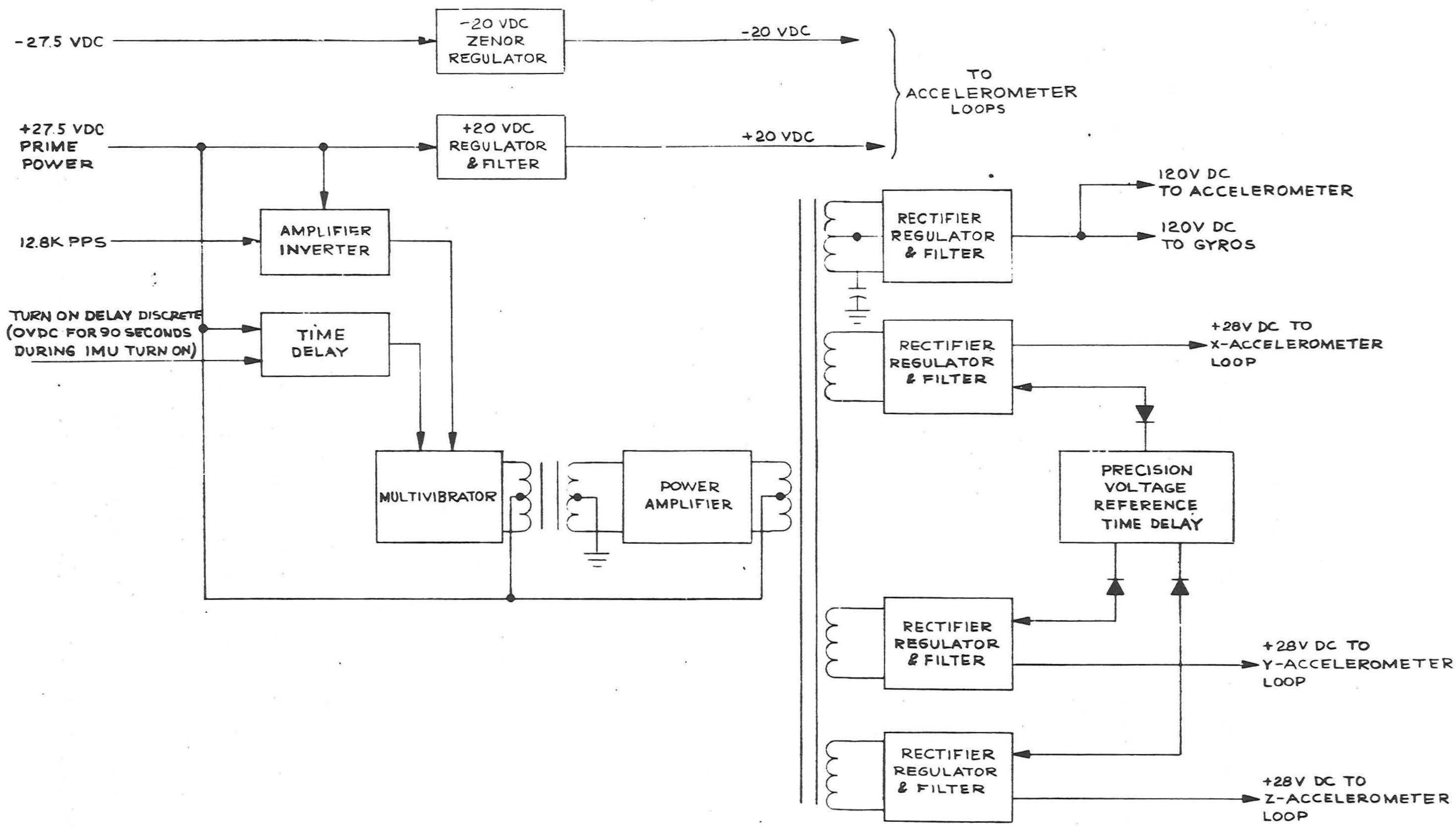


Fig. 2-14. Pulse Torque Power Supply.

Zero and pi phase, 800 cps pulse trains from the CMC synchronize the multivibrator at 800 cps. (See Fig. 2-15.) In absence of the CMC pulses, the multivibrator free runs between 720 and 800 cps. The multivibrator output controls the operation of the chopper and filter circuit. A feedback from the 1 percent amplifier is detected and added to a dc reference signal. The positive sum is filtered and provides a dc bias to the multivibrator driven chopper for amplitude control. Each of the 5 percent amplifiers perform a -90 degree phase shift to achieve the output voltage phasing. A power factor correction is maintained by the IMU load compensation network for regulating the three output voltages.

2.1.4.3 -28 vdc Power Supply

The -28 vdc power supply provides input power to the three gimbal servo amplifiers in the stabilization loops and to the pulse torque power supply to generate -20 vdc for use in the accelerometer loops. (See Fig. 2-16.) The 25.6 kpps synchronization pulse input is amplified and inverted for use in synchronizing the multivibrator-chopper at 12.8 kcps. The output of the power amplifier is transformer coupled to a full wave rectifier and filter whose positive side is reference to ground to provide a -27.0 (±1.0) vdc output.

2.1.4.4 3200 cps Power Supply

The 3200 cps power supply provides excitation voltage for the signal generator and the magnetic suspension portions of the gyro and accelerometer ducosyns. The 3200 cps output is also used as a reference for the demodulator in the gimbal servo amplifiers.

The excitation voltage to the signal generators requires both voltage stability and phase stability. (See Fig. 2-17.) To accomplish this stability,

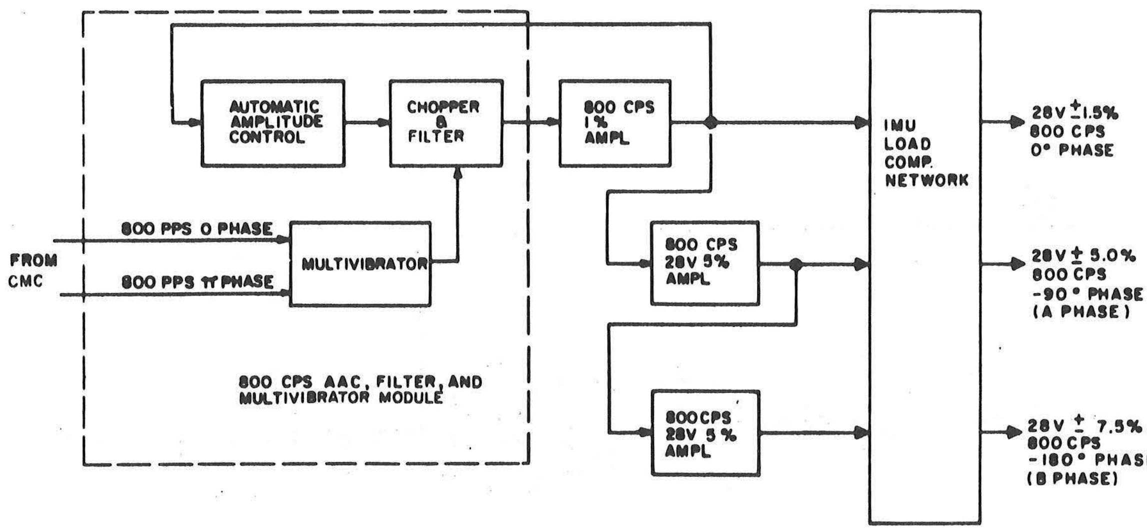


Fig. 2-15. 800 CPS Power Supply

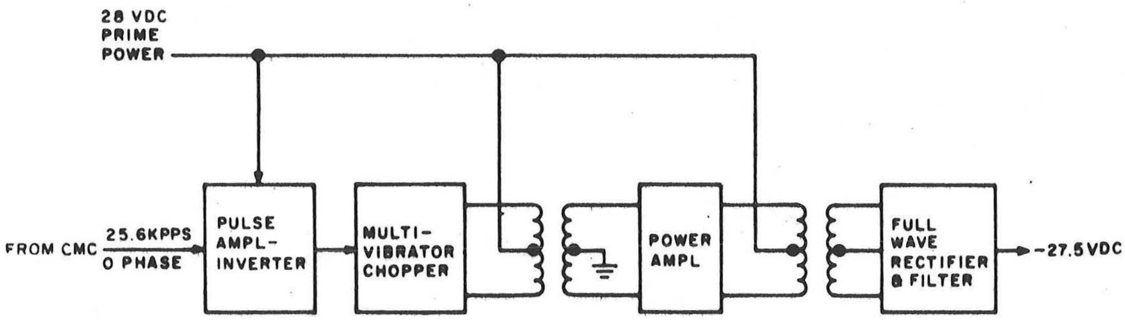


Fig. 2-16. -28 VDC Power Supply.

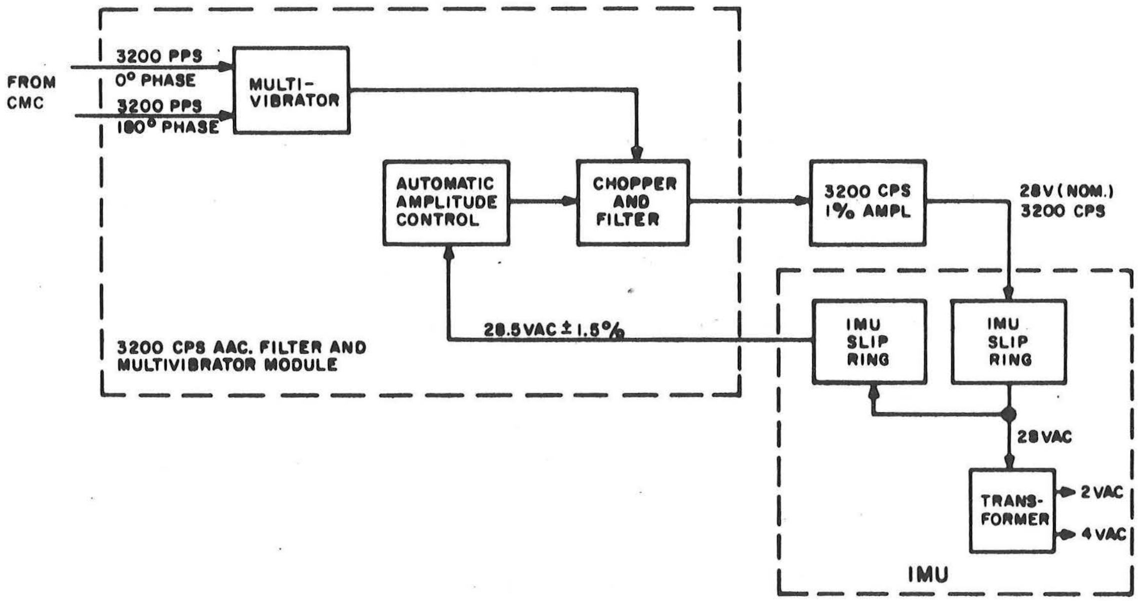


Fig. 2-17. 3200 CPS Power Supply.

the excitation voltage power transmission to the stable member is through a step down transformer on the stable member which reduces the slip ring current and, therefore, voltage drop effects due to slip ring, cable, and connector resistance. In addition, each wire connecting the output of the transformer to the input terminal of each accelerometer is cut to exactly the same length. The voltage level at the primary of the transformer is fed back to the power supply and is compared to a voltage reference.

The 3200 pps pulse train inputs synchronize the multivibrator which controls the operation of the chopper circuit. The 28 volt rms output of the amplifier is transmitted through the slip rings to the transformer on the stable member where the voltage is stepped down to 2 volts for the accelerometer ducosyns and 4 volts for the gyro ducosyns. A sample of the 28 volt level at the primary of the transformer is fed back through the slip rings to the automatic amplitude control circuit. The positive peaks of the feedback signal are detected and added to a dc reference signal. The sum is filtered and provides a dc bias to the chopper circuit. The dc bias controls the amplitude of the chopper output to the filter.

2.2 OPTICAL SUBSYSTEM

The OSS consists of an optical unit (including a sextant and a scanning telescope), two CDU channels, portions of the G & N control panel, and portions of the PSA. The control panel contains the controls and indicators that are used to establish OSS operating modes.

Figure 2-18 is a functional block diagram of the OSS. The diagram shows the flow of data for the various modes of operation selected by mode switching and the functional relationship among the various blocks. Each functional block is described in subsequent paragraphs.

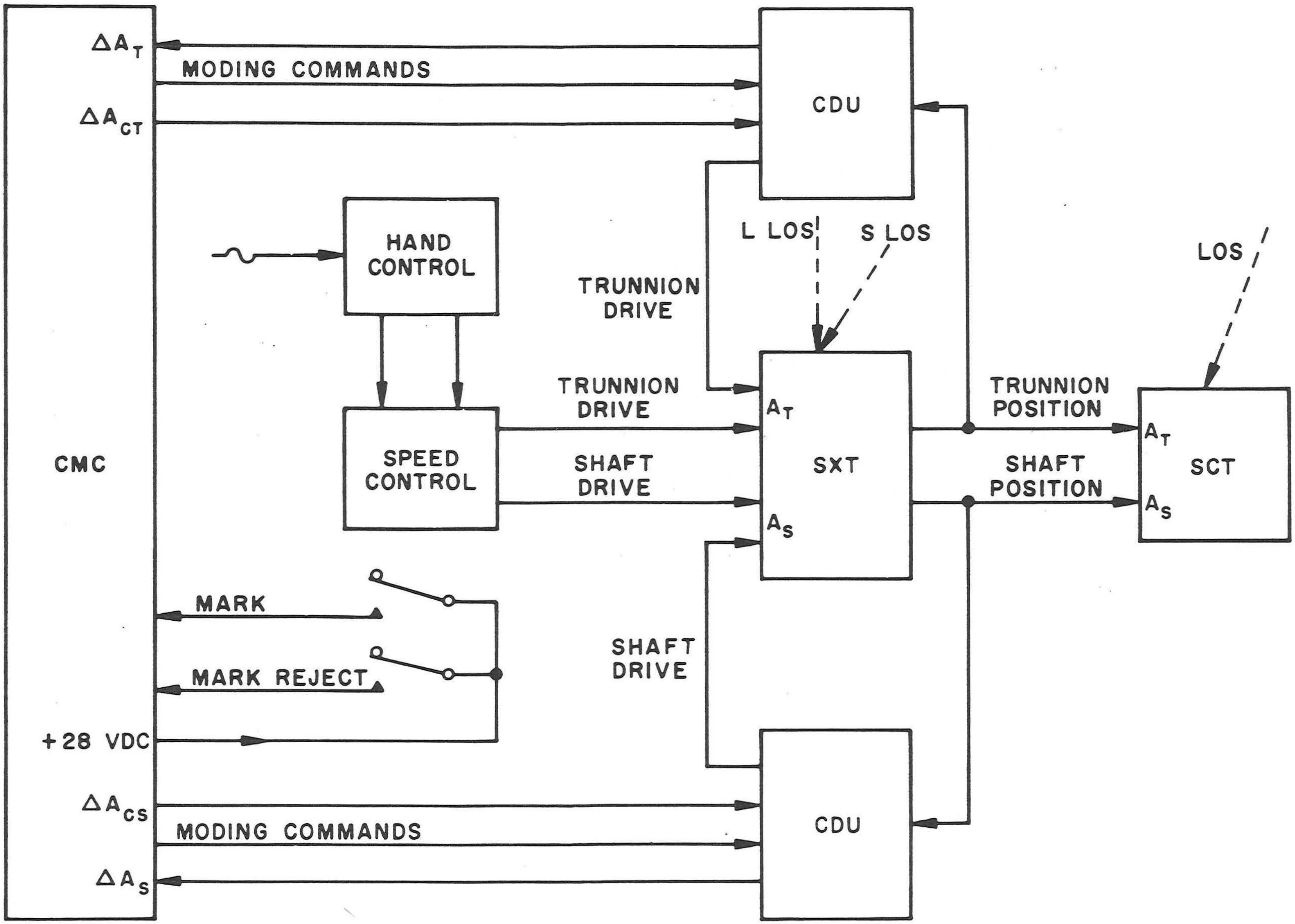


Fig. 2-18. OSS Functional Block Diagram

2.2.1 Scanning Telescope

The scanning telescope (SCT) is a one-power, 60-degree field-of-view optical instrument, capable of changing the line-of-sight (LOS) of the viewing field. The LOS is positioned by rotation of a viewing prism about its trunnion axis and by rotation of the outer telescope tube assembly about its shaft axis. Trunnion and shaft are rotated by separate servos, each commanded from the sextant (SXT). The SCT is able to scan a conic viewing area of 110 degrees. The SCT wide field of view is used for general celestial viewing and recognition of target bodies for sighting setups and measurements. In addition, it is used to track landmark points during earth and lunar orbits.

The SCT has two axes of rotational freedom, defined as the shaft and trunnion axes. Rotation about the shaft axis defines increments of shaft angle movement (A_s). Rotation about the trunnion axis defines increments of trunnion angle movement (A_t).

The prime element of the SCT is a double dove prism, mounted in the head assembly. (See Fig. 2-19.) The prism introduces the target image into the SCT optical system. The prism is positioned about the two axes interpreted as A_s and A_t. Mechanically, this is accomplished by rotation, through a differential, of the complete head assembly and driving of the prism on its mount. A differential gearing system enables independent positioning of A_s and A_t. The independent positioning enables the LOS established through the prism to traverse within the following limits: zero degrees (parallel to shaft axis) to ±60 degrees at A_t elevation, unlimited 360 degrees in A_s. When the SCT is slaved to the SXT, rotation is limited to 270 degrees due to limit stops along the SXT shaft axis. Due to obstructions created by aperture limitation

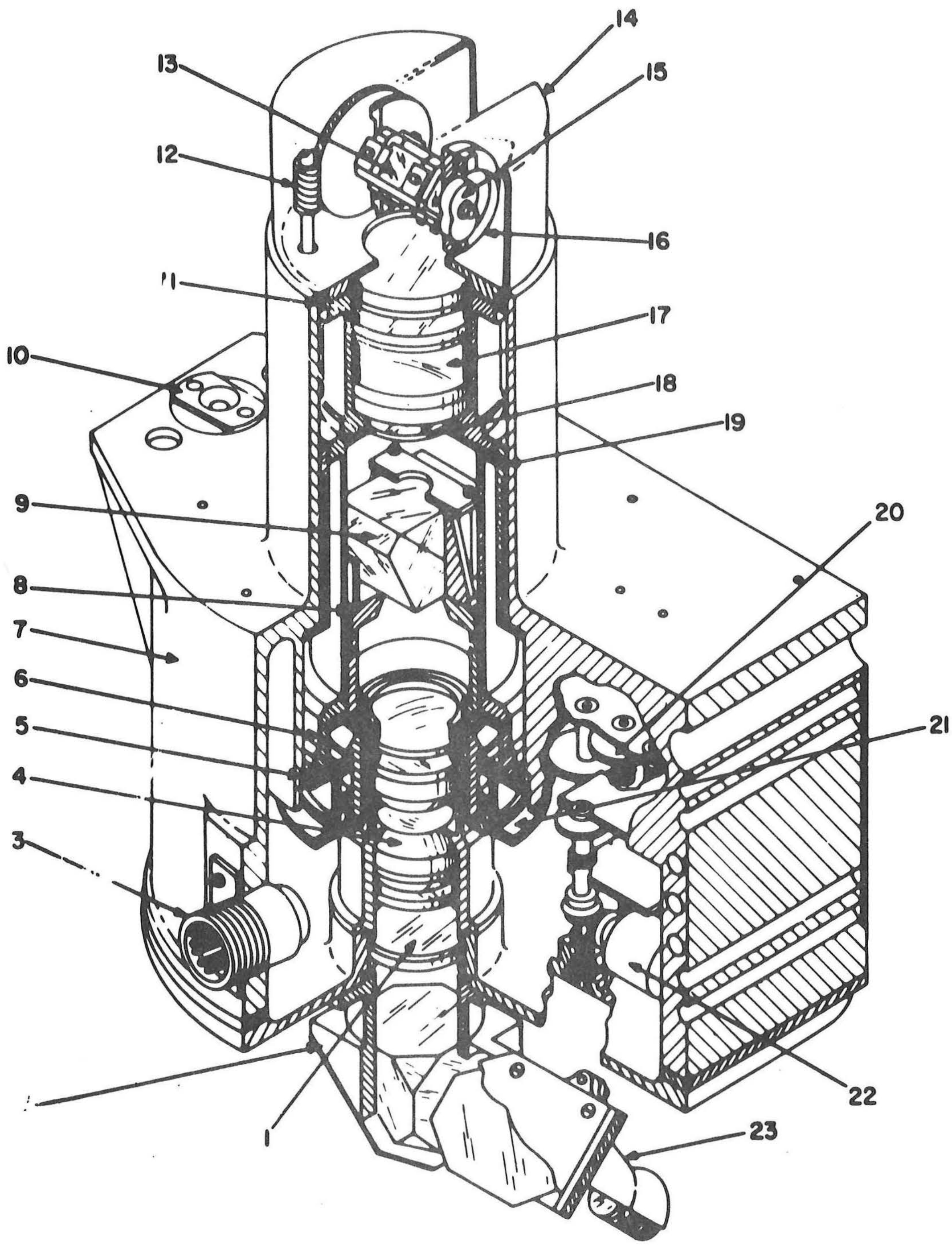


Fig. 2-19. Scanning Telescope (Sheet 1 of 2)

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

Fig. 2-19. Scanning Telescope (Sheet 2 of 2) in the spacecraft heat shield, the LOS along the trunnion axis has a useful range of approximately 45 degrees. Therefore, the aggregate maximum field that can be viewed by rotating the trunnion and shaft within their respective limits is 90 degrees.

The optics hand controller controls the shaft and trunnion drive rates. The drive rates are integrated by SXT servos which position the SCT LOS. The shaft and trunnion angles can be read directly from the SCT by counters mounted in the face of the optical panel.

The SCT contains an optics head assembly, a rotatable outer telescope tube assembly, a stationary inner telescope tube assembly, an eyepiece prism housing assembly, and an adjustable focus eyepiece assembly. The optics head assembly contains a double dove prism and mount assembly, mount, support, cam-follower and spring assembly, and trunnion worm shaft. The outer telescope tube assembly contains the objective lens assembly and the reticle. A housing and lamp assembly, used to illuminate the SCT reticle, is mounted in the optical base around the outer telescope tube assembly. The inner telescope tube assembly contains a pechan prism and relay lens assembly. Contained within the eyepiece prism housing assembly are two right-angle prisms. The adjustable focus eyepiece assembly contains an objective lens assembly. The objective lens assembly and reticle in the outer telescope tube assembly and the pechan prism and part of the relay lens assembly in the inner telescope tube assembly form the optical complex of a minus 4.6-power telescope. The portion of the relay lens assembly in the inner telescope tube assembly, the eyepiece prism housing assembly, and the adjustable focus eyepiece assembly form the optical complex of a plus 4.6-power telescope.

2.2.1.1 SCT Optics

The SCT optics (Fig. 2-20) consists of a double dove prism, a minus 4.6-power telescope, and a plus 4.6-power telescope.

2.2.1.1.1 Double Dove Prism. The double dove prism contains two optically matched dove prisms. The prisms are aluminized and cemented together at the hypotenuse and accurately positioned and clamped to a mount. The double dove prism is the first optical element in the SCT optics to pick up the target image. Each dove prism inverts and transmits an image to the objective lens assembly. Optically the prism functions as a compact, wide-angle mirror that is rotatable about two axes, trunnion and shaft. The rotational limitations of the prism about the trunnion axis are from -5 to +50 degrees. At zero degrees, the reflective surface of the prism is parallel to the shaft axis and to the selected target LOS, when the selected target is centered on the reticle crosshairs. The images of the targets pass through the angular entrance face of the prism, are refracted toward the prism's reflective surface, and are reflected off the prism's mirrored surface at the angle at which they were received, toward the exit face of the prism. At the angular exit face, the images are refracted again and the now inverted image is transmitted parallel to the shaft axis. When the prism is rotated about the trunnion axis, the selected target increases in angular position to the prism's reflective surface. With an increase in angular position of the selected target, the images entering the prism become increasingly inclined to the prism's angular face. As the images entering the prism increase in inclination to the angular face, the degree of refraction caused by the prism decreases until, at perpendicularity, there is no refraction. However, in use, the prism field-of-view is

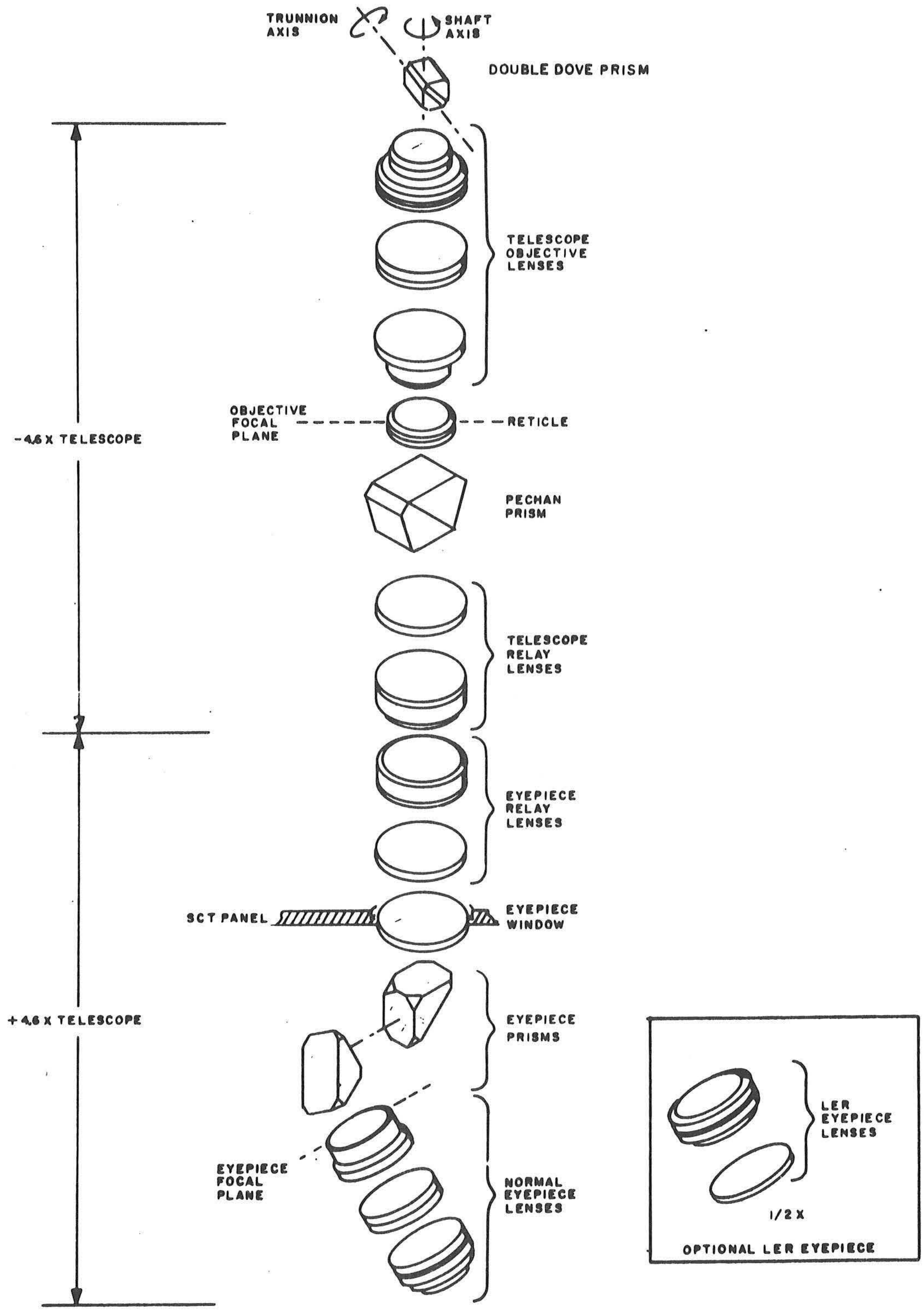


Fig. 2-20. SCT Optical Diagram

limited by the SCT head assembly, the command module optics opening, and the size of the objective lens. These limitations restrict the useful field-of-view to 45 degrees and the conic scan to 90 degrees. At all useful positions of the prism, the images reflected off the mirrored surface of the prism are transmitted parallel to the shaft axis by the objective lens assembly.

A worm gear and worm shaft drive the double dove prism and mount. The worm shaft is driven by a motor generator in the SCT trunnion drive gearbox. An angle counter, seen through the SCT panel window, displays the trunnion angle and is mounted in the trunnion drive gearbox.

2.2.1.1.2 Minus 4.6-Power Telescope. The minus 4.6-power telescope consists of an objective lens assembly, reticle, pechan prism, and part of the relay lens assembly. (See Fig. 2-20.)

The objective lens assembly consists of three cemented doublets, made up of a positive and negative lens, fitted into the upper end of the outer telescope tube assembly. This objective cluster collects light from the double dove prism and produces an image at the reticle plane.

The reticle (Fig. 2-21) is adjacent to the objective lens assembly and is accurately positioned in the focal plane of the objective lens assembly. The inverted images transmitted by the objective lens assembly are focused onto the reticle. The reticle crosshair intersection is the reference target for the image transmitted from the double dove prism and objective lens assembly.

The reticle is lighted from the edge by four incandescent lamps located in the housing and lamp assembly.

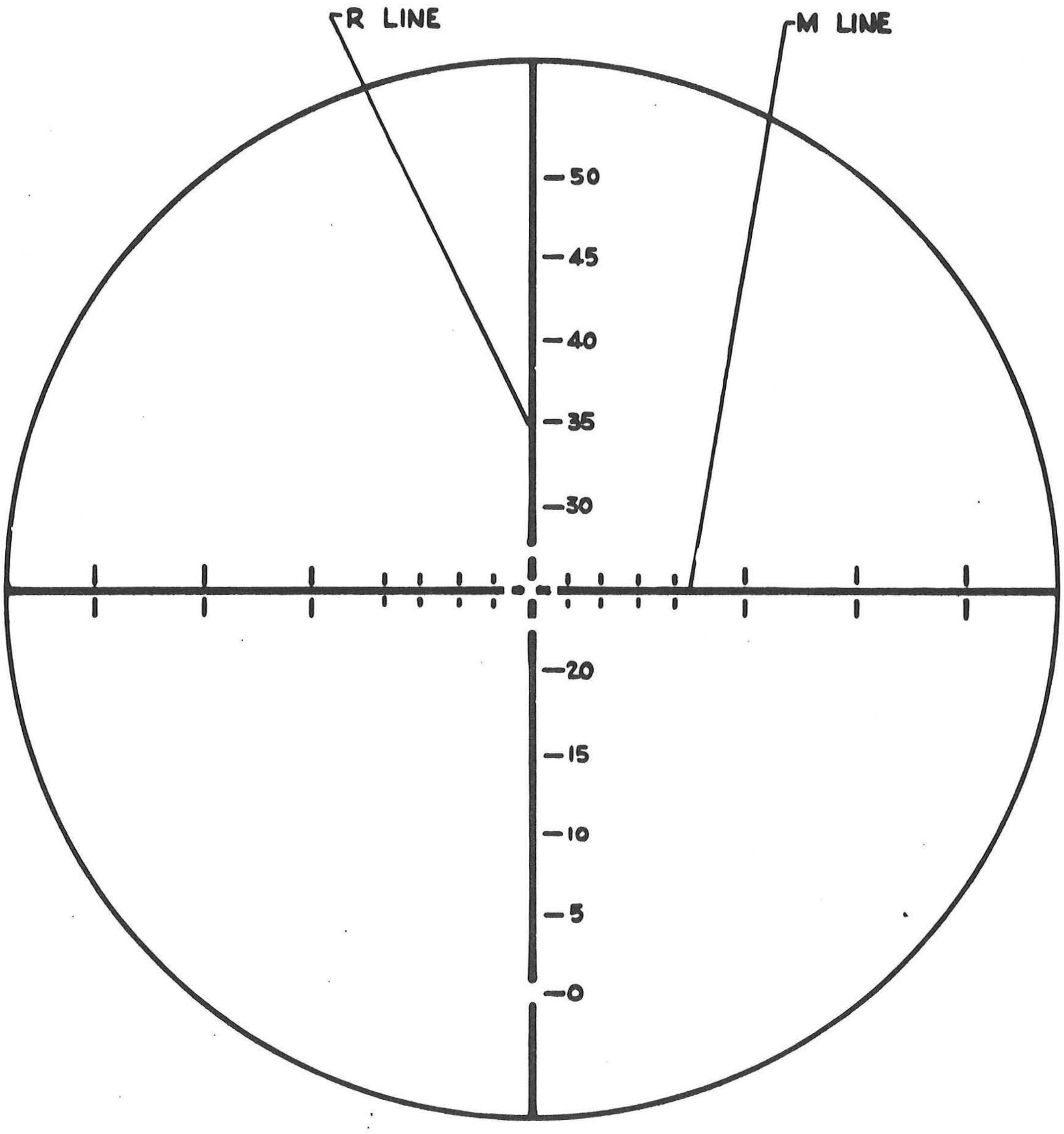


Fig. 2-21. SCT Reticle Pattern.

The pechan prism erects the inverted images. The prism is in the optical path between the reticle and the relay lens assembly. The pechan prism consists of two sections separated by an air space. This design achieves the erecting of the images and increases the axial length of the optical path and decreases the physical length of the SCT.

The relay lens assembly consists of a group of relay lenses fastened to the end of the inner telescope tube assembly opposite the end holding the pechan prism. The relay lenses receive the erected image from the pechan prism and transfer it without distortion to the relay lenses of the plus 4.6-power telescope.

2.2.1.1.3 Plus 4.6-Power Telescope. The plus 4.6-power telescope consists of part of the relay lens assembly, an eyepiece window, an eyepiece prism assembly, and an adjustable focus eyepiece. (See Fig. 2-20.)

The relay lenses receive the images transmitted by the minus 4.6-power telescope relay lenses and transfer them through the eyepiece window to the eyepiece prism assembly.

The eyepiece window acts as a seal between the eyepiece prism assembly and SCT components exposed to environmental conditions outside the command module. The eyepiece window has no optical effect and transmits the image directly from the relay lens assembly to the SCT eyepiece prism assembly.

The eyepiece prism assembly is fastened to the front of the SCT panel assembly. It transfers the image from the relay lens assembly to the eye of the observer. The eyepiece prism assembly contains two right-angle prisms, one small and one large. The small prism is mounted in-line with the shaft axis and receives the images from the relay lens assembly and reflects the images 90 degrees into the large prism. The large prism is mounted in a manner that corrects for this 90 degree image orientation by reflecting the images 90 degrees into the adjustable focus eyepiece parallel to the SCT shaft axis. The prism mountings enable the adjustable focus eyepiece to be mounted in a position that provides the astronaut with the most viewing comfort. Enlarged thumb screws are provided which allow the astronaut to quickly disconnect and remove the prism assembly while wearing gloves.

The adjustable focus eyepiece is mounted to the eyepiece prism assembly. This assembly contains three telescope objective lens doublets, heater, thermostat, insulation, and connector. The objective lenses are optically identical to the minus 4.6-power telescope objective lenses. The heater, thermostat, and insulation maintain the adjustable focus eyepiece assembly at a constant temperature to prevent moisture condensation on the eyepiece components. Heater current is provided through the connector when connected to the harness plug on the eyepiece storage unit. Focus adjustment compensates for astronaut sight differences and enlarged thumb screws allow the astronaut to quickly disconnect and remove the adjustable focus eyepiece assembly while wearing gloves.

A SCT eyeguard is fastened to the end of the eyepiece and is adjustable in an axial direction to allow for differences in facial contours of the astronauts.

The SCT long eye relief (LER) can replace the SCT adjustable focus eyepiece for use while wearing a helmet. It contains a lens assembly, a positive lens, heater, thermostat, insulation, and connector mounted into a SCT eyepiece housing.

2.2.1.1.4 SCT Optics Light Transmittance. The optical efficiency of the SCT allows 38 $\pm$ 1 percent of the light impinging on the double dove prism to be transmitted to the eyepiece. Light losses in the SCT are held to a minimum by the use of multiple anti-reflection coatings which increase the efficiency of all transmitting surfaces.

2.2.1.2 SCT Mechanical Drive

The single speed SCT obtains rotational drive about shaft and trunnion axes through two motor generators, one for each axis. Reduction gearing, motor generators, resolvers, and angle counters for shaft and trunnion axes are assembled in two separate gearboxes located in the optical base.

SCT shaft and trunnion axis drives are linked by a differential gear assembly. The differential gear assembly permits trunnion axis positioning independent of shaft axis, and shaft axis rotation without introducing errors in the trunnion axis. The A_s trunnion drive gear and the trunnion positioning planetary gearing system are pinned to the differential drive shaft, while the A_t trunnion drive gear and the trunnion positioning gear can rotate about the differential drive shaft. The SCT shaft axis drive motor restricts rotation of the A_s trunnion drive gear and the trunnion positioning planetary system then permits the trunnion positioning gear to rotate about the differential drive shaft when the A_t trunnion drive gear is rotated (SCT trunnion axis positioning). Likewise, the SCT trunnion axis drive motor restricts rotation of the A_t trunnion drive gear and the trunnion positioning planetary system then permits the trunnion position gear to rotate with the differential drive shaft when the A_s trunnion drive gear is rotated (SCT shaft axis positioning).

Two identical counters displaying SCT shaft and trunnion axis angles are located in the optical base. The counters are viewed through lighted bezel windows in the SCT panel. A flip-up counter shade is geared to the drums to permit continuous numerical display. The counter is calibrated to display readouts from 0 to 359.98 degrees with graduations in 0.02 degree increments. Counter rotation is continuous in either direction. One revolution of the counter input shaft results in a one degree change in counter indication.

2.2.1.3 SCT Servo Loops

Shaft and trunnion servo loops are used to position the SCT. The shaft and trunnion servo loops function as single speed repeater servos. Trunnion servo loop operation is determined by mode switching.

2.2.1.3.1 SCT Shaft Servo Loop. A single speed positioning servo loop (Fig. 2-22) is used to rotate the SCT optics about the shaft axis. The electrical input to the SCT shaft 1X resolver is the sine-cosine output signal from the SXT shaft 1X resolver in the SXT shaft servo loop. The SXT shaft 1X resolver generates an error signal proportional to the mechanical rotor displacement from electrical null. The SCT resolver error signal is applied to the MDA summing network. Feedback from the motor-generator is applied through a feedback compensation network of the MDA summing network. The amplifier circuit generates the motor drive signals in the phase and magnitude required to drive the rotor of the SCT shaft 1X resolver to null and to position the SCT shaft at a new angle. The SCT shaft movement is thus slaved to SXT shaft movement.

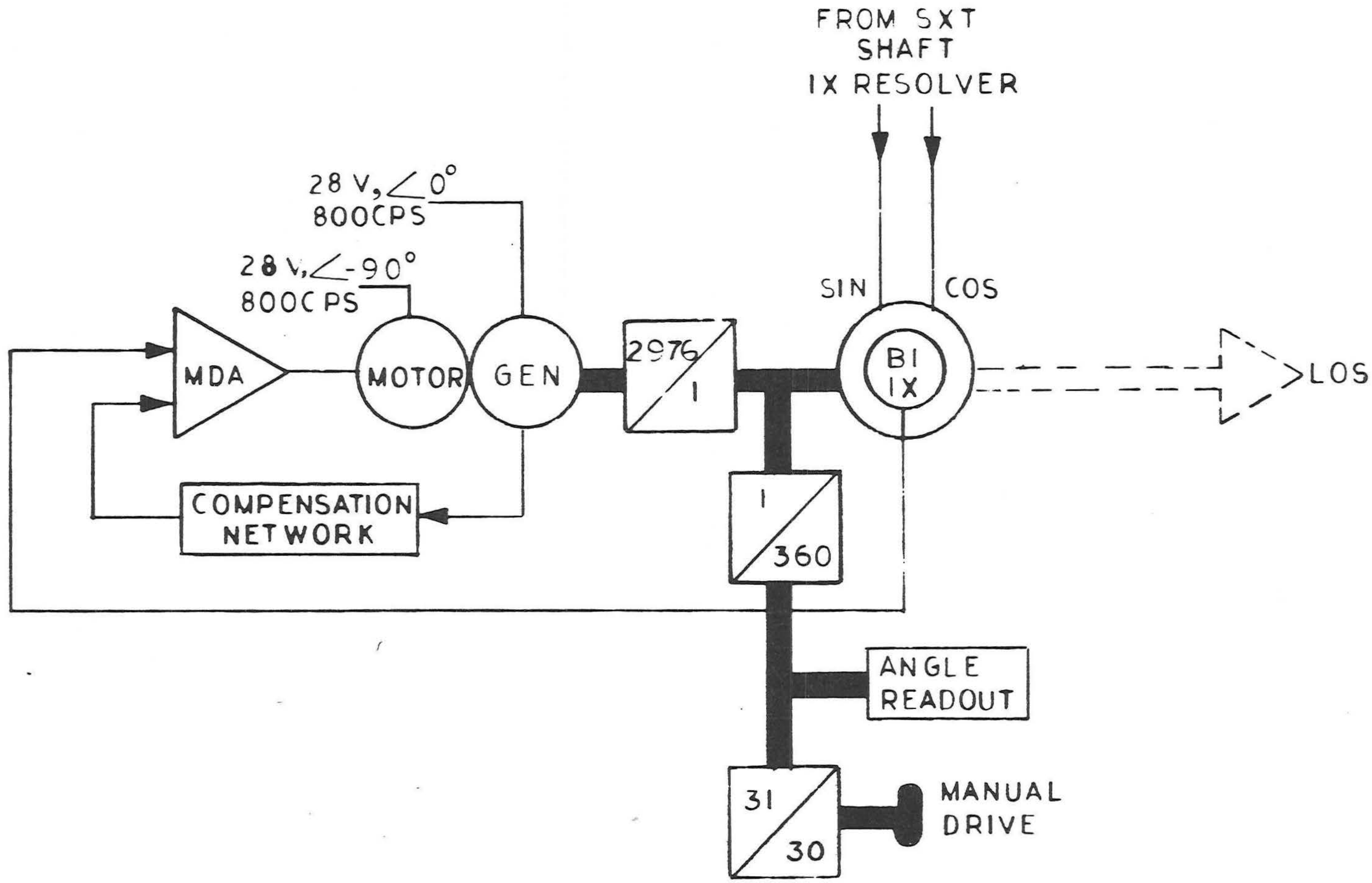


Fig. 2-22. SCT Shaft Servo Loop

2.2.1.3.2 SCT Trunnion Servo Loop. Rotation of the double dove prism and mount assembly about the trunnion axis is controlled by the SCT trunnion servo loop (Fig. 2-23). This servo functions as a single speed, positioning servo. The SCT trunnion 1X resolver generates an error signal proportional to the mechanical rotor displacement from electrical null. The electrical input to the SCT trunnion resolver is determined by the configuration of the SCT trunnion relays, K2, K3, and K4. These relays are controlled by the position of the TEL TRUN switch.

When the TEL TRUN switch is in the 0° position, the 0° and SLAVE relays, K2 and K4, are energized. This disconnects the input sine-cosine signals from the SXT trunnion 1X resolver; applies a fixed 28 volt, 800 cps, 0 phase reference signal to the sine winding of the SCT trunnion 1X resolver; and shorts out the cosine winding to establish a zero electrical reference.

When the TEL TRUN switch is in the 25° position, the 25° and SLAVE relays, K2 and K3, are energized. This disconnects the input sine-cosine signals from the SXT trunnion 1X resolver; applies a fixed 28 volt, 800 cps, 0 phase reference signal to the sine winding of the SCT trunnion 1X resolver; and applies a fixed reference voltage from the secondary of a transformer to the cosine winding to establish an electrical reference which causes the SCT to move to a fixed 25° trunnion angle offset.

When the TEL TRUN switch is in the SLAVE to SXT position, relays K2, K3,and K4 are all deenergized to connect the sine and cosine windings of the SXT trunnion resolver transmitter to the sine and cosine windings of the SCT trunnion 1X resolver.

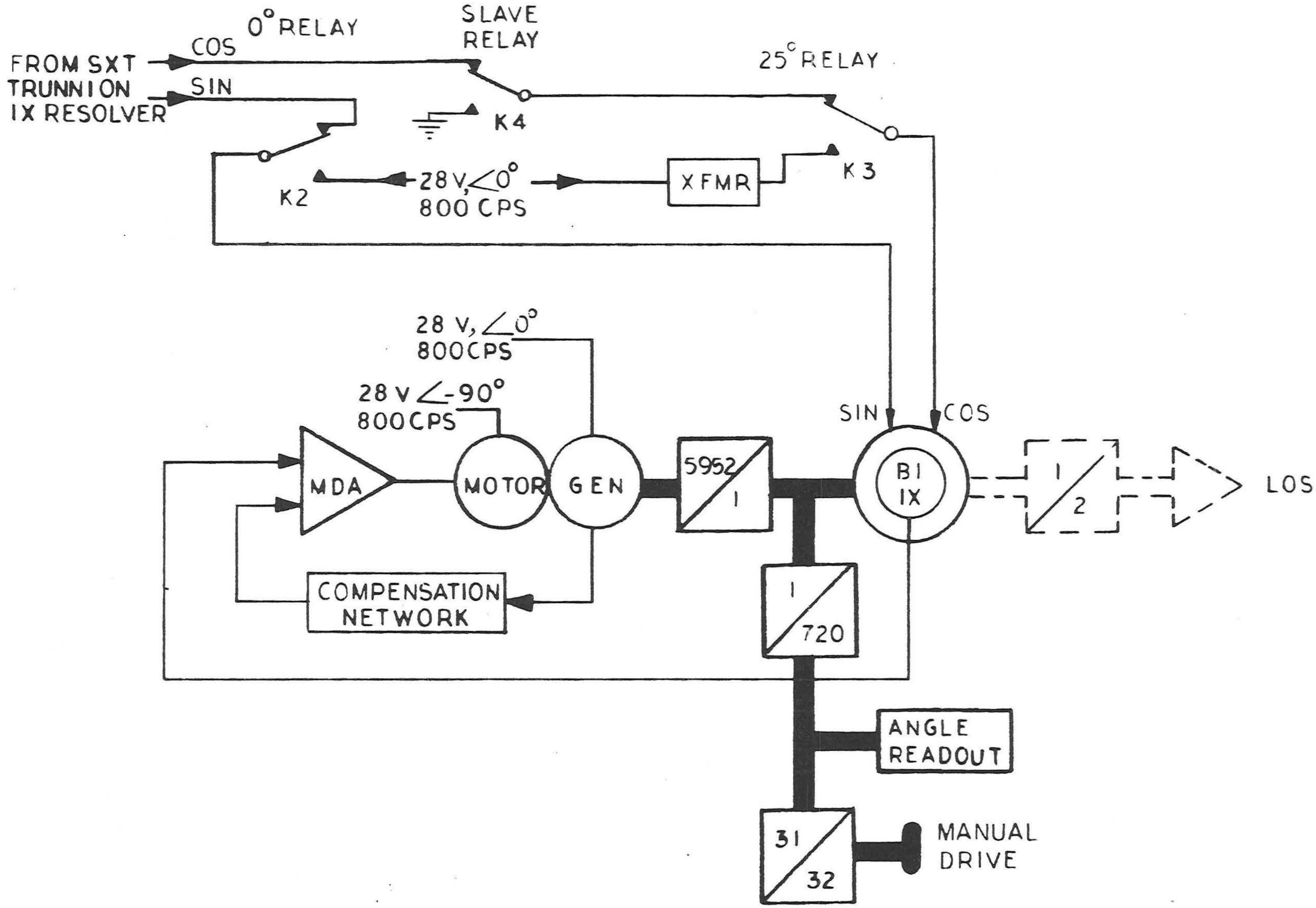


Fig. 2-23. SCT Trunnion Servo Loop

The error signal from the SCT trunnion 1X resolver is applied to the MDA summing network. The feedback from the motor-generator is also applied to the MDA summing network. The amplifier circuit generates the motor drive signals in the phase and magnitude required to drive the rotor of the SCT trunnion 1X resolver to a null and to position the SCT trunnion at a new angle.

2.2.2 Sextant

The SXT is a highly accurate, dual LOS, electro-optical instrument with 28 power magnification and 1.8 degrees field of view. It is capable of sighting two celestial targets simultaneously and measuring the angle between them with 10 arc seconds accuracy. One LOS, called landmark LOS (LLOS) is fixed along the shaft axis normal to the local conical surface of the spacecraft. The LLOS is positioned by changes in spacecraft attitude. The other LOS, called star LOS (SLOS), has two degrees of rotational freedom about the shaft and trunnion axes. Variation about the trunnion axis is represented by movement of an indexing mirror. SLOS positioning is controlled by electromechanical integration loops consisting of servos, tachometers, and associated electronics. The SLOS movement is independent of the fixed LLOS. Measurements are made by first sighting into the SXT eyepiece and adjusting spacecraft attitude until the LLOS image is centered on the SXT reticle. Subsequent positioning of the SLOS to locate the star image coincident with the LLOS is done to satisfy requirements necessary for measurements to be taken between the two images. (Coincidence must be as near the reticle center as possible.) Positioning accuracies of the SXT trunnion and shaft axes are within 10 and 40 arc seconds, respectively.

The SXT is divided into the index head assembly and the base section. (See Fig. 2-24.) The SXT index head assembly contains the indexing mirror, SXT right angle mirrors, beam splitter, and trunnion drive electromechanical components.

The SXT portion of the optical base contains the shaft axis assembly, shaft drive electromechanical components (motor-generator, shaft drive gearbox, and resolvers), and SXT eyepiece. Rotating components, mounted on the shaft axis assembly include the SXT telescope tube assembly (with objective and intermediate lens), the SXT reticle, and the shaft resolver rotors. The SXT panel assembly covers the underside (face) of the optical base. This assembly contains the eyepiece window and has provision for mounting the SXT mirror housing and eyepiece assembly.

2.2.2.1 <u>SXT Optics</u>

The SXT optics consists of SXT indexing mirror, right angle mirrors, beam splitter, SXT telescope lenses, and eyepiece assembly.

2.2.2.1.1 <u>Indexing Mirror</u>. The SXT indexing mirror (Fig. 2-25) is used to pick up and direct a target star image onto the right angle mirrors. The indexing mirror is mounted on the sextant head and rotates in the trunnion axis. For every one degree of indexing mirror movement, the SLOS moves two degrees.

2.2.2.1.2 <u>Right Angle Mirrors</u>. Two mirrors (Fig. 2-25) are fixed at right angles to each other. They are used to reflect the star image, from the indexing mirror, onto the reflecting surface on the underside of the beam splitter.

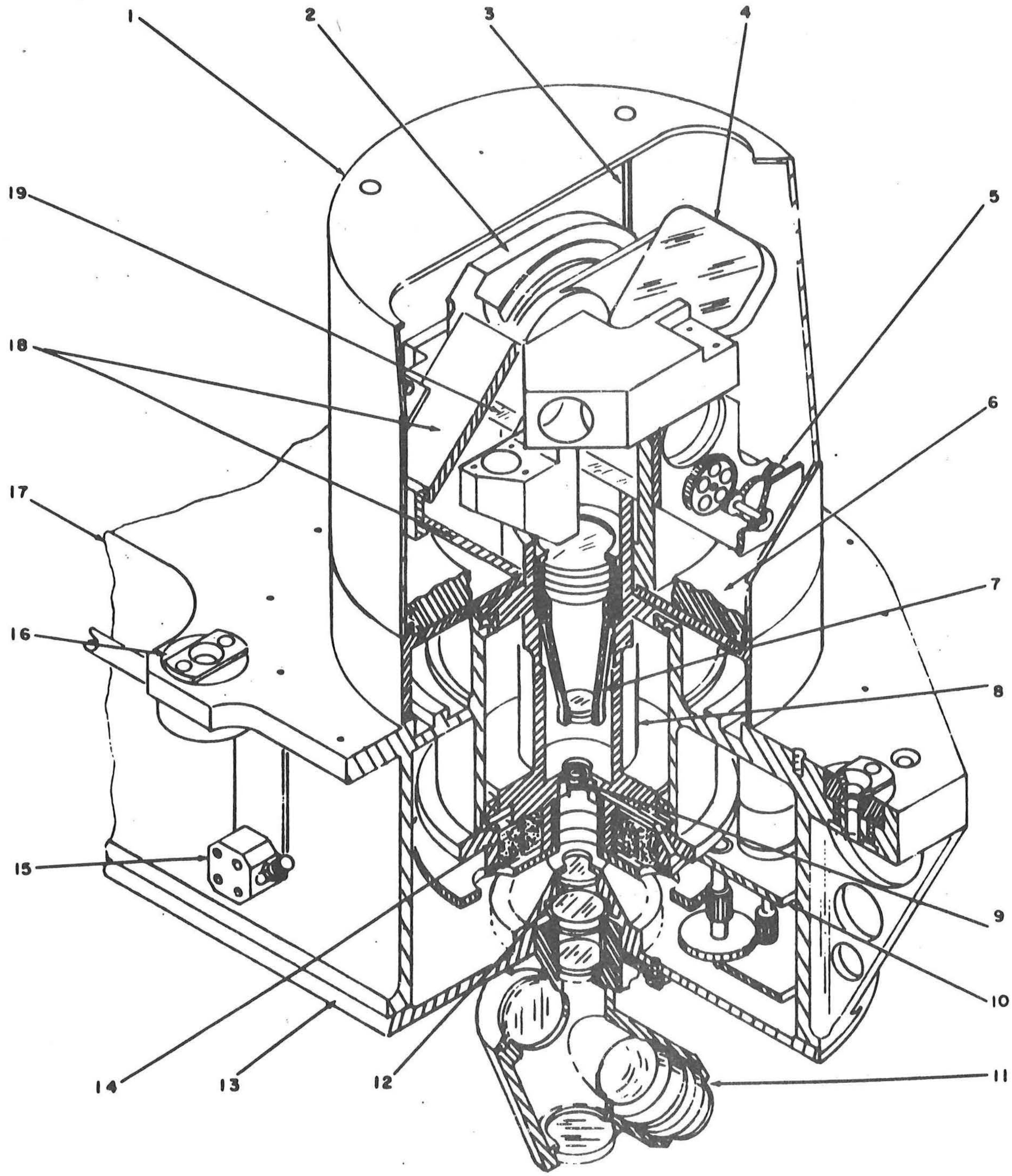


Fig. 2-24. Sextant (Sheet 1 of 2)

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

Fig. 2-24. Sextant (Sheet 2 of 2)

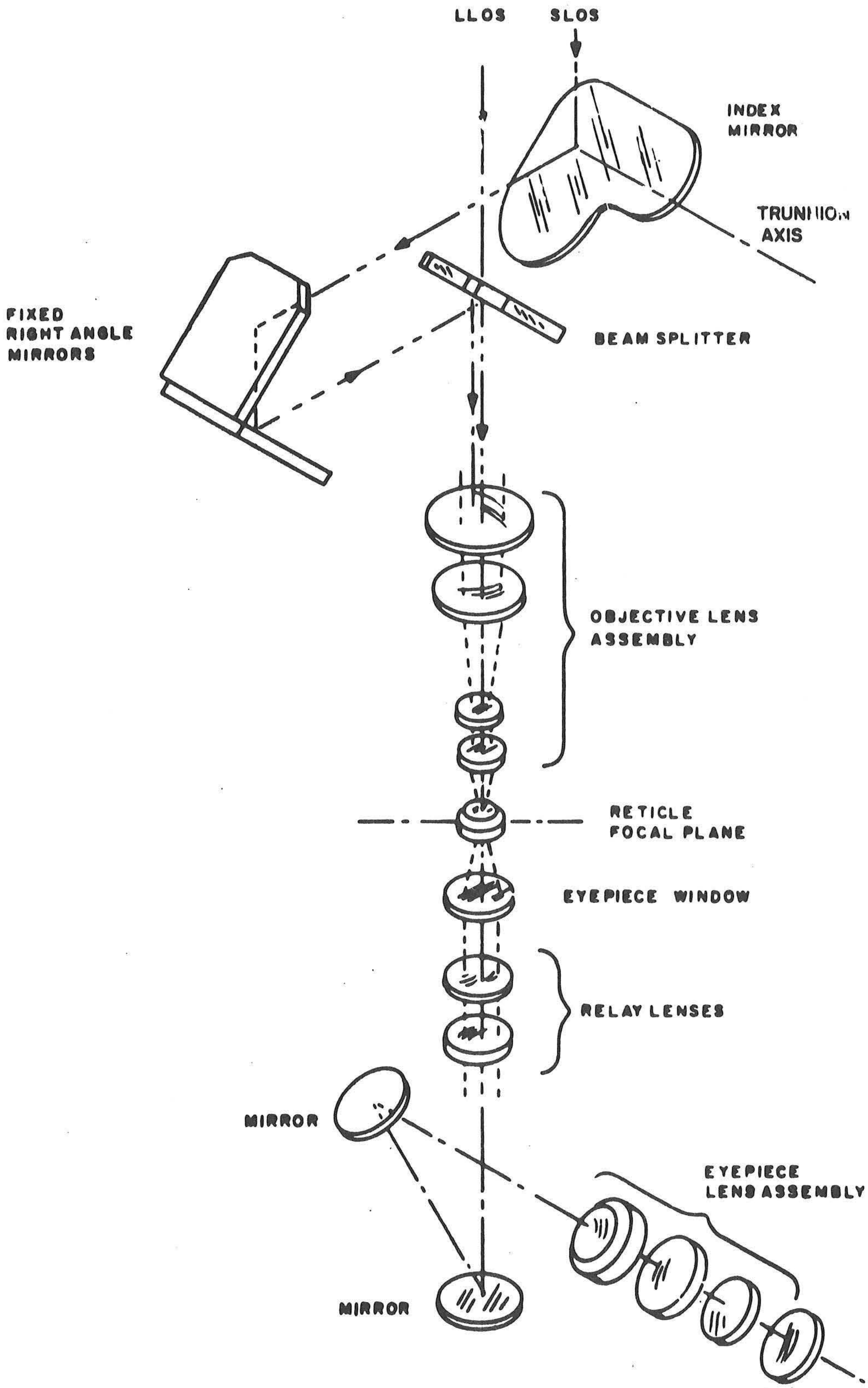


Fig. 2-25. SXT Optical Diagram

2.2.2.1.3 Beam Splitter. The SXT optics provides two distinct lines of sight with different degrees of light transmission for two simultaneously viewed images. This capability is provided by the beam splitter (Fig. 2-25). The beam splitter is more properly termed a beam combiner since its function is to reflect the SLOS into the same path as the transmitted LLOS.

The landmark image is brighter than the star image, therefore it is necessary to transmit the image intensities at different levels to keep the landmark image from obscuring the star image. The beam splitter provides the required variations in transmission by its surface reflectivity characteristics.

2.2.2.1.4 SXT Telescope Optical Complex. The SXT telescope optical complex (Fig. 2-25) consists of an objective lens, the intermediate lens, and reticle. A triplet and a single lens form the objective lens assembly at the upper end of the lens holder. The intermediate lenses are mounted at the lower end of the lens holder assembly. The objective and intermediate lens assemblies form a telephoto type lens system. The reticle (Fig. 2-26) is positioned in the forward vacuum focal plane of the SXT optics. This position provides optimum focus of the reticle vacuum pattern etched on the forward face of the reticle assembly. When operating in the earth atmosphere, the reticle vacuum pattern becomes indistinct due to a shift in the focal plane of the SXT optics. An air pattern is etched on the rear face of the reticle and an air focusing shim is inserted between the SXT plate and eyepiece assemblies to compensate for the shift. The air focusing shim is removed prior to launch for vacuum operation of the SXT. The edge illumination of the SXT reticle is provided by four lamps which light three transmitting rods spaced evenly

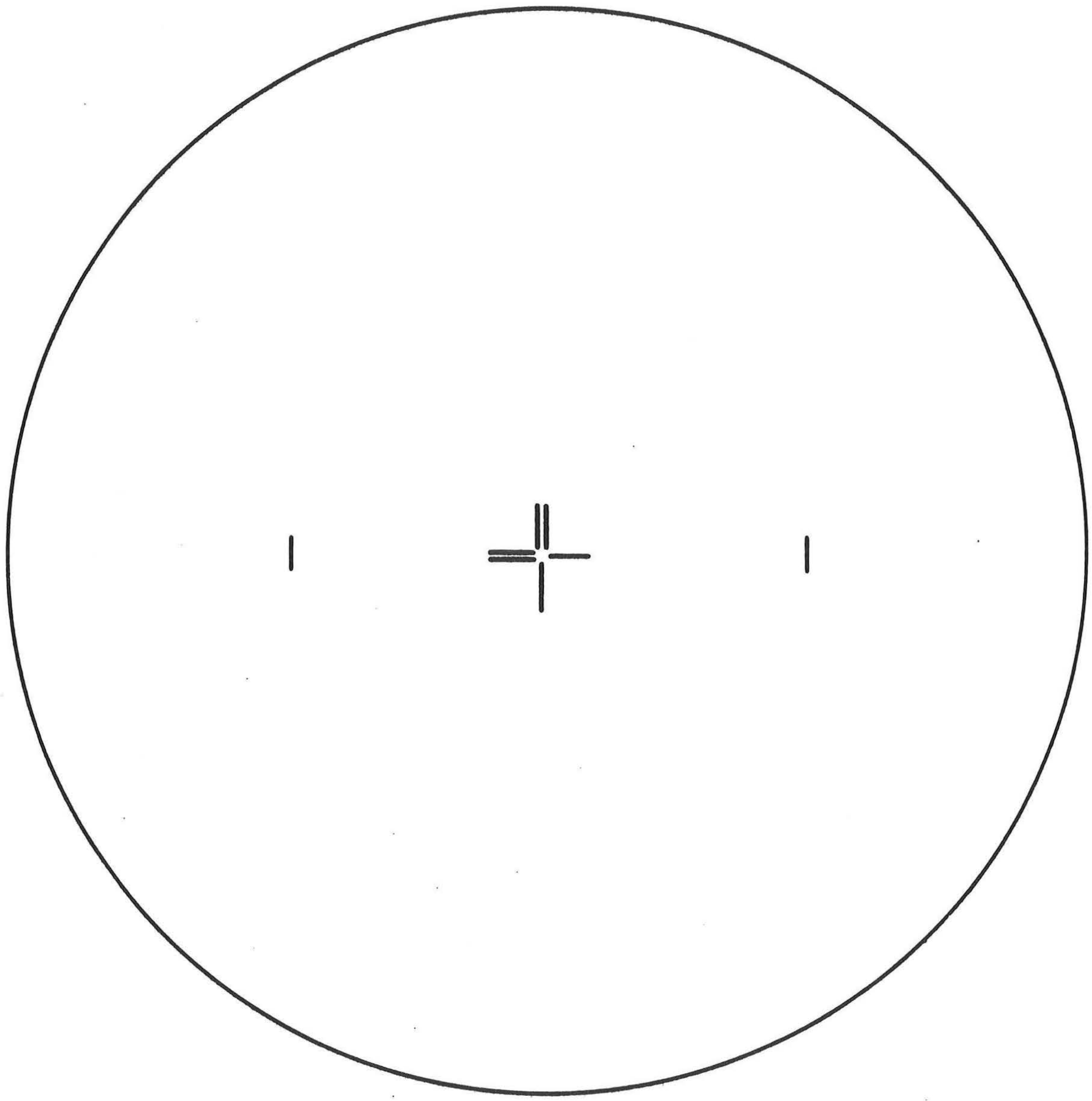


Fig. 2-26. SXT Reticle Pattern.

around the reticle. The eyepiece window serves as a seal in the SXT panel. The SXT eyepiece window is similar in function to the SCT eyepiece window.

2.2.2.1.5 Mirror Housing and Eyepiece. The SXT mirror housing and eyepiece assembly consists of the mirror housing and heater assembly, and the eyepiece assembly. Enlarged thumb screws allow the astronaut to quickly disconnect and remove the SXT mirror housing and eyepiece assembly while wearing gloves.

The mirror housing and heater assembly (Fig. 2-25) consists of the relay lens assembly, two mirrors, heater, thermostat, insulation, and connector. The relay assembly contains two lens doublets which relay the image to the primary of the two mirrors. The mirrors reduce the length of the system and transfer the image into the eyepiece assembly. The heater, thermostat, and insulation maintain the SXT mirror housing and heater assembly along with the attached eyepiece assembly at a constant temperature to prevent moisture from condensing on components. Heater current is provided through the connector when connected to the harness plug on the eyepiece storage unit.

The SXT eyepiece contains two lens doublets, a single lens, and an adjustable polaroid filter. The polaroid filter provides landmark (LLOS) image brightness adjustment without affecting star image (SLOS).

In effect, the SXT eyepiece assembly represents a telemicroscope of 0.34 inch focal length and contributes to the SXT 28 power magnification by providing 3.4 power magnification from the relay assembly. Focal length of the eyepiece equals one inch, which results in a total magnification of 28 power.

A SXT eyeguard, fastened to the SXT eyepiece, adjustable in an axial direction, allows for differences in facial contours of the astronauts.

2.2.2.1.6 <u>SXT Optics Light Transmittance</u>. When a beam of light passes from one medium to a different medium, the intensity will decrease. This loss of intensity is due mainly to absorption. With respect to the SXT SLOS, incident light impinging on and emerging from the trunnion mirror is reduced by a factor of approximately 4 percent. The resulting 96 percent is passed on to the first fixed mirror, which causes a further reduction of 4 percent passing on 92 percent of the light to the second fixed mirror. The second fixed mirror further reduces transmitted light by 4 percent, leaving approximately 88 percent to be reflected by the beam splitter. The beam splitter will reflect approximately 82 percent of the light principally in the shorter wavelength of the visible spectrum. Light loss in the objective lens assembly and through the eyepiece results in total light transmissions of approximately 25 percent for the SLOS.

The total light losses in the LLOS amount to approximately 97 percent, with 89 percent occurring at the beam splitter. The remaining 11 percent emerging from the beam splitter is further attenuated through the objective and eyepiece assemblies. This results in an overall transmittance of 3.2 percent.

2.2.2.2 <u>SXT Mechanical Drive</u>

The SXT obtains rotational movement about shaft and trunnion axes through two motor generators. Reduction gearing, motor generators, and resolvers are contained in two separate gearboxes. One is located in the optical base; the other is located in the index head assembly.

In trunnion axis, positioning of the indexing mirror is restricted mechanically to a range of -5 to +50 degrees through the use of a limit stop.

2.2.2.3 SXT Servo Loops

Shaft and trunnion loops are used to position the SXT. Either loop may function as a two-speed positioning servo or as an integrating servo loop. The loop function is determined by mode switching.

2.2.2.3.1 SXT Shaft Servo Loop. Rotation of the SXT index head about the shaft axis is controlled by the SXT shaft servo loop. This loop may function as either a precision two speed positioning servo loop or as an integrating servo loop. In manual and computer modes it is used as an integrating loop; in the zero optics mode the servo loop is set as a two speed positioning servo.

When the ZERO switch is placed in ZERO position, the two-speed switch, zero relay (K5), and auto-optics and zero relay (K7) are energized. (See Fig. 2-27.) The output of the secondary windings of the SXT 16X resolver (fine) and 1/2X resolver (coarse) are applied to the two-speed switch. Relay K5 disconnects the direct tachometer feedback from the MDA input summing network and applies it through the compensation network as required for the positioning servo configuration.

Relay K7 places the rate input to the MDA summing network at zero. Consequently, the error input to the servo is taken from the two speed switch and is proportional to the SXT shaft displacement from the zero electrical reference. The zero reference for 1/2X coarse resolver is obtained from the 28 volt, 800 cps stator excitation supply. The error reference for the 16X fine resolver is more precise and is established by the 28 volt, 800 cps rotor excitation. The two speed servo loop drives the SXT gear train into accurate alignment with the zero reference.

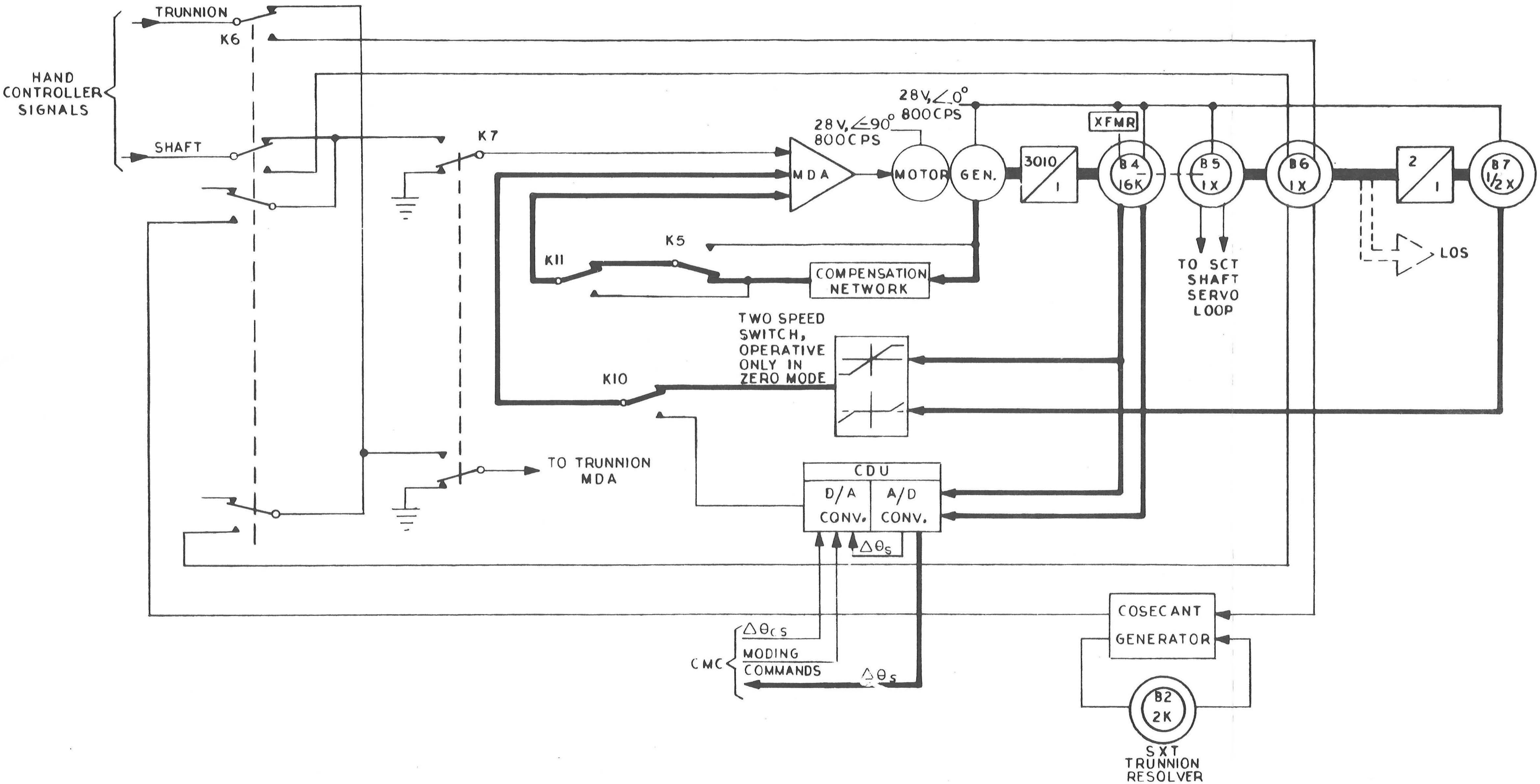


Fig. 2-27. SXT Shaft Zero Positioning Servo Loop

In system modes of operation, other than zero optics and CMC, relays K5 and K7 and the two speed switch are deenergized. This sets up the servo as an integrating loop and places the two speed inputs to the MDA summing network at zero. Deenergizing relay K7 removes the zero input to the MDA summing network and switches in the rate error. The rate error is obtained from one of two drive rate sources depending on mode switching.

When the system is in manual resolved mode (Fig. 2-28), the resolved mode relay (K6) is energized. The optics hand controller drive rate signal is applied through closed contacts of the relay to the SXT shaft 1X resolver. The output of the SXT shaft 1X resolver goes to the cosecant generator and, through relays K6 and K7, to the MDA summing network. The cosecant function generator output also goes to the 2X computing resolver in the SXT trunnion servo loop.

In the manual direct mode (Fig. 2-29), all the relays are deenergized. The source of the drive rate error signal then is the optics hand controller. The signal is fed through relays K6 and K7 to the MDA summing network.

In the computer mode (Fig. 2-30), the CMC mode relay (K10) is energized. This connects the CMC to the MDA summing network through the DAC in the CDU. Relay K7 disables manual control of the loop.

2.2.2.3.2 <u>SXT Trunnion Servo Loop</u>. Rotation of the SXT indexing mirror about the trunnion axis is controlled by the SXT trunnion servo loop. This servo is similar to the SXT shaft servo in that mode relays select a precise two speed positioning servo loop in the zero optics mode (Fig. 2-31) and an integrating servo loop in the remaining modes (Figs. 2-32, 2-33, and 2-34).

The same series of input relays switch the input to the MDA summing network from one of two sources: (1) the SXT trunnion hand controller during direct manual mode; (2) the resolved drive rate from the shaft 1X resolver during resolved manual mode. All relays are energized as explained previously.

SXT trunnion and shaft angles are obtained by interpreting displacement of the SXT indexing mirror about both axes. Two pancake resolvers, mechanically linked with the SXT indexing mirror and SXT head assembly, sense and transmit analog equivalents of SXT mirror displacements about trunnion and shaft axes.

2.2.3 OSS Moding

The OSS incorporates multiple modes of operation to facilitate the taking of precise measurements within short time increments. The specific mode selected effectively adapts the system to fit the needs of the astronaut under varying situations prior to sightings. The OSS operates in one of three prime modes and can be controlled in either of two control modes. Each is selected by switches on the indicator control panel. The modes are:

(1) Zero Optics

(2) Manual

- (a) 0°
- (b) 25°
- (c) Slave to SXT
- (d) Direct
- (e) Resolved

(3) Computer

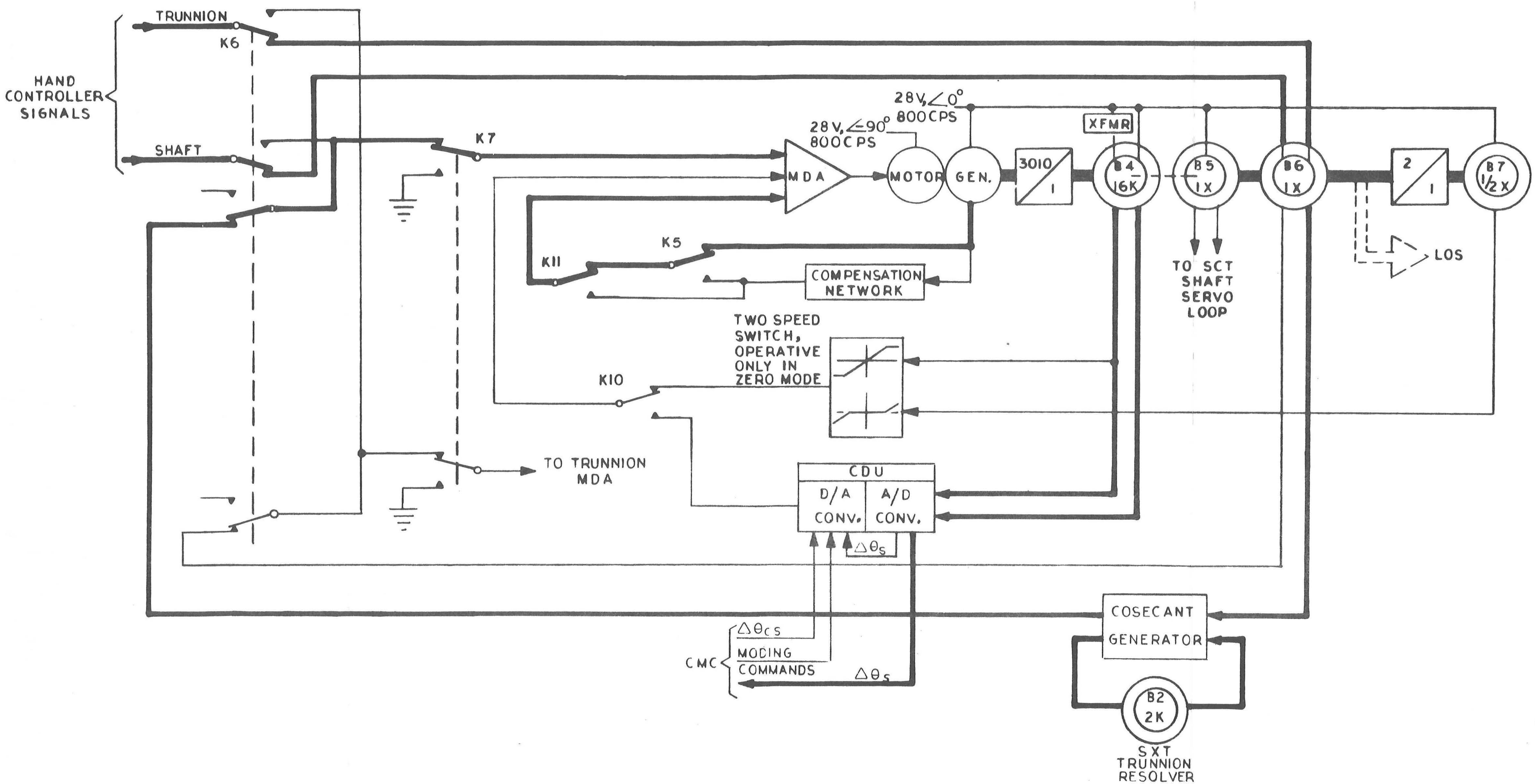


Fig. 2-28. SXT Shaft Resolved Mode Integrating Servo Loop

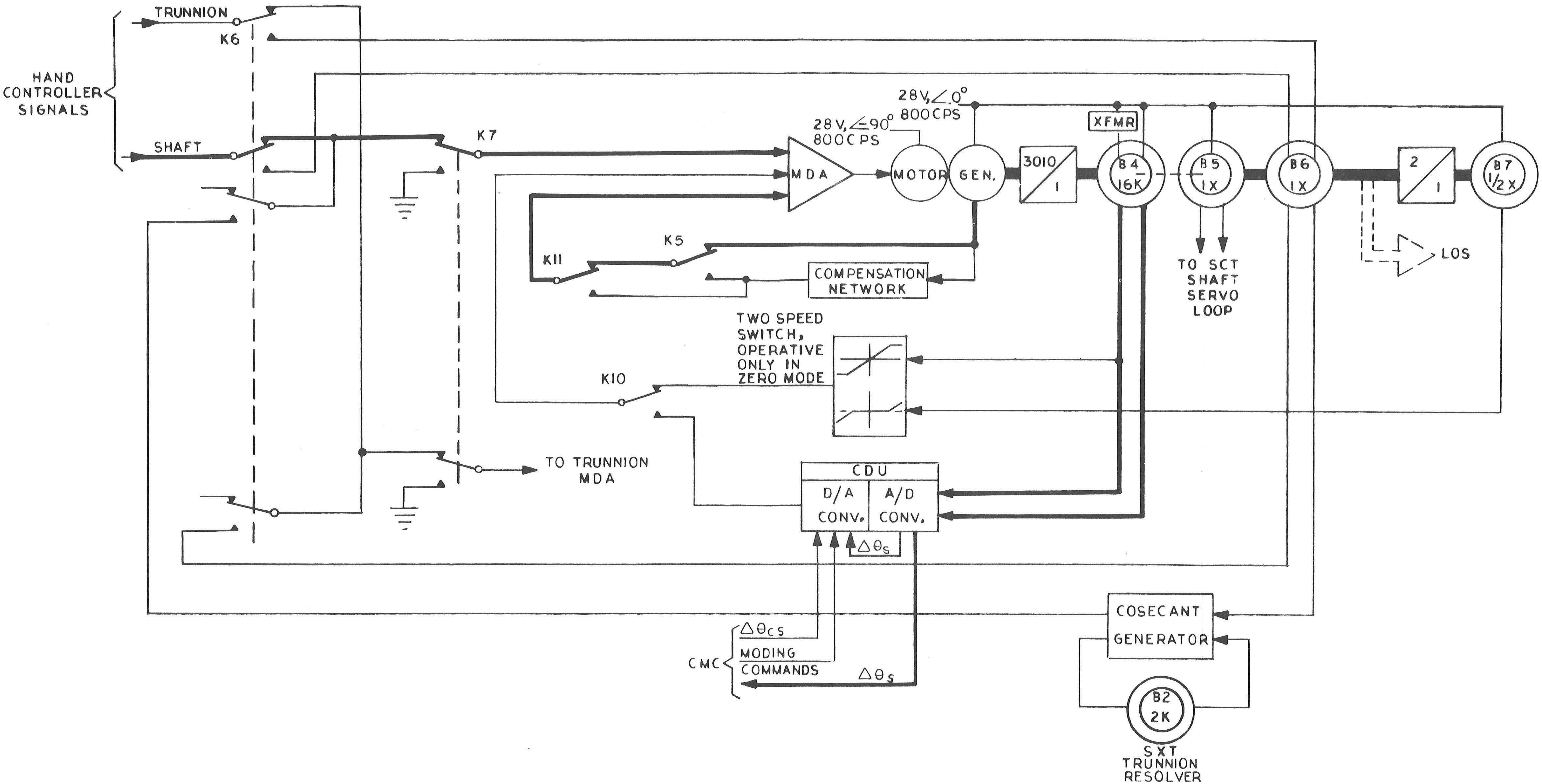


Fig. 2-29. SXT Shaft Direct Mode Integrating Servo Loop

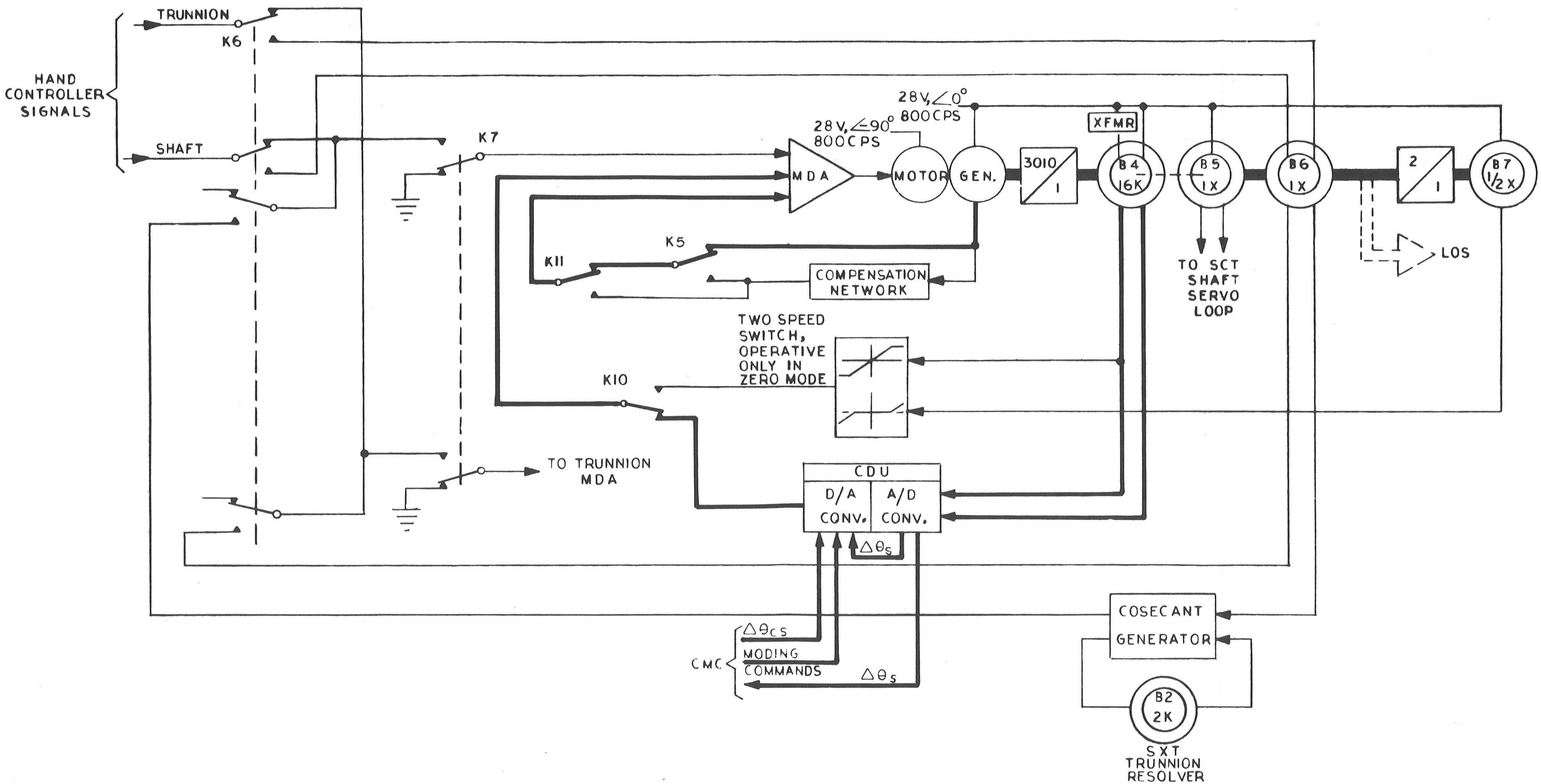


Fig. 2-30. SXT Shaft Computer Mode Integrating Servo Loop

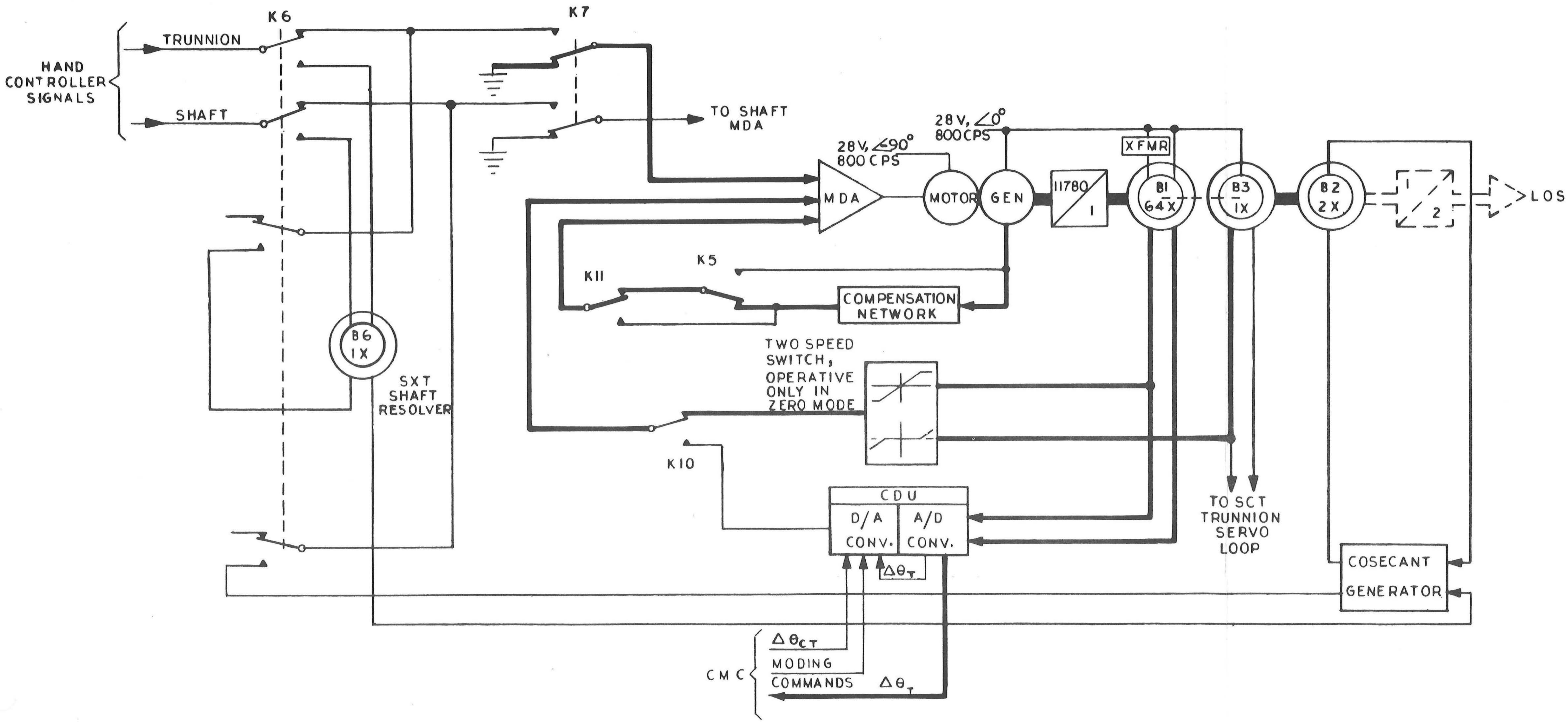


Fig. 2-31. SXT Trunnion Zero Positioning Servo Loop

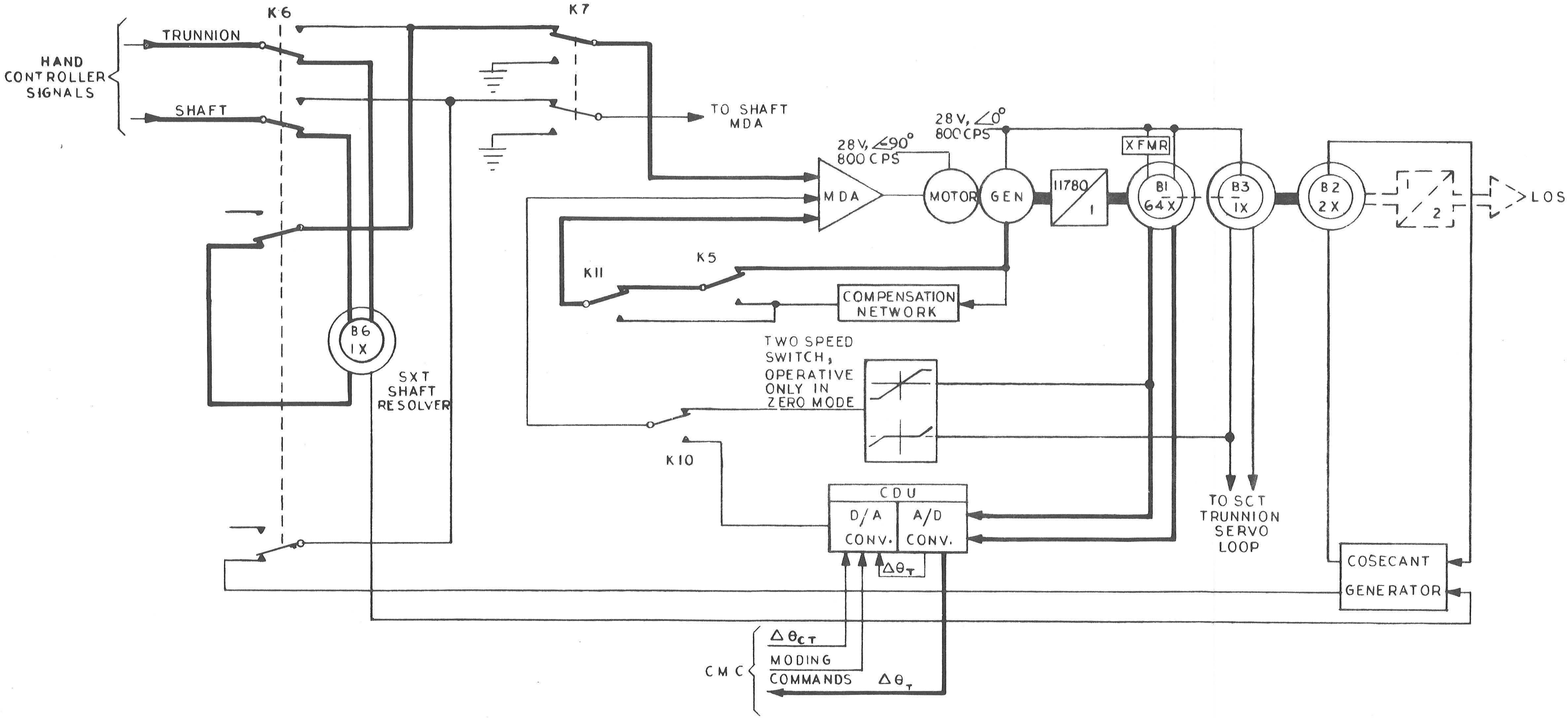


Fig. 2-32. SXT Trunnion Resolved Mode Integrating Servo Loop

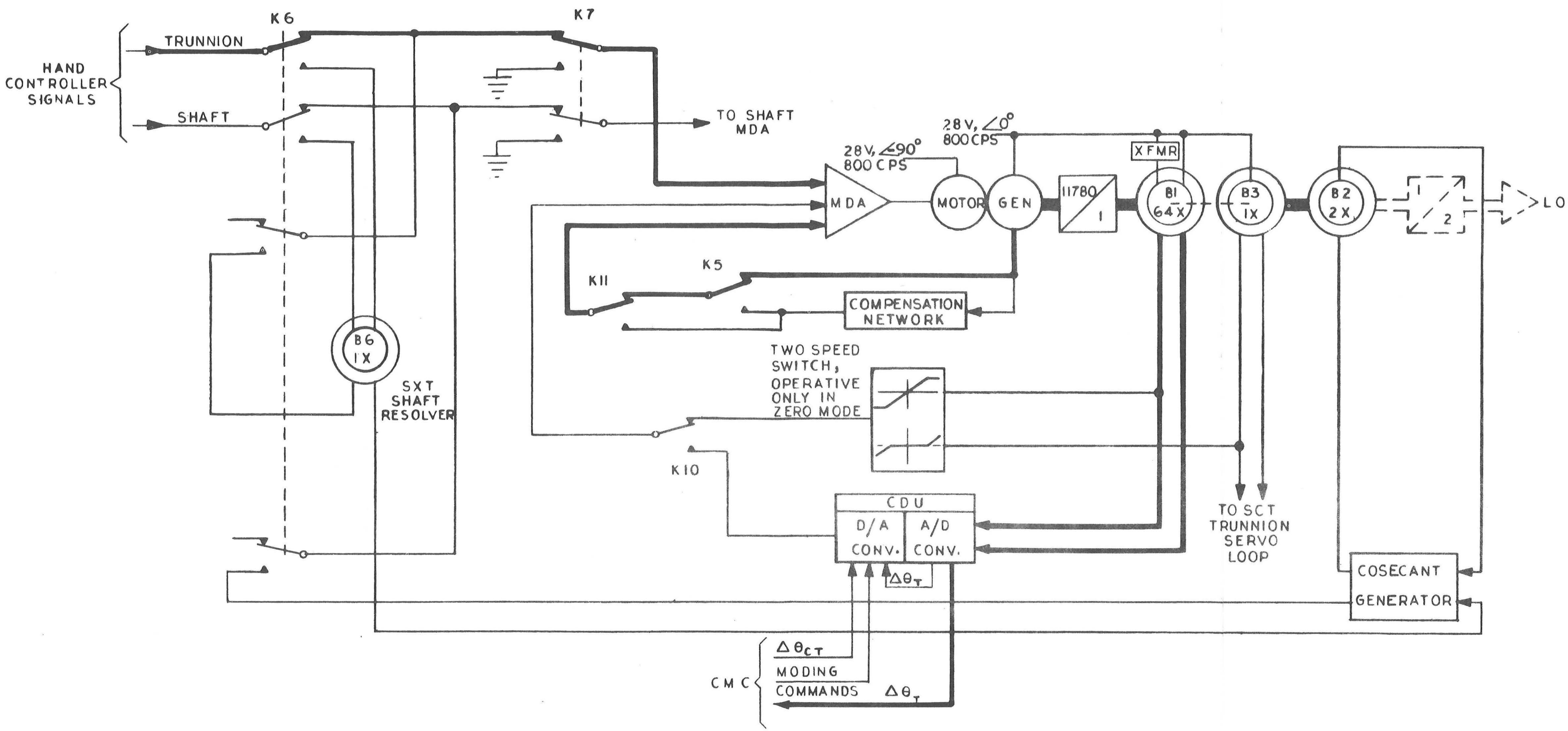


Fig. 2-33. SXT Trunnion Direct Mode Integrating Servo Loop

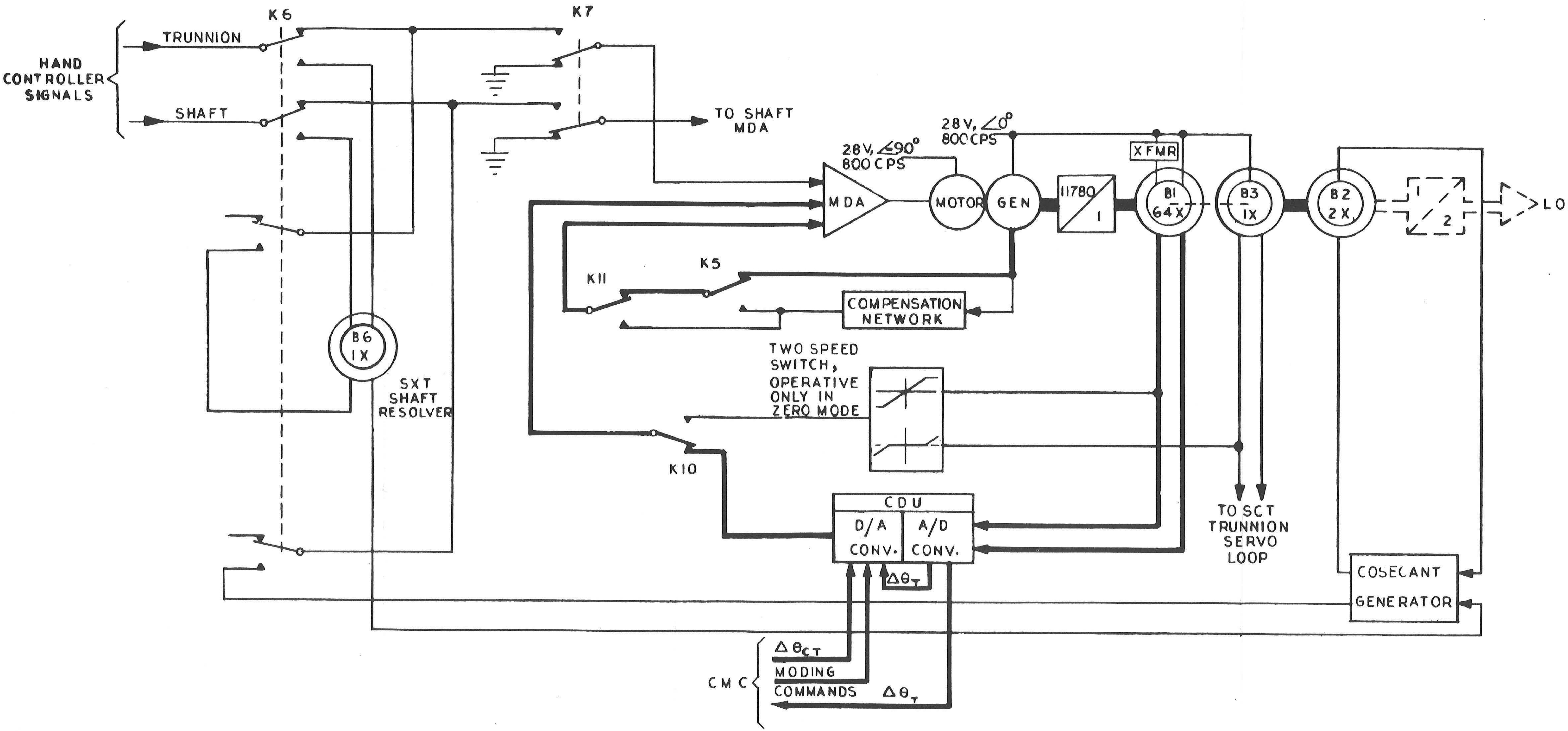


Fig. 2-34. SXT Trunnion Computer Mode Integrating Servo Loop

2.2.3.1 Zero Optics Mode

In zero optics mode, relays convert the SXT trunnion and shaft loops into two speed null sensing servos. The positioning servos then drive the SXT optics into alignment with zero reference inputs. This mode of operation is normally established as a part of a preliminary procedure for taking optical sightings.

The zero optics mode (Fig. 2-35) is selected manually by setting the ZERO switch to ZERO, which energizes the two-speed switches. The CMC is notified of the zero optics mode by a signal when the ZERO switch is in the ZERO position.

Entering the zero optics mode causes relays K5 and K7 to be energized and K10 and K11 to be deenergized. This configuration disconnects the SXT loops from all data source drive rate inputs and switches in zero alignment reference inputs and serves to mechanize each loop as a positioning servo.

The OSS is mechanized so that the CMC may command zero optics mode. This is done by CMC issuance of an enable zeroing discrete and a disengage DAC discrete. The enable zeroing discrete energizes relay K9, which provides energization to the two-speed switches, if the MODE switch is set to CMC. The disengage DAC discrete energizes relay K8, which in turn deenergizes relay K10, to disconnect the DAC from the MDA, and energizes relay K11, to connect the compensation network into the tachometer feedback loop to the MDA.

In the SXT trunnion loop, the 1X and 64X resolver transmitter outputs are switched back to the MDA by a two-speed, coarse-fine switch. The resolvers are mechanized as control transformer error detectors for the trunnion integrating loop circuit and generate error signals proportional to the displacement of the mechanical shaft from the electrical zero reference. These error signals are used to drive the mechanical shaft until it is precisely aligned to the zero reference. The zero optics relay, K5, reconnects the tachometer generator from direct to compensated feedback so that the servo assumes the characteristics of a positioning servo.

The SXT trunnion loop accuracy is determined by the 64X resolver. However, since the 64X resolver passes through 64 nulls in 180 degrees of trunnion rotation, the 1X resolver output overrides the 64X resolver output and drives the SXT trunnion near zero. When the SXT trunnion angle is within 2.8 degrees of zero (5.625 degrees SLOS), the 64X resolver output is switched into the MDA to drive the SXT trunnion to zero. The SXT trunnion CDU read counter is then cleared by the CMC CDU zero discrete.

The SXT shaft integrating loop is mechanized identically to that of the trunnion loop. In the SXT shaft loop, the 1/2X and 16X resolvers serve as error detectors for the two-speed, shaft positioning servo.

2.2.3.2 Manual Modes

The manual modes are enabled by setting the ZERO switch to OFF and the MODE switch to MAN. In manual modes of operation, the direction and rate of image motion viewed on the SC T and SXT eyepieces are manually controlled. The optics hand controller and speed selector are used for manually acquiring the landmark and star targets. Displacement of the optics hand controller generates SXT trunnion and shaft angular drives (A_t and A_s).

The manual mode provides three modes of operation associated with the SCT: 0°, 25°, and Slave to SXT; and two modes pertaining to the relative

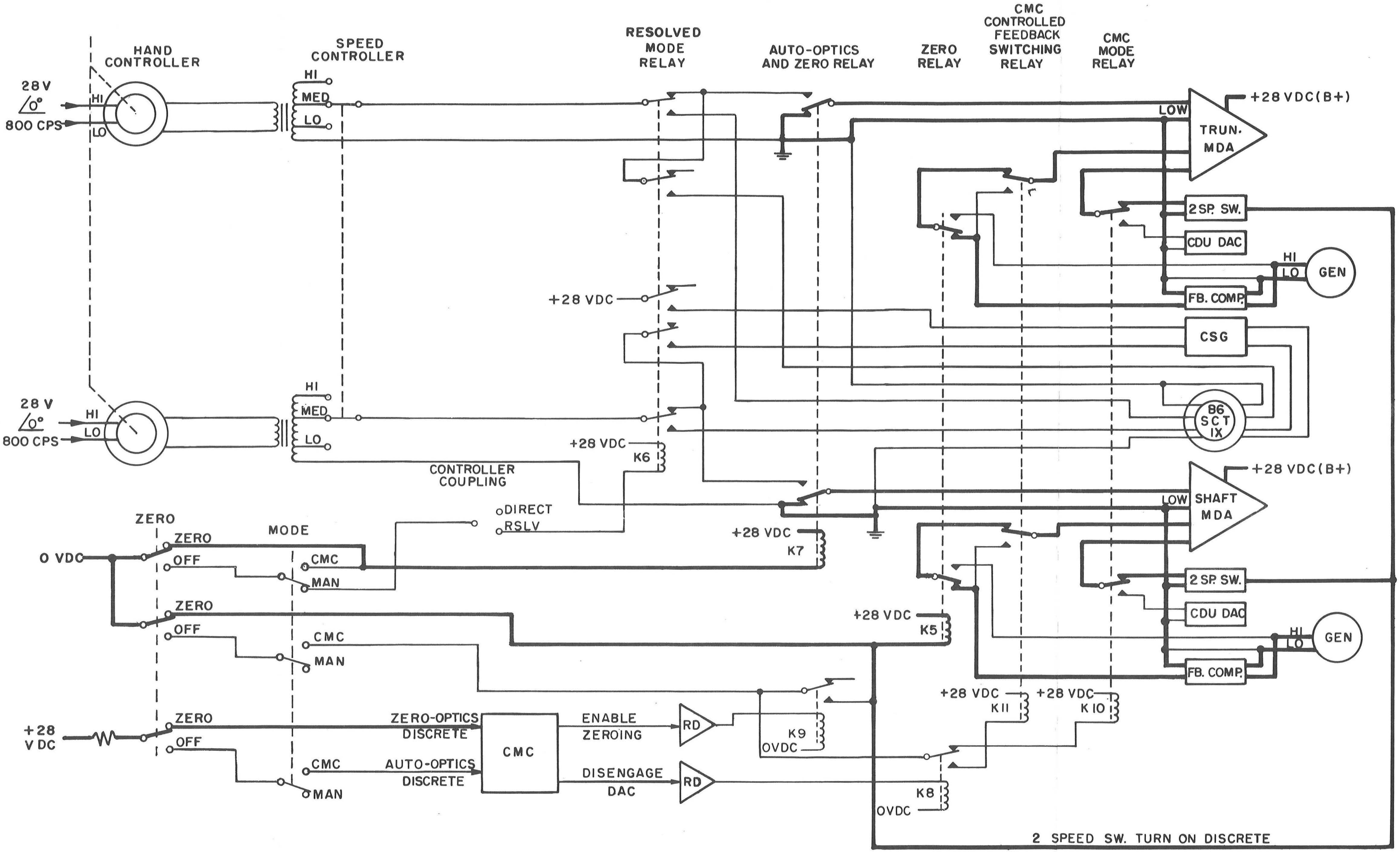


Fig. 2-35. Zero Optics Mode Switching

movement of the target image: direct and resolved. The SCT trunnion modes are selected by the TEL TRUN switch which controls the configuration of the SCT trunnion relays K2, K3, and K4. (See Fig. 2-36.)

2.2.3.2.1 0° Mode. In this mode, SCT trunnion relays K2 and K4 are energized. Relay K2 applies 28 volt, 800 cps power directly to the SCT trunnion 1X resolver cosine winding and relay K4 shorts out the sine winding. This causes a zero output from the 1X resolver thus preventing SCT trunnion movement.

2.2.3.2.2 25° Mode. In this mode, SCT trunnion relays K2 and K3 are energized. Relay K2 applies 28 volt, 800 cps power directly to the SCT trunnion 1X resolver cosine winding and relay K3 applies 28 volt, 800 cps power through the 25° offset transformer to the sine winding. This causes the SCT trunnion to be displaced 25° from the zero position, permitting the scanning of a 110 degree cone by rotation of the SCT shaft.

2.2.3.2.3 Slave to SXT Mode. In this mode, all three SCT trunnion relays are deenergized. The configuration applies the SXT trunnion 1X resolver sine and cosine outputs directly to the sine and cosine windings, respectively, of the SCT trunnion 1X resolver. This drives the SCT trunnion to follow the SXT trunnion.

2.2.3.2.4 Manual Direct Mode. The manual direct mode (Fig. 2-37) permits image movement in a coordinate system.

In manual direct mode, the SXT trunnion and shaft servos are mechanized as rate integrating servo loops. The trunnion and shaft angular drive rate signals (A_t and A_s) are fed through deenergized switching relays K6 and K7 directly into the MDA of their respective servos.

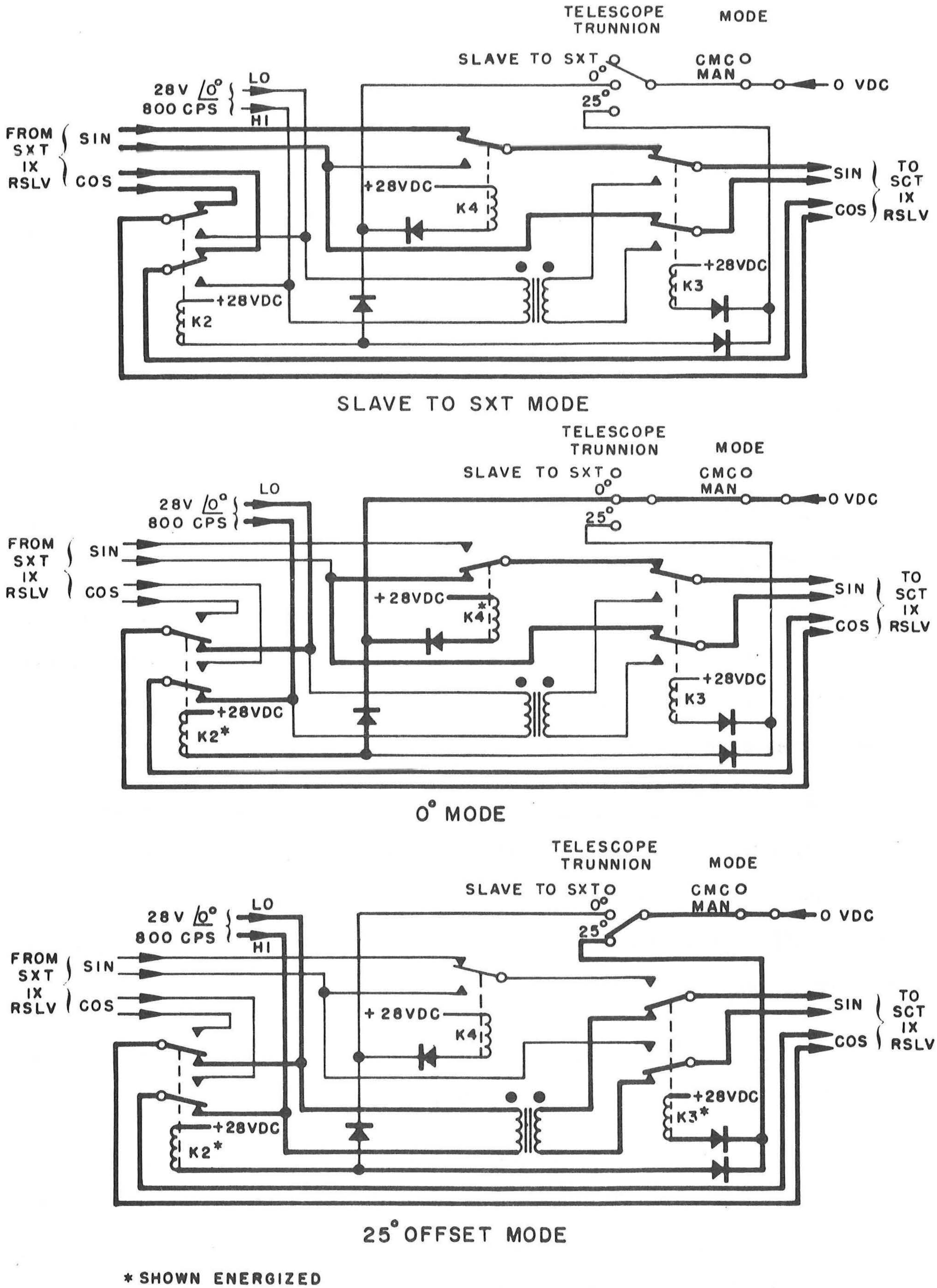


Fig. 2-36. SCT Trunnion Mode Selection

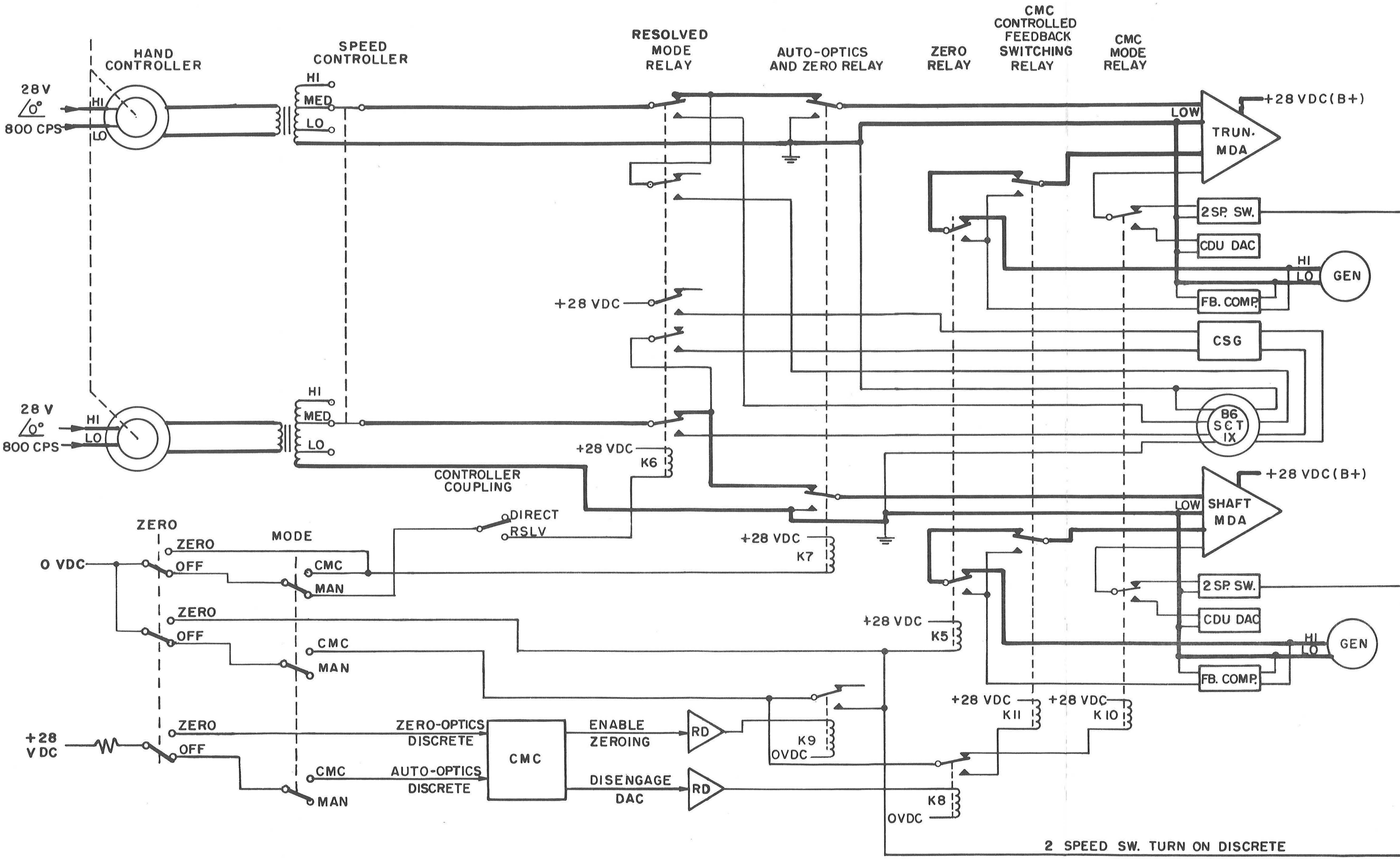


Fig. 2-37. Manual Direct Mode Switching

The trunnion drive rate signal (A_t) causes the trunnion servo, located in the SXT optics, to drive the SXT indexing mirror around the trunnion axis in a direction and at a rate proportional to the direction and displacement of the optics hand controller. Similarly, the shaft drive rate signal (A_s) causes the shaft to rotate the entire SXT optics around the shaft axis.

The sine and cosine error signals from the SXT trunnion 64X resolver and the SXT shaft 16X resolver are applied through the CDU A/D converter to the read counters. The $\pm\Delta\theta_T$ and $\pm\Delta\theta_S$ pulses sent from the read counters to the CMC represent the amount of SXT trunnion and shaft angle rotation. The CMC can use this data to display the SXT angles on the DSKY and to determine spacecraft position and trajectory.

2.2.3.2.5 Manual Resolved Mode. The manual resolved mode (Fig. 2-38) permits independent movement of the image coordinates relative to a rectangular system.

In manual resolved mode, the SXT trunnion and shaft servos are mechanized as rate or integrating loops. Drive rate resolution and variable gain are added to the shaft servo loops to make the rate and direction of the image motion independent of the shaft axis and trunnion angle.

Switching relay K6 directs the drive rate signals (up-down and left-right) from the optics hand controller to the 1X resolver in the SXT shaft. The rotor of the 1X resolver is positioned to the shaft angle (A_s). The voltages induced in the stator windings are a function of the two rotor input voltages and the shaft angle. The R and M coordinates drive rate signals are resolved by the 1X resolver into shaft and trunnion signals. The trunnion signal is fed directly to the MDA, while the shaft signal is fed through the cosecant generator to the MDA. This servo causes the SXT indexing mirror to rotate around the trunnion axis at a rate and direction proportional to the drive rate signal causing the image to move up or down for an up-down drive rate signal.

The left or right drive rate signal from the 1X resolver is fed to the SXT shaft through the cosecant generator, which is connected in the input circuit by switching relay K6. The cosecant generator functions as a variable gain device between trunnion angles of 10 to 60 degrees. It employs a 2X computing resolver in the SXT trunnion servo as a minor loop. The effect of this cosecant generator is to make the rate of image motion (angular velocity) independent of changes in trunnion angle, by decreasing the shaft speed as trunnion angle increases. The reduction in shaft speed enables a constant rate of trunnion peripheral velocity to be achieved regardless of trunnion angle. The purpose of this is to prevent the optics LOS from sweeping past the target before recognition.

One input to the summing network of the cosecant generator is the drive rate along the Y axis, which is obtained after resolution by the 1X resolver in the shaft servo. The motion along this axis increases at a rate proportional to the sine of the trunnion angle (A_t). To compensate for this effect, an inverse sine factor (the cosecant) is introduced. A computing resolver in the SXT trunnion gear train is employed to yield the function $0.5C \sin A_t$ to

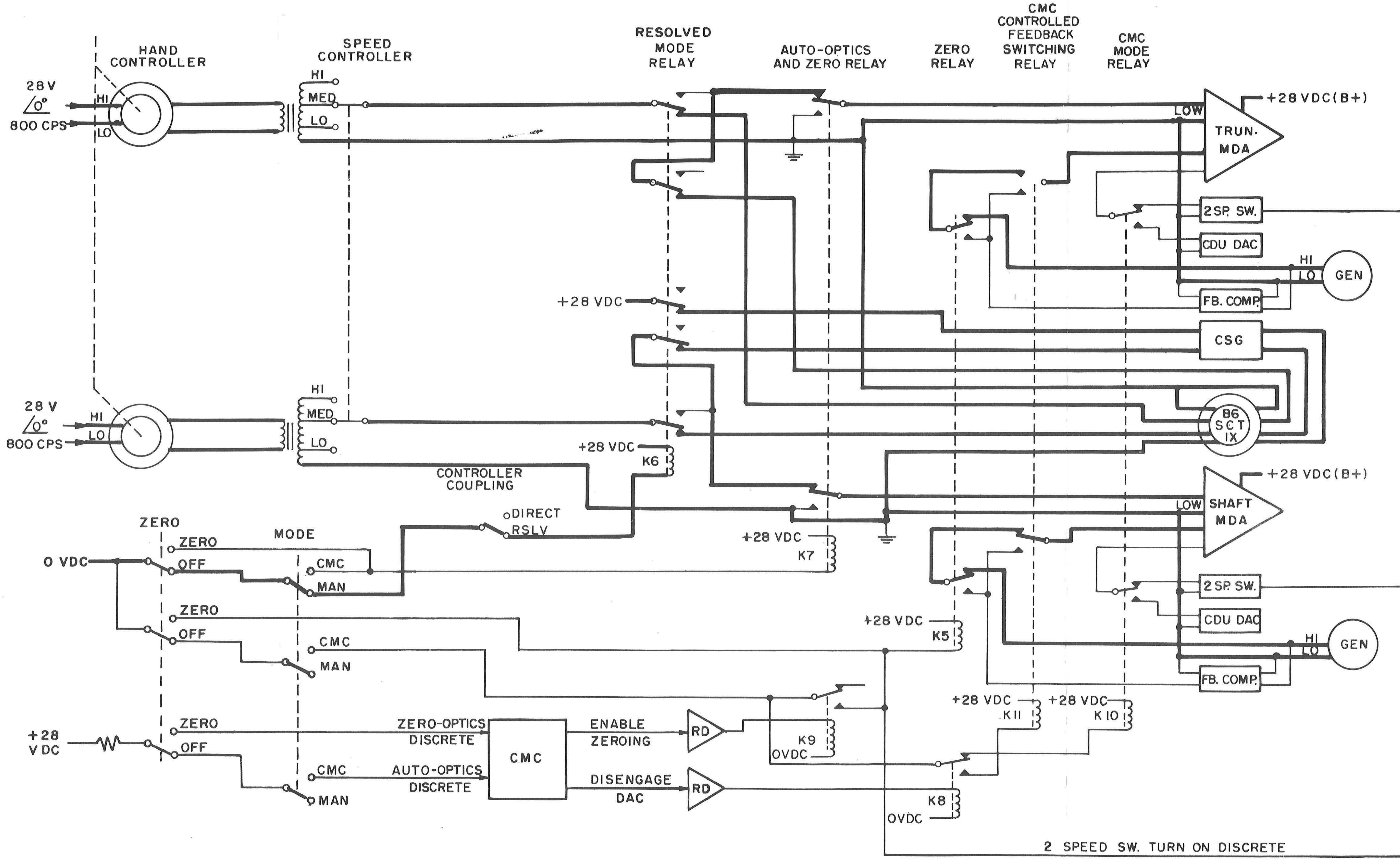


Fig. 2-38. Manual Resolved Mode Switching

compensate for the gear train ratio. The controlled electrical variable (C) drives the SXT shaft integrating loop so that its angular velocity is independent of the trunnion angle. In this way, a uniform sweep rate along the Y axis is achieved throughout the range of trunnion angles. The resolution of the drive rates onto the Y axis is used as a direct input to the shaft integrating servo loop.

2.2.3.3 Computer Mode

The computer mode (Fig. 2-39) is initiated by setting the MODE switch to CMC. The CMC then controls and drives the OSS loops.

When the MODE switch is in the CMC position, relays K7 and K10 are energized and relays K5 and K11 are deenergized. Relay K7 disconnects the hand controller from the MDA's. Relay K10 connects the DAC outputs to the MDA's. Relays K5 and K11 remove the compensation network from the tachometer feedback loops. Mechanization for a CMC commanded zero optics mode is described in paragraph 2.2.3.1.

During CMC driving mode, the CMC issues the enable error counter discrete which enables the error counters to receive $\pm\Delta\theta_{CT}$ and $\pm\Delta\theta_{CS}$ pulses from the CMC. These pulses represent the desired angle of the optics as computed by the computer. The output of the error counters are fed to the DAC's where it is converted to an ac signal and used to position the SXT loops through the MDA. As the SXT is driven, the CDU read counters receive the trunnion and shaft resolver error signals and register the SXT angles. A feedback circuit from the read counter to the error counter reduces the error counter contents as the read counter increases. This feedback nulls the error counter; and the SXT stops driving. The CMC receives the $\pm\Delta\theta_T$ and $\pm\Delta\theta_S$ pulses from the read counter and determines when the optics are at the desired angles.

2.2.4 OSS 800 CPS Power Supply

The OSS 800 cps power supply consists of three modules: an automatic amplitude control, filter, and multivibrator; a 1 percent amplifier; and a 5 percent amplifier. The 1 percent amplifier provides resolver and tachometer excitation and the input to the 5 percent amplifier. The 5 percent amplifier provides SXT and SCT motor excitation. The outputs of the 1 percent amplifier and 5 percent amplifier are applied to their respective loads through the optics load compensation network which provides power factor correction.

The operation of the OSS 800 cps power supply is identical to the operation of the ISS 800 cps power supply (paragraph 2. 1. 4. 2) except that it has only one rather than two 5-percent amplifiers.

2.3 COMPUTER SUBSYSTEM

The computer subsystem (CSS) is the control and computational center of the GNCS. It consists of the CMC and the two DSKY's. The CMC is a core memory, parallel digital control computer with two types of memory, fixed and erasable. The main task of the CMC is to execute the programs stored in the memory. Programs are written in a digital machine language called basic instructions. A basic instruction contains an operation (order) code

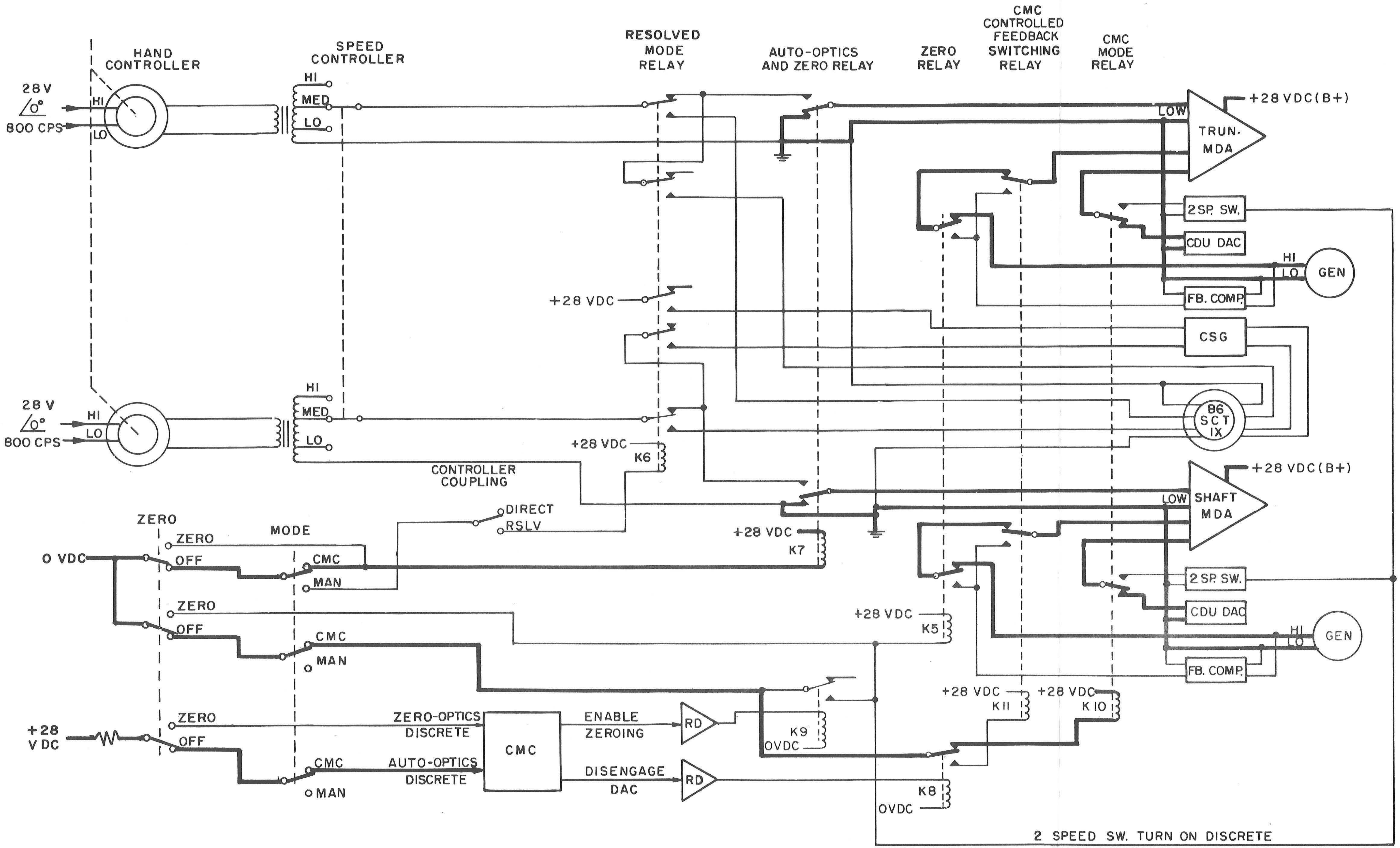


Fig. 2-39. Computer Mode Switching

and a relevant address. The computer logic decodes the order code to obtain the data flow within the CMC and uses the address code to select the data that is to be used for computations. With the DSKY keyboard the astronaut can load information into the CMC, initiate programs stored in memory, and retrieve and display information contained in the CMC.

The CMC stores data pertinent to the flight profiles that the spacecraft must assume in order to complete its mission. This data includes position, velocity, and trajectory information and is used by the CMC to solve the various flight equations. (Spacecraft position and velocity is maintained within the CMC in the form of a six-dimensional vector called the state vector.) The results of these equations can be used to determine the required magnitude and direction of thrust required. Corrections to be made are established by the CMC. The spacecraft engines are turned on at the correct time, and when required, steering signals are controlled by the CMC to reorient the spacecraft to a new trajectory. The ISS senses acceleration and supplies velocity changes to the CMC for calculating the total velocity. Drive signals are supplied from the CMC to the ISS for alignment of the IMU and to the OSS for optics positioning. Error signals are fed to the CDU to provide the capabilities to steer the spacecraft. CDU position signals are fed to the CMC to indicate changes in gimbal angles, which are used to keep cognizant of the gimbal positions. The CMC receives angular information from the OSS to calculate present position and orientation and to refine trajectory information.

2.3.1 CMC Language

The CMC uses the binary ones complement number system. In this system, a negative binary number is the complement of the corresponding positive binary number. Functional operations occur through the processing of words. All words are 16 bits long in the CMC and are of two basic types: data words and instruction words. The format of the words depends on where the words are located. Figure 2-40 shows the word formats in memory and in the central processor. In memory, data words contain a parity bit, fourteen magnitude bits, and a sign bit. In the sign bit, a binary one indicates a negative number and and a binary zero indicates a positive number. When located in the central processor, bits 1 through 14 are the magnitude bits, bit 15 is the uncorrected sign bit, and bit 16 is the sign bit as before. The uncorrected sign bit is used to enable an overflow detection without destroying the sign bit when two numbers are manipulated. Parity bits are only included in words that are stored in memory.

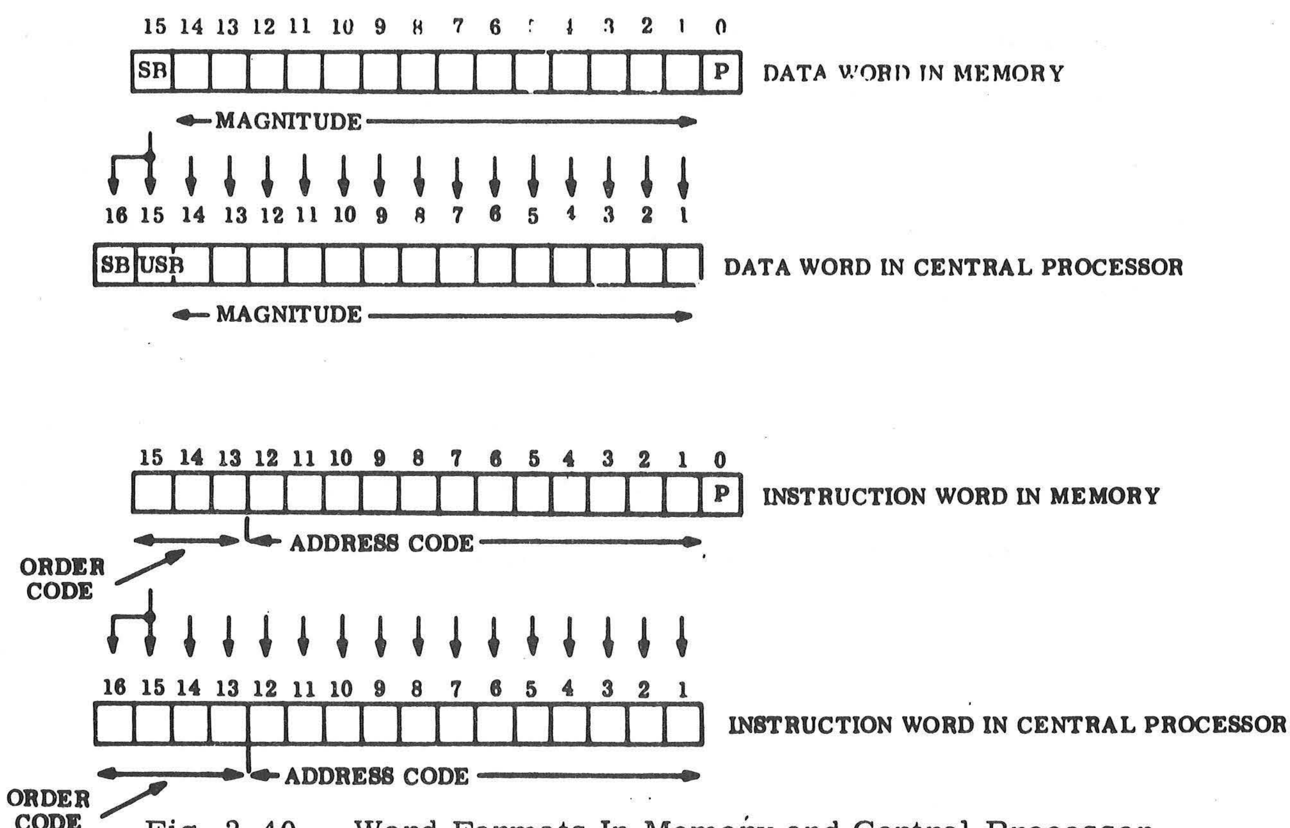


Fig. 2-40. Word Formats In Memory and Central Processor.

2.3.1.1 Instructions

An instruction word in memory contains a 12 bit address code and a 3 bit order code. Bits 10 through 12 are sometimes used to extend the order code when transferring to the SQ register. The address code normally calls out a word location in memory or in the central processor. The order code represents an operation which is to be performed on the data whose location is defined by the address code.

The CMC has three classes of instructions: regular, involuntary, and peripheral. Regular instructions are programed and are executed in whatever sequence they are stored in memory. Involuntary instructions are not programable, with the exception of one instruction which may be programed to test computer operations. Involuntary instructions have priority over regular instructions and are executed at the occurrence of certain events during normal operation. The peripheral instructions are used when the CMC is connected to ground test equipment and are therefore not used during a flight.

2.3.1.1.1 Regular Instructions. Four types of instructions comprise the regular instruction class. They are the basic, channel, extracode, and special instructions. Basic instructions are the most frequently used instructions. The instruction words stored in memory are called basic instruction words. As shown in Fig. 2-41, these words contain a three bit order code field and a twelve bit address field. The content of the order code field defines the instruction and is represented by a single-digit octal number with the octal point at the right. The content of the address field defines a location and is represented by a four-digit octal number with the

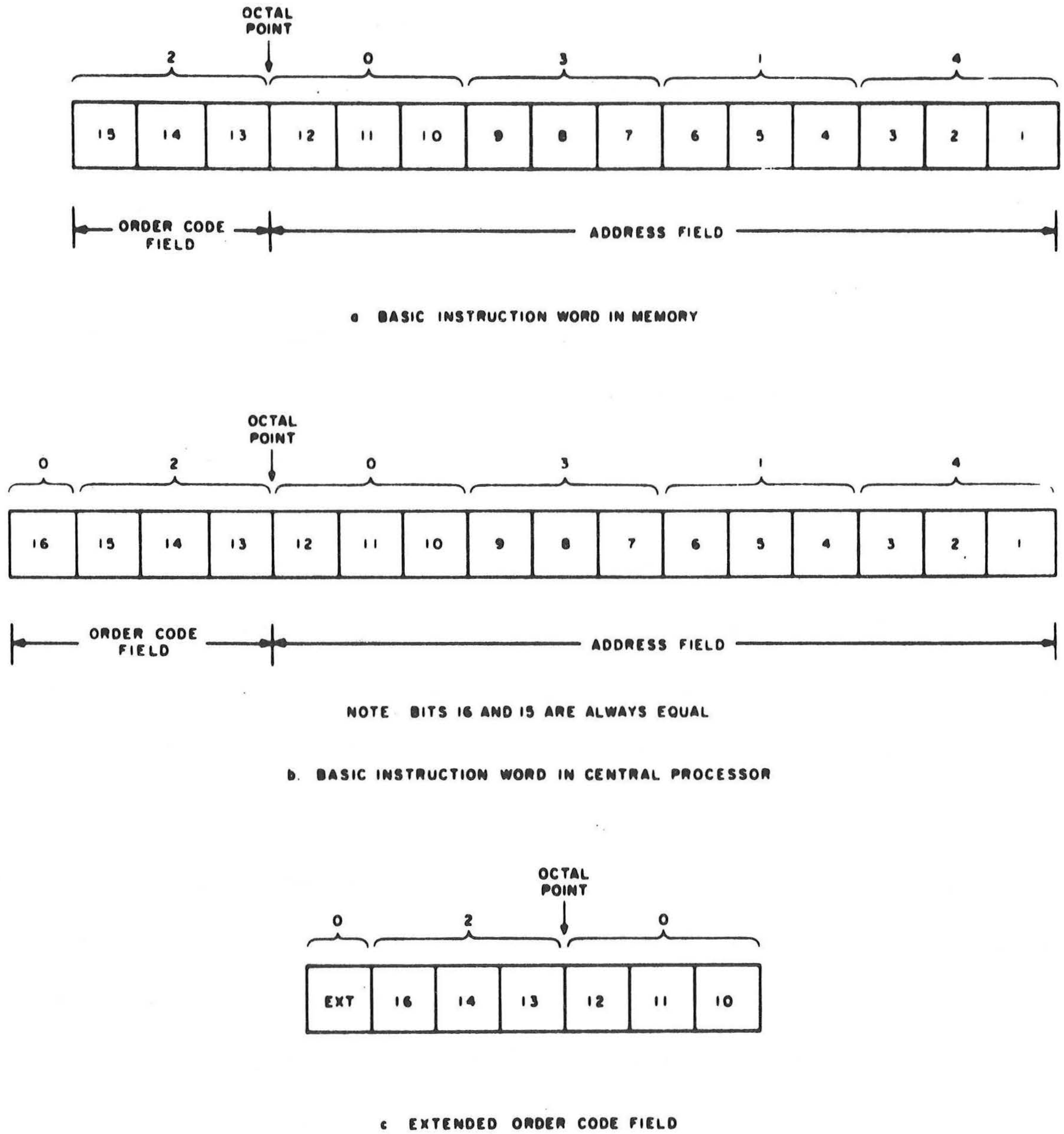


Fig. 2-41. Instruction Word.

octal point at the left. An instruction word in memory therefore may be written as a five digit octal number (e. g., 2. 0314). The order code field is extended an additional bit when the basic instruction is transferred from memory to the central processor. Therefore, the instruction word used in the example changes to 02. 0314 in the central processor. This additional high order bit is always zero for basic instructions. When the CMC is switched to the extend mode, the high order bit is one, indicating that an extracode or channel instruction will be executed next.

Computer logic permits the use of the three high order bits (one octal digit) of the address field to further lengthen the order code field. A typical instruction can then be represented as 02. 0 numerically. This encroachment on the address field limits the use of some instructions to a certain portion of memory. The high order bits of the address field may be used this way because of the differences between fixed and erasable memory. The instructions which apply only to erasable memory do not copy the two high order bits of the address field into the address register. However, the address register receives the entire address field for those instructions which apply to fixed memory.

The editing or special instructions are address-dependent basic instructions which have predefined addresses and order codes whereas basic instructions have only predefined order codes. The order codes are represented as 00. 0006 numerically. Those address-dependent instructions which may be combined with any order code are represented, for example, as 0. 0021 which is the entire content of the address field.

The special instructions are used to control certain operations in the

CMC. For example, one special instruction, as mentioned previously, is used to switch the CMC to the extend mode of operation. This mode extends the length of the order code field and converts basic instruction words to channel or extra code instruction words. Channel instructions can only be used with input/output channel addresses. Extra code instructions perform the more complex and less frequently used arithmetic operations.

2.3.1.1.2 Involuntary Instructions. The involuntary instruction class contains two types of instructions — interrupt and counter. The interrupt instructions use the basic instruction word format just as the regular instructions do. However, the interrupt instructions are not entirely programable. The contents of the order code field and the address field are supplied by computer logic rather than the program. The counter instructions have no instruction word format. Signals which function as a decoded order code specify the counter instruction to be executed and the computer logic supplies the address. The address for these instructions is limited to one of 29 counter locations in memory.

There are two interrupt instructions. One instruction initializes the CMC when power is first applied and when certain program traps occur. The other interrupt instruction is executed at regular intervals to indicate time, receipt of new telemetry or keyboard data, or transmission of data by the CMC. This interrupt instruction may be programed to test the CMC.

There are several counter instructions. Two instructions will either increment or decrement by one the content of a counter location using the ONE's complement number system. Two other instructions perform the same function using the TWO's complement number system. Certain counter instructions control output rate signals and convert serial telemetry data to parallel CMC data.

2.3.1.2 Programs

The CMC performs such tasks as solving guidance and navigation problems by means of a set of instructions called a program. A program consists of a group of program sections that are classified according to the functions they perform. These functions are defined as mission functions, auxiliary functions, and utility functions.

Mission functions are performed by program sections that implement operations concerned with the major objectives of the mission. These operations include aligning the IMU stable member and computation of spacecraft position and velocity during coasting periods of the flight by solution of second-order differential equations which describe the motions of a body subject to the forces of gravity.

Auxiliary functions are executed at the occurrence of certain events, requests, or commands. These functions are performed by program sections that provide a link between the CMC and other elements of the GNCS. This link enables the CMC to process signals from various devices and to send commands for control and display purposes. In addition, the auxiliary functions implement many and varied operations within the CMC in support of the mission functions.

Utility functions are performed by program sections that coordinate and synchronize CMC activity to guarantee orderly and timely execution of required operations. These functions control the operation of the mission functions and schedule CMC operations on either a priority or a real-time basis. The utility functions also translate interpretive language to a basic machine language which allows complex mathematical operations such as matrix multiplication, vector addition, and dot product computations to be performed within the framework of compact routines. In addition, the utility functions save the contents of registers A and Q during an interrupt condition and enable data retrieval and control transfer between isolated banks in the fixed-switchable portion of fixed memory.

2.3.2 CSS Theory of Operation

The CMC consists of nine functional sections as illustrated in Fig. 2-42. The sequence generator controls data flow. The order code of each instruction is entered into the sequence generator, and the sequence generator produces a different sequence of control pulses for each instruction. The execution of each instruction sets the conditions for the execution of the next instruction. In order to specify the sequence in which instructions are to be executed, the instructions are normally stored in successive memory locations. By adding the quantity one to the address of an instruction being executed, the location of the instruction to be executed next is derived. Execution of an instruction is complete when the order code of the next instruction is transferred to the sequence generator and the relevant address is in the central processor.

The central processor consists of several flip-flop registers. It performs arithmetic operations and data manipulations on information accepted from memory, the input registers, and priority control. Arithmetic operations are performed using the ONE's complement number system. Values up

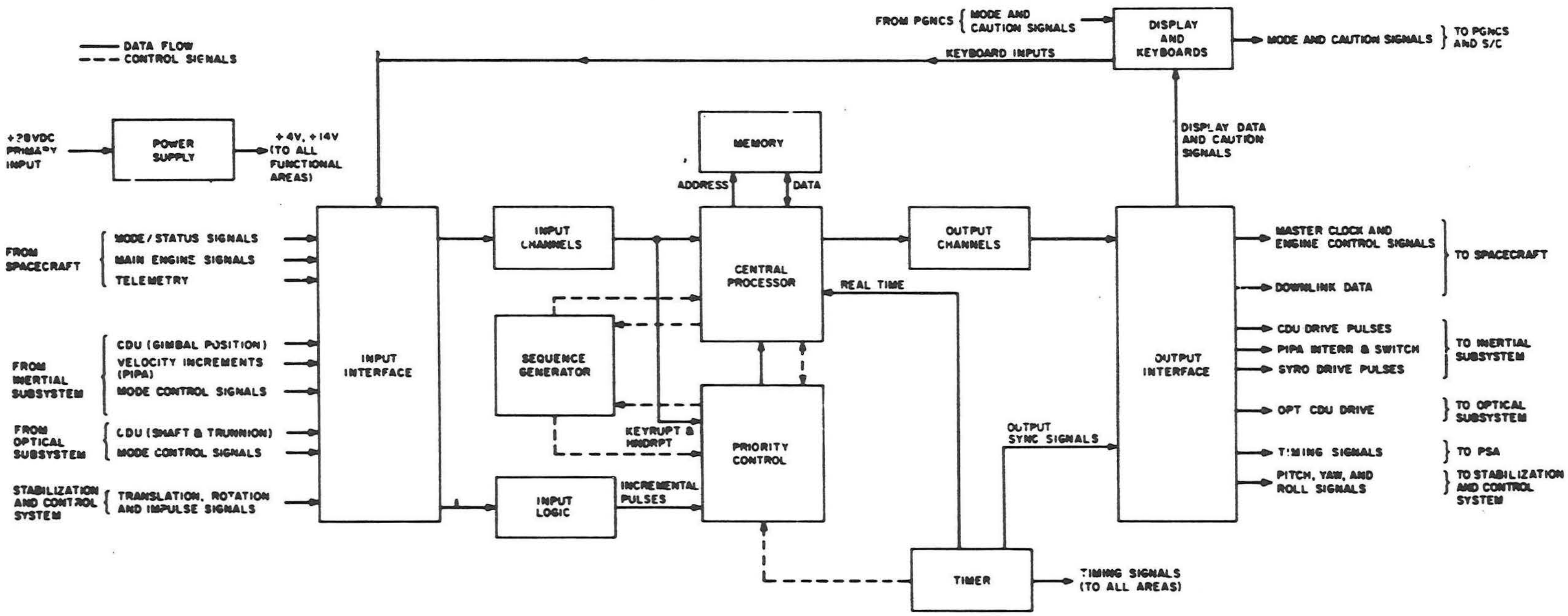


Fig. 2-42. CSS Functional Block Diagram

to 14 bits (excluding sign) can be processed with an additional bit produced for overflow or underflow. All operations within the central processor are performed under control of pulses generated by the sequence generator (indicated by dashed lines in Fig. 2-42). In addition, all words read out of memory are checked for correct parity, and a parity bit is generated for all words written into memory within the central processor. Odd parity is used; therefore, all words stored in memory including the parity bit contain an odd number of ONE's. The central processor also supplies data and control signals through the output registers and interface to the various spacecraft subsystems.

The CMC has provision for ten program interrupts. These ten interrupts, with their order of priority are: T6RUPT, T5RUPT, T3RUPT, T4RUPT, KEYRUPT 1, KEYRUPT2, UPRUPT, DOWNRUPT, RADARRUPT, and HCRUPT. The T3RUPT, T4RUPT, T5RUPT, and T6RUPT routines are initiated by counter overflows in the CMC. The DOWNRUPT routine is initiated at the completion of every parallel-to-serial conversion for telemetry downlink operation. KEYRUPT1 and 2 and UPRUPT routines are initiated by external inputs to the CMC. The KEYRUPT 1 routine is initiated when a main panel DSKY pushbutton is pressed. The KEYRUPT2 routine is initiated when a LEB DSKY pushbutton is pressed or when priority control receives a mark signal from the OSS. The UPRUPT routine is initiated upon receipt of each uplink word. RADARRUPT is used for VHF ranging. HCRUPT is not used.

Before a priority program can be executed, the current program must be interrupted; however, certain information about the current program must be preserved. This includes the program counter and any intermediate results contained in the central processor. Priority control produces an interrupt request signal, which is sent to the sequence generator. This signal acting as an order code, causes the execution of an instruction that transfers the current contents of the program counter and any intermediate results to memory. In addition, the control pulses transfer the priority program address in the priority control to the central processor, and then to memory through the write lines. As a result, the first basic instruction word of the priority program is entered into the central processor from memory, and execution of the priority program is begun. The last instruction of each priority program restores the CMC to normal operation, provided no other interrupt request is present. This instruction transfers the previous program counter and intermediate results from their storage locations in memory back to the central processor.

Certain data pertaining to the flight of the spacecraft is used to solve the guidance and navigation problems. This data, which includes real time, acceleration, and IMU gimbal angles, is stored in memory locations, called counters. The counters are continuously updated as new data becomes available. An incrementing process implemented by priority control changes the contents of the counters. Data inputs to priority control are called incremental pulses. Each incremental pulse produces a counter address and a priority request. The priority request signal is sent to the sequence generator, where it functions as an order code. The control pulses produced by the sequence generator transfer the counter address to memory through the write lines of the central processor. In addition, the control pulses enter the contents of the addressed counter into the central processor for incrementing.

Real time plays a major role in solving guidance and navigation problems.

Real time is maintained within the CMC in the main time counter of memory. The main time counter provides a 745.65 hour (approximately 31 days) clock. Incremental pulses are produced in the timer and sent to priority control for incrementing the main time counter. The Apollo mission requires that the CMC clock be synchronized with the Eastern Test Range (ETR) clock. The CMC time is compared with ETR time once every two seconds by downlink telemetry.

Continuous drive pulses originate in the timer as fixed-frequency timing and strobe signals. The timing signals strobe the outputs from the output registers and the resulting continuous drive pulses are sent to the spacecraft. Rate signals, which are bursts of drive pulses, originate in the output section and are sent to the gyros and the ISS portion of the CDU, and to the OSS portion of the CDU. Rate signals are also used for controlling the attitude of the spacecraft. The number of pulses in each burst and occurrence of each burst are controlled by a program. The program is dependent on incremental pulse feedback to priority control from the IMU. The destination of the various rate signals, as well as the type of rate signals (incrementing or decrementing), are also selected by this program.

The downlink operation of the CMC is asynchronous to the spacecraft telemetry system. The telemetry system supplies all the timing signals necessary for the downlink operation. These signals include start, end, and bit sync pulses. The end pulse is also sent to priority control.

A key code is assigned to each DSKY keyboard operation. When a keyboard pushbutton is pressed, the keycode is produced and sent to an input register. The same keycode is also sent to priority control, where it produces both the address of a priority program stored in memory and a priority request signal, which is sent to the sequence generator. An interrupt request functions as an order code and initiates an instruction for interrupting the program in progress and executing the priority program stored in memory. A function of this program is to transfer the keycode, temporarily stored in the input register, to the central processor, where it is decoded and processed. A number of keycodes are required to specify an address or a data word. The program initiated by a keycode also converts the information from the DSKY keyboard to a coded display format. The coded display information is transferred by another program to an output register and sent to the display portion of the DSKY. The display notifies the astronaut that the keycode was received, decoded, and processed properly by the CMC.

2.3.2.1 Timer

The timer portion of the CMC generates all of the timing signals required for operation of the computer and also supplies timing signals to other spacecraft subsystems. The timer is divided into the functional areas indicated in Fig. 2-43. The oscillator is a crystal controlled modified Pierce oscillator that generates a source frequency of 2.048 mc for the clock divider logic. Temperature compensated components in the oscillator circuit maintain a high degree of stability and assure an extremely accurate output frequency to the divider logic.

The 2.048 mc input from the oscillator is applied to the main divider logic. This circuit divides the input frequency by two and generates the following outputs: clear, write, and read control pulses which are applied to

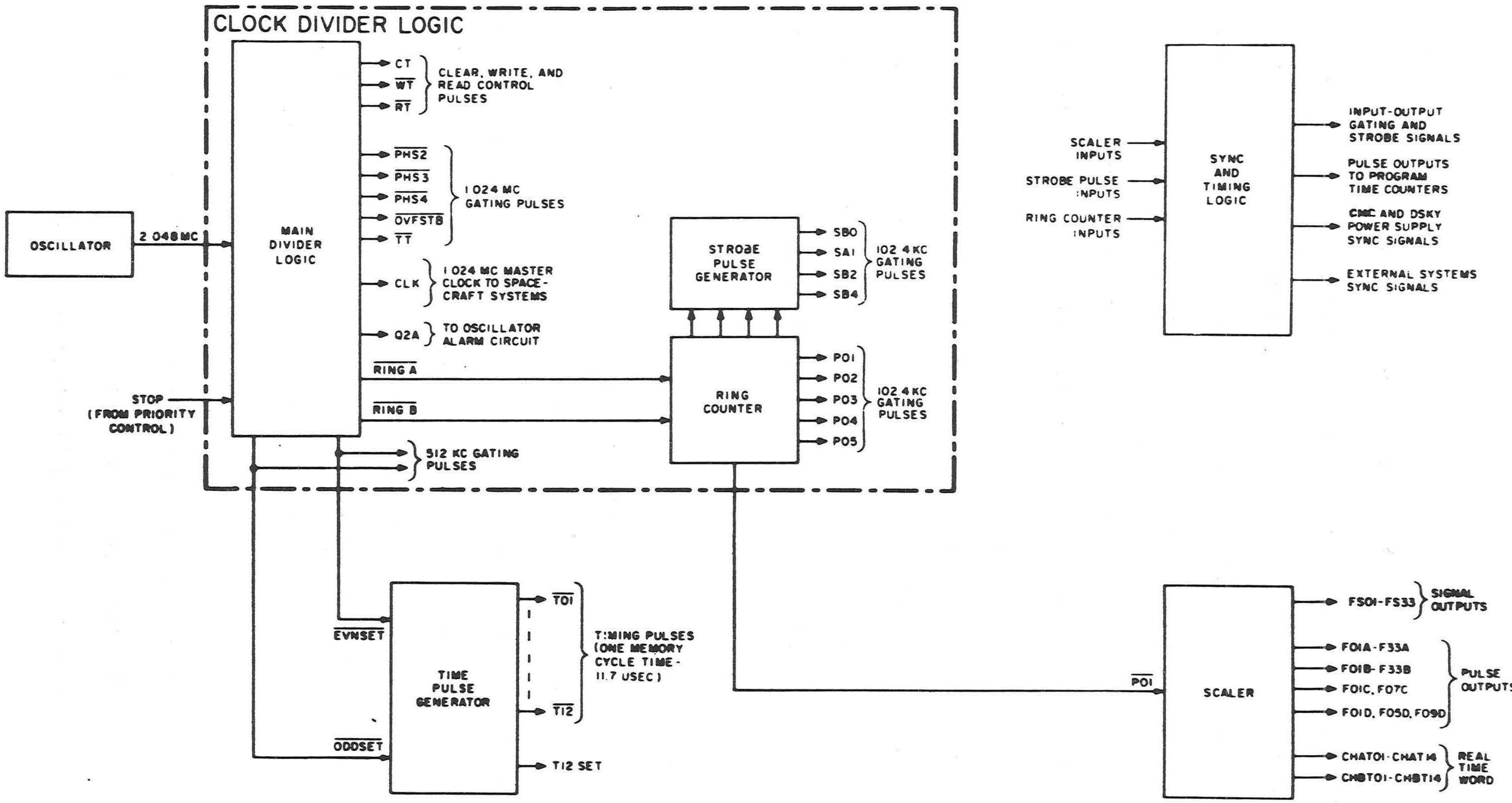


Fig. 2-43. Timer Functional Block Diagram.

the central processor to produce the signals necessary to clear, write into, and read out the flip-flop registers; 1.024 mc gating pulses which are used throughout the CMC; the master clock signal which is used to synchronize other spacecraft systems; and a signal which is applied to the oscillator alarm circuit in the power supply to indicate oscillator activity. In addition, the main divider, by further frequency division, supplies 512 kc signals to drive the ring counter and signals to the time pulse generator.

The ring counter generates pulses of 5 microseconds at a 102.4 kc rate which are used for gating and for deriving other timing functions in the CMC. Ring counter outputs also provide the strobe pulses of 2 and 3 microseconds at a 102.4 kc rate.

The scaler consists of 33 identical divider stages (flip-flops) which are cascaded so that frequency division is successive. The outputs include timing and gating pulses, and the real time word which indicates time intervals up to 23.3 hours.

The time pulse generator consists of 12 flip-flops which generate a sequence of 12 timing pulses (T01 through T12). This sequence of timing pulses defines one memory cycle within the CMC or a period of 11.7 microseconds in which word flow takes place. The STOP signal is used during preinstallation testing to inhibit the time pulses from being generated, and thereby preventing CMC word flow.

The ring counter, strobe pulse generator, and the scaler supply inputs to the sync and timing logic. These inputs are used to derive gating and strobe signals for the input and output channels, pulse outputs for the program time counters in memory, and synchronization signals.

During standby operation, the oscillator, clock divider logic, and the scaler are operative. The only outputs, however, that have functional significance at this time are the real time word from the scaler and the synchronization signals to other spacecraft systems.

2.3.2.2 Sequence Generator

The sequence generator contains the order code processor, command generator, and control pulse generator (see Fig. 2-44). The sequence generator executes the instructions stored in memory by producing control pulses which regulate the data flow of the computer. The order code processor receives signals from the central processor and priority control. The order code signals are stored in the order code processor and converted to coded signals for the command generator. The instruction commands are sent to the control pulse generator to produce a particular sequence of control pulses depending on the instruction being executed. At the completion of each instruction, new order code signals are sent to the order code processor to continue the execution of the program.

2.3.2.2.1 Order Code Processor. The register SQ control portion of the order code processor is regulated by special purpose control pulses from the control pulse generator. These control pulses produce clear and write signals for register SQ and initiate a read signal for register B. The clear, read, and write signals place the order code content of register B onto the write lines and into register SQ. The order code signals from the priority control portion to instructions start, interrupt, and transfer control to specified address. These order code signals cause the register SQ control to produce the clear signals. If the order code signal is start or transfer control to

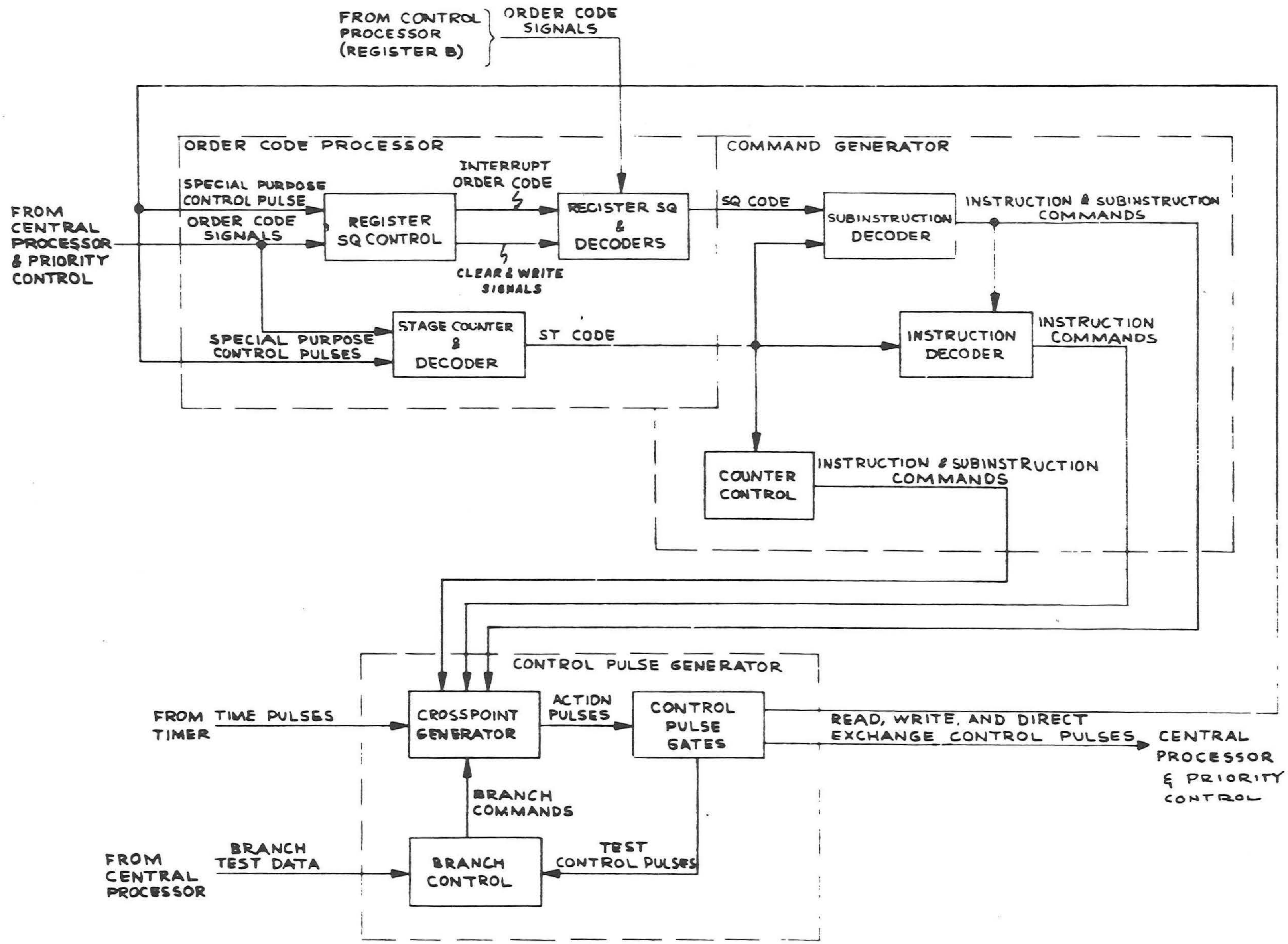


Fig. 2-44. Sequence Generator Functional Block Diagram.

specified address, no further action occurs because the order code for each of these instructions is binary 0 000 000. If the order code is interrupt, register SQ is set to 1 000 111.

Register SQ is a seven-bit register with only six of its bit positions (16 and 14 through 10) connected to the central processor write lines. The seventh (high order) bit position is the extend bit which is a zero for basic instructions and is a one for other instructions.

The stage counter is a three-state gray counter. Most instructions are several memory cycle times (MCT's) long. The stage counter controls the length of each instruction. Most instructions use the two low-order bits of the stage counter. The stage counter always starts an instruction with count 000. Then it may be advanced to 001, 010, or 011 by special purpose control pulses ST1 and ST2 from the control pulse generator. The gray code count is used for the divide instruction. Control pulse DVST advances the counter through the states 000, 001, 011, 111, 110, and 100. The control pulse ST2 sets the stage counter to 010 to complete the divide instruction. The content of the stage counter is decoded into the ST code signals. Some of the ST code signals reflect the standard binary count from octal 0 through 3, and others reflect the gray code count of octal 0, 1, 3, 7, 6, and 4. The order code signals from the priority control sets the stage counter to a particular state in a manner similar to that in which the SQ register is set. The interrupt order code signal sets the stage counter to 000, the start order code signal sets it 001, and the transfer control to specified address signal sets it to 011. The outputs of the SQ and stage decoders are sent to the command generator where they are used to produce subinstructions and instruction commands.

2.3.2.2.2 Command Generator. The subinstruction coder receives SQ and ST code signals from the order code processor. These signals represent the order codes of all machine instructions and are decoded into subinstruction and instruction commands.

The instruction decoder receives the coded signals from the order code processor in addition to certain subinstruction commands. It produces signals called instruction commands. An instruction command is used for two or more subinstructions as compared to a subinstruction command which is only used for one subinstruction.

The counter control receives instruction signals from the priority control. These signals are applied to separate circuits which control the individual counter instructions. The instruction signals from the priority control pertain to counter locations and the instruction(s) associated with the location.

2.3.2.2.3 Control Pulse Generator. Subinstruction and instruction command outputs of the command generator are used by the control pulse generator in conjunction with time pulses T01 through T12 to produce action pulses. The crosspoint generator produces an action pulse when a command signal and a time pulse are ANDed. This is called the crosspoint operation. The branch commands are used to change the action pulse that normally is produced at a given time.

The control pulse gates perform the Boolean NOR function. There is one gate for each control pulse. These gates split the action pulse into as many control pulses as are required for a particular operation. Some of the control pulses produced by the control pulse gates are used by the sequence generator. These include the special purpose control pulses which control the operation of the order code processor and the test control pulses which are applied to the branch control. The other control pulse groups, namely the read, write, and direct exchange control pulses are used in the central processor and the priority control.

The branch control is connected to the write lines of the central processor. Data placed onto the write lines by read control pulses are tested in the branch control. The branch control contains two stages. Branch 1 normally tests for sign and branch 2 tests for full quantities such as plus or minus zero. Both branches test for positive and negative overflow and have the overflow bits written directly into the branch register. Positive overflow is 01 where branch 1 is the high order bit. Negative overflow is 10. The branch commands sent to the crosspoint generator affect the action pulses at given times.

2.3.2.3 Central Processor

All data and arithmetic manipulations within the CMC take place in the central processor (see Fig. 2-45). It primarily performs operations indicated by the basic instructions of programs stored in memory. Communication within the central processor is accomplished through the write amplifiers. Data flows from memory to the flip-flop registers or vice-versa, between individual flip-flop registers, or into the central processor from external sources. In all instances, data is placed on the write lines and routed to a specific register or to another functional area under control of the write, clear, and read logic. This logic section accepts control pulses from the sequence generator and generates signals to read the content of a register onto the write lines, and write this content into another register of the central processor

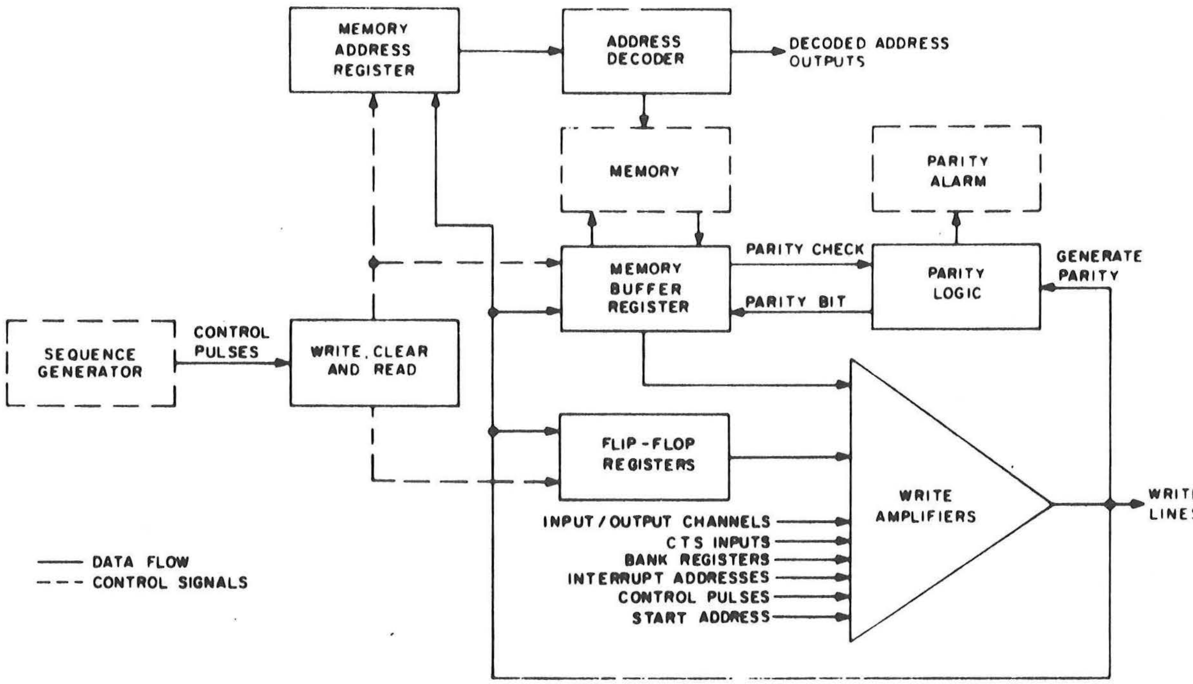


Fig. 2-45. Central Processor Functional Block Diagram.

or to another functional area of the CMC. The particular memory location is specified by the content of the memory address register. The address is fed from the write lines into this register, the output of which is decoded by the address decoder logic. Data is subsequently transferred from memory to the memory buffer register. The decoded address outputs are also used as gating functions within the CMC.

The memory buffer register buffers all information read out or written into memory. During readout, parity is checked by the parity logic and an alarm is generated in case of incorrect parity. During write-in, the parity logic generates a parity bit for information being written into memory. The flip-flop registers are used to accomplish the data manipulations and arithmetic operations. Each register is 16 bits or one computer word in length. Data flows into and out of each register as dictated by control pulses associated with each register. The control pulses are generated by the write, clear, and read control logic.

External inputs through the write amplifiers include the content of both the erasable and fixed memory bank registers, all interrupt addresses from priority control, control pulses, which are associated with specific arithmetic operations, and the start address for an initial start condition. Information from the input and output channels is placed on the write lines and routed to specific destinations either within or external to the central processor.

2.3.2.4 Memory

Memory consists of an erasable memory with a storage capacity of 2,048 words, and a fixed core rope memory with a storage capacity of 36,864 words. (See Fig. 2-46). Erasable memory is a random-access, destructive-readout

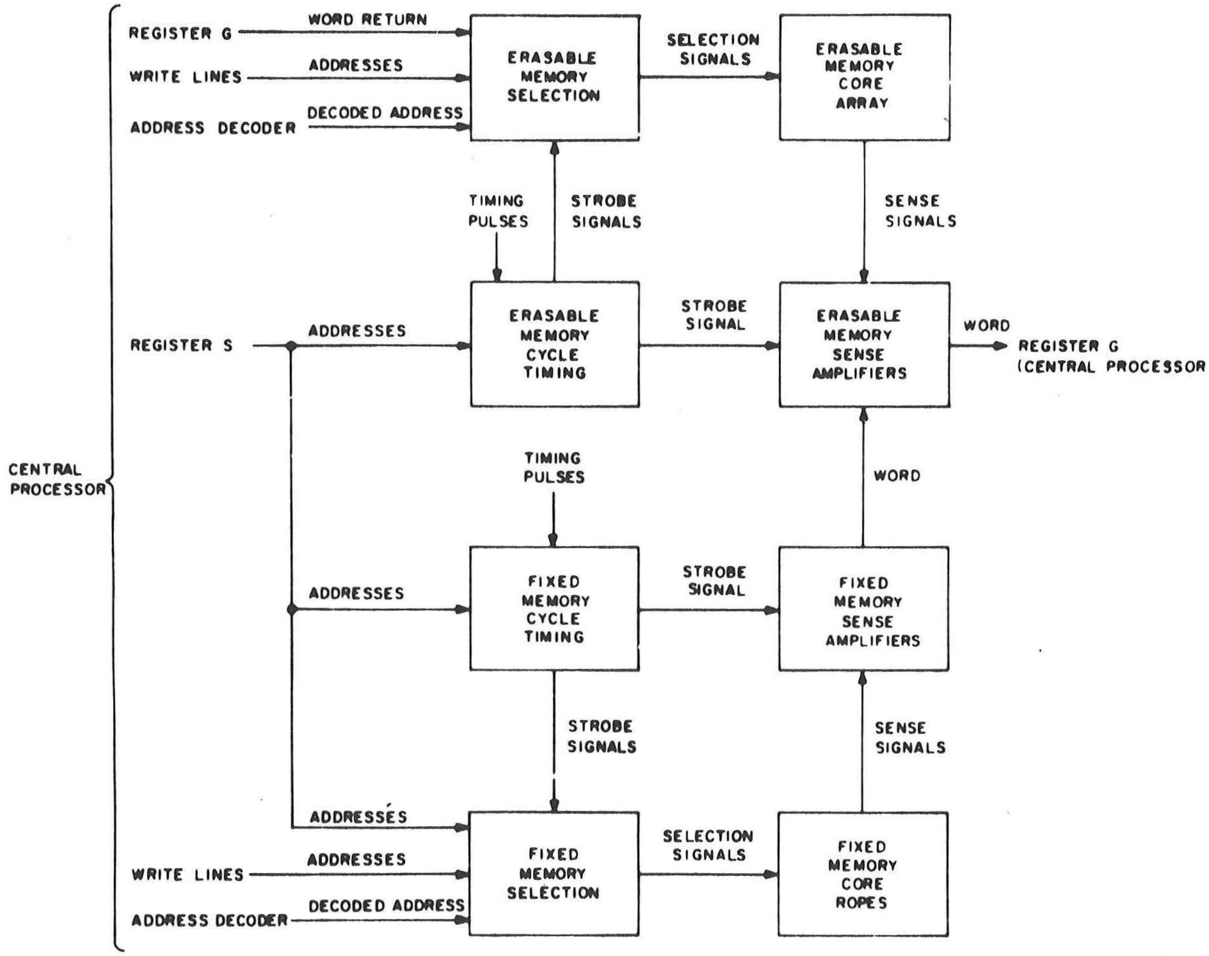


Fig. 2-46. Memory Functional Block Diagram.

storage device. Data stored in erasable memory can be altered or updated. Fixed memory is a nondestructive storage device. Data stored in fixed memory is unalterable since the data is wired in and readout is nondestructive.

Both memories contain magnetic-core storage elements. In erasable memory the storage elements form a core array; in fixed memory the storage elements form three core ropes. Erasable memory has a density of one word per 16 cores; fixed memory has a density of 12 words per core. Each word is located by an address.

In fixed memory, addresses are assigned to instruction words to specify the sequence in which they are to be executed, and blocks of addresses are reserved for data, such as constants and tables. Information is placed into fixed memory permanently by weaving patterns through the magnetic cores. The information is written into assigned locations in erasable memory with the DSKY's, uplink, or program operation.

Both memories use a common address register (register S) and an address decoder in the central processor. When register S contains an address pertaining to erasable memory, the erasable memory cycle timing is energized. Timing pulses sent to the erasable memory cycle timing then produce strobe signals for the read, write, and sense functions. The erasable memory selection logic receives an address and a decoded address from the central processor and produces selection signals which permits data to be written into or read out of a selected storage location. When a word is read out of a storage location in erasable memory, the location is cleared. A word is written into erasable memory through the memory buffer register (register G) in the central processor by a write strobe operation. A word read from a storage location is applied to the sense amplifiers. The sense amplifiers are strobed and the information is entered into register G of the central processor. Register G receives information from both memories.

The address in register S energizes the fixed memory cycle timing when a location in fixed memory is addressed. The timing pulses sent to the fixed memory cycle timing produce the strobe signals for the read and sense functions. The selection logic receives an address from the write lines, a decoded address, and addresses from register S, and produces selection signals for the core rope. The content of a storage location in fixed memory is strobed from the fixed memory sense amplifiers to the erasable memory sense amplifiers and then entered into register G of the central processor.

2.3.2.5 Priority Control

Priority control is related to the sequence generator in that it controls all involuntary or priority instructions. Priority control processes input-output information and issues order code and instruction signals to the sequence generator and twelve-bit addresses to the central processor. (See Fig. 2-47.)

Priority control consists of the start, interrupt, and counter instruction control circuits. The start instruction control initializes the CMC if the program works itself into a trap, if a transient power failure occurs, or if the interrupt instruction control is not functioning properly. The CMC is initialized with the start order code signal, which not only forces the sequence generator to execute the start instruction, but also resets many other CMC circuits. When the start order code signal is being issued, the T12 stop signal is sent to the timer. This signal stops the time pulse generator until all

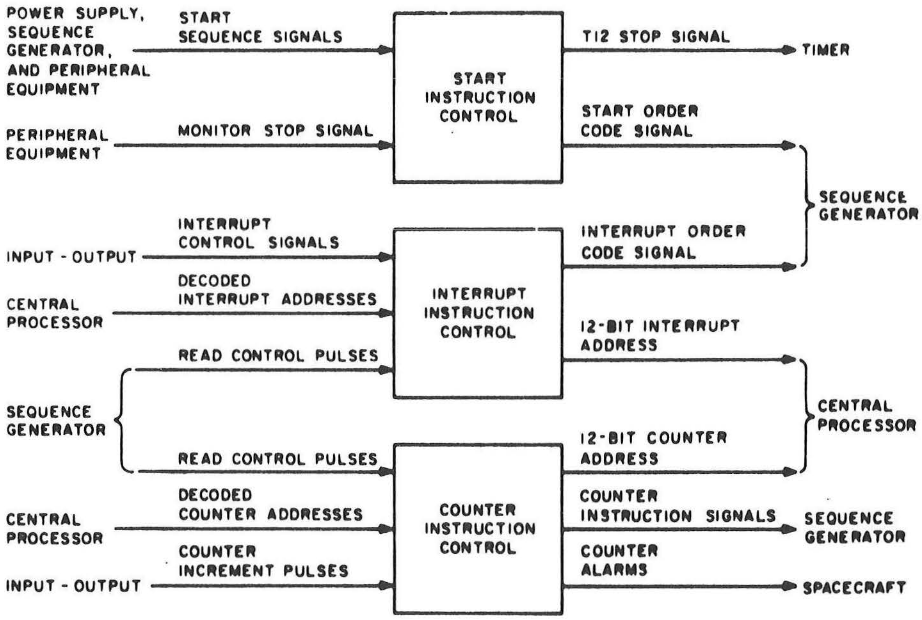


Fig. 2-47. Priority Control Functional Block Diagram.

essential circuits have been reset and the start instruction has been forced by the sequence generator.

The interrupt instruction control can force the execution of the interrupt instruction. This is done with the interrupt order code signal which is sent to the sequence generator and the twelve bit address sent to the central processor. There are ten addresses each of which accounts for a particular function that is regulated by the interrupt instruction control. The interrupt instruction control links the keyboards, telemetry, and time counters to program operations. The interrupt addresses are transferred to the central processor by read control pulses from the sequence generator. The source of the keyboard, telemetry, and time counter inputs is the input-output circuits. The interrupt instruction control has a built-in priority chain which allows sequential control of the ten interrupt addresses. The decoded interrupt addresses from the central processor are used to control the priority operation.

The counter instruction control is similar to the interrupt instruction control in that it links input-output functions to the program. It also supplies twelve-bit addresses to the central processor and instruction signals to the sequence generator. The instruction signals cause a delay (not an interruption) in the program by forcing the sequence generator to execute a counter instruction. The addresses are transferred to the central processor by read control pulses. The counter instruction control also has a built-in priority of the 29 addresses it can supply to the central processor. This priority is also controlled by decoded counter address signals from the central processor. The counter instruction control contains an alarm detector which produces an alarm if an incremental pulse is not processed properly.

2.3.2.6 Input-Output

The input-output section accepts all inputs to, and routes to other subsystems all outputs from the CMC. Most of the input channels and the output channels are flip-flop registers similar to the flip-flop registers in the central processor. (See Fig. 2-48.) Certain discrete inputs are applied to individual gating circuits which are part of the input channel structure. Typical inputs to the channels include keycodes from the DSKY, from other GNCS subsystems, and other spacecraft systems as shown. Input data is applied directly to the input channels; there is no write process as in the central processor. However, the data is read out to the central processor under program control. The input logic circuits accept inputs which cause interrupt sequences within the CMC. These incremental inputs (such as, acceleration data and SXT shaft and trunnion angles) are applied to the priority control circuits and subsequently to associated counters in erasable memory.

Outputs from the CMC are placed in the output channels, and are routed to specific systems through the output interface circuits. The operation is identical to that in the central processor. Data is written into an output channel from the write lines and read-out to the interface circuits under program control. Typically, these outputs include outbits to the reaction control system, the DSKY, the ISS, and OSS. The downlink word is also loaded into an output channel, and routed to the spacecraft telemetry system by the downlink circuits.

The output timing logic gates synchronization pulses (fixed outputs) to the other GNCS subsystems and the spacecraft. These are continuous outputs since the logic is specifically powered during normal operation of the CMC and during standby.

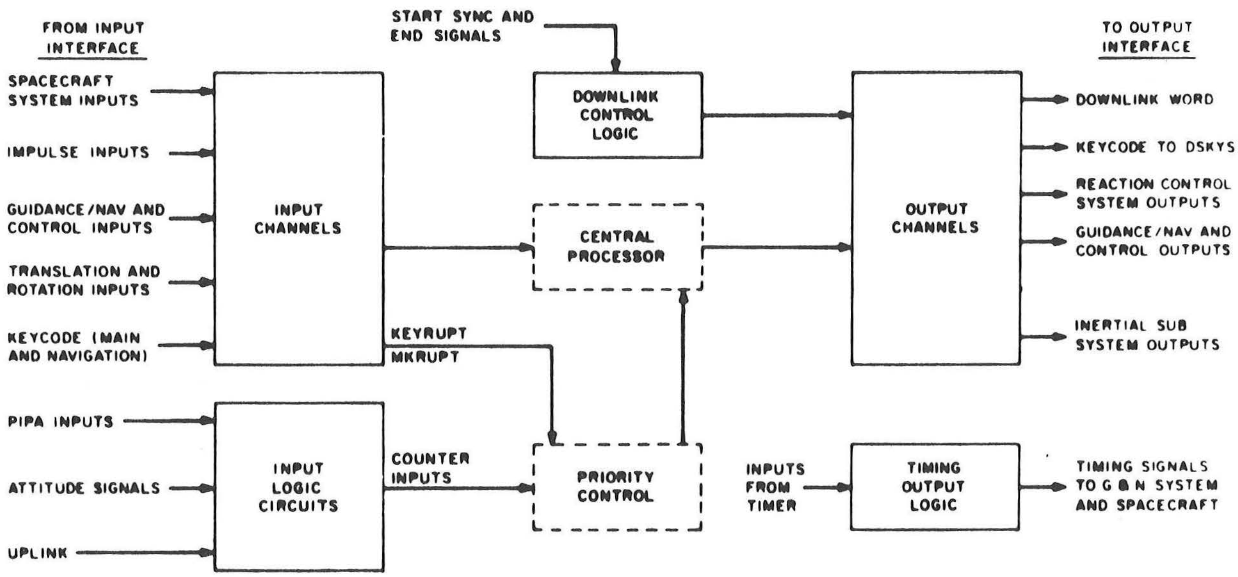


Fig. 2-48. Input-Output Functional Block Diagram.

2.3.2.7 Display and Keyboard

The display and keyboard (DSKY) allows the astronaut to exercise control of the CMC. The DSKY consists of a keyboard, power supply, decoder, relay matrix, status and caution circuits, and displays (see Fig. 2-49).

The keyboard contains the key controls with which the astronaut operates the DSKY. Each of the key controls is lighted by 115 vac, 400 cps. Inputs to the CMC initiated from the keyboard are processed by the program. The results are supplied to either the decoder and relay matrix or to the status and caution circuits for display. Each key when pressed produces a 5-bit code. The keycode enters the CMC and initiates an interrupt to allow the data to be accepted. The key reset signal (+28 vdc) is generated each time a key is released, and conditions the CMC to accept another keycode. The reset code and signal (+28 vdc) is used when the astronaut wishes certain display indicators to go out. It also checks on whether a particular indication is transient or permanent. The clear code is used when the astronaut wishes to clear displayed sign and digit information. Key release turns the control of displaying information on the DSKY over to the CMC. The proceed signal commands the CMC to continue the program without further crew action. It also is used to command the CMC to the standby mode.

The power supply utilizes +28 vdc and +14 vdc from the CMC power supply and an 800 cps sync signal from the timer to generate a 250 volt, 800 cps display voltage. The display voltage is applied to the displays through the relay matrix and status and caution circuits.

The decoder receives a four bit relay word (bits 12 through 15) from channel 10 in the CMC. The decoded relay word, in conjunction with relay

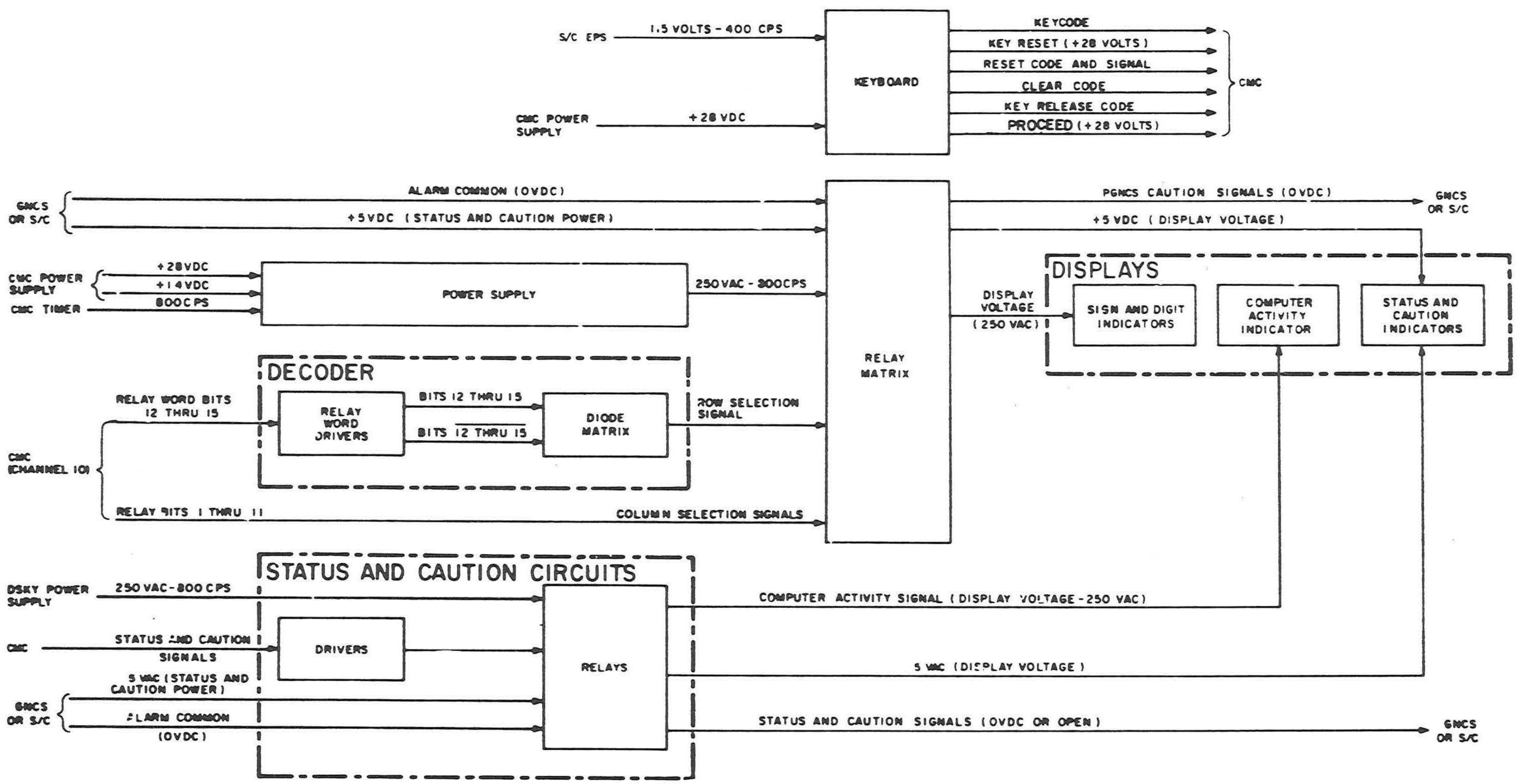


Fig. 2-49. DSKY Functional Block Diagram

bits 1 through 11 from channel 10, energizes specific relays in the matrix. The relays are energized by the coincidence of a selection signal from the diode matrix in the decoder which produces a row selection signal, and relay bits which produce column selection signals. Relay selection allows the display voltage (250 vac) from the power supply to be routed to the proper sign and digit indicators. Relay selection also allows the alarm common (0 vdc), or +5 vdc from the GNCS, or +5 vdc from the spacecraft to be routed through the relay to the GNCS, or the spacecraft (caution signals), or the proper status and caution indicators, respectively. All relays associated with the relay matrix are the latching type.

The status and caution circuits receive all CMC status and caution signals. Each signal is applied to a driver circuit and to an associated relay. When a relay is energized, it allows the voltage from the DSKY power supply (250 vac) or +5 vdc or 0 vdc from the GNCS or spacecraft to be routed to the proper display indicators or equipment. The voltage from the power supply is routed through a relay to the computer activity indicator (COMP ACTY). The +5 vdc is routed through relays to the following status and caution indicators: UPLINK ACTY, RESTART, OPR ERR, KEY REL, and TEMP.

The displays consist of sign and digital (operational and data display) and status and caution indicators. The sign and digital indicators allow the astronaut to observe the data entered or requested from the keyboard. The status and caution indicators present an indication of any variance from certain normal operations.

2.3.3 CMC Power Supplies

The CMC power is furnished by the switching regulator power supplies, +4 volt and +14 volt. (See Fig. 2-50.) Primary +28 vdc power is applied to the power input circuit of the +4 vdc power supply, filtered, and applied to the power output circuit. A second filter supplies output +28 COM to both the CMC and the DSKY. A zenor diode regulator in the power input circuit supplies +9.2 vdc to the voltage regulator. The voltage regulator is a parallel regulator which operates on a 50 kc sync signal from the timer. The 50 kc signal triggers a multivibrator circuit in the voltage regulator, the output of which is of sufficient duration to provide 4 vdc to the power output circuit. The 4 vdc output is regulated by feedback from the power output circuit.

Operation of the +14 volt power supply is identical to the +4 volt power supply with the exception that a 100 kc sync signal is used instead of 50 kc.

Standby operation, which is initiated by the PRO button on the DSKY, allows the CMC to conserve power by operating in a low power mode. (Retention of stored data is maintained during the standby state.) Signal SBYREL disables the +4 SW and BPLSSW outputs during the standby mode.

2.3.4 CSS Modes of Operation

The mission is divided into programs. The currently active program is displayed as a two-digit, decimal number in the DSKY program display. A few programs are automatically entered upon termination of a previous program: e.g., entry programs. Most programs are initiated by the crew through the DSKY.

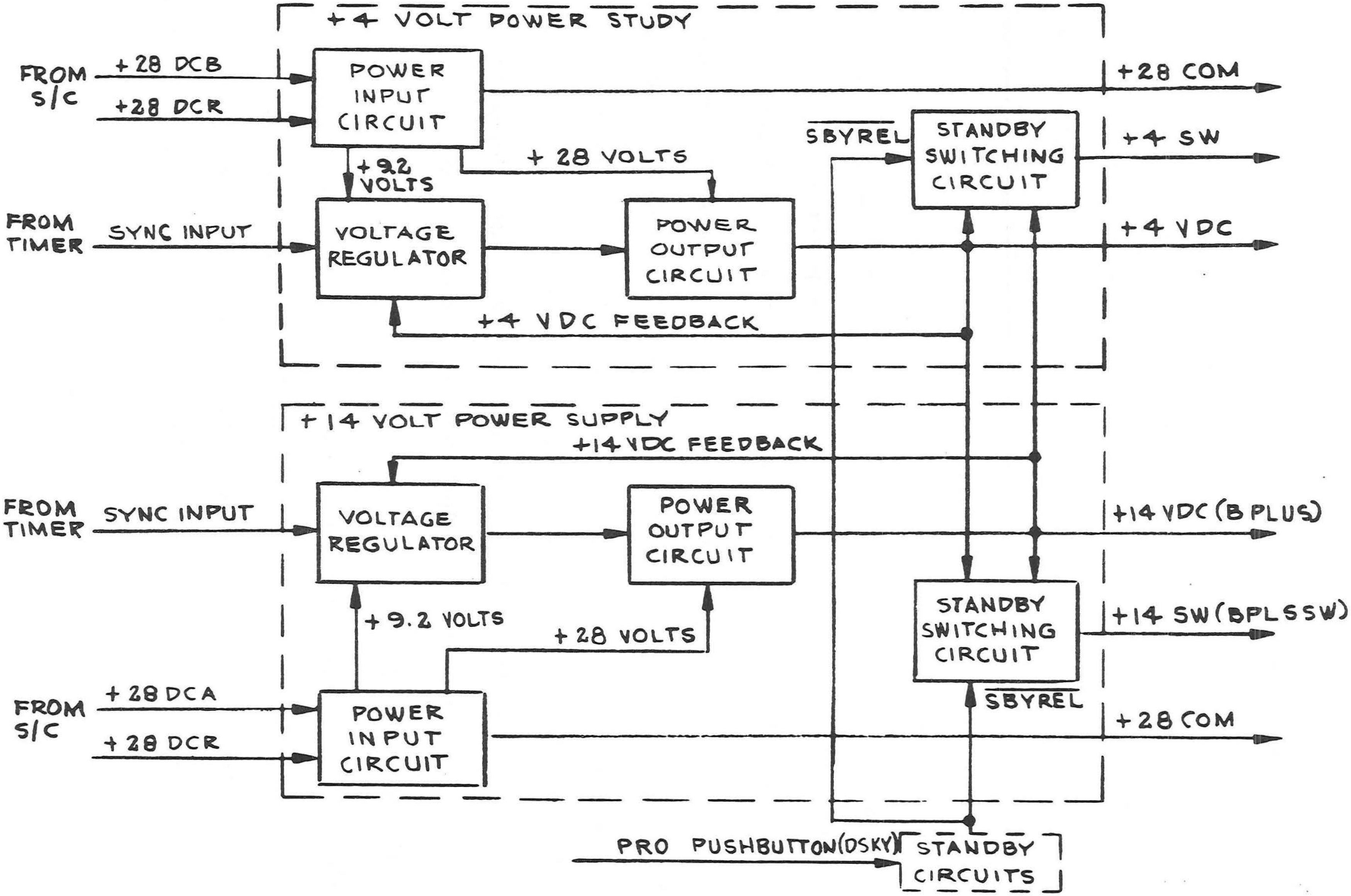


Fig. 2-50. CMC Power Supplies Functional Block Diagram.

Submodes which consist of routines or a component of a routine are normally performed in succession automatically or semiautomatically. Some subroutines may be specifically called for by the crew by selecting the specific keyboard combinations. Upon completion of any subroutine, the entire routine may be halted by DSKY entry.

A CMC standby state is entered by pressing the PRO pushbutton on the DSKY (see paragraph 2.3.3). During this state, the maximum average CMC power dissipation drops from 100 watts to 10 watts.

2.3.5 CMC Monitoring

2.3.5.1 CMC Alarm Detection Circuits

The alarm detection circuits perform monitoring and conditioning of some key CMC signals. These circuits do not particularly belong to any of the functional areas described in paragraph 2.3.2, but monitor and provide alarm signals to many of these circuits (see Fig. 2-51).

The voltage alarm circuit monitors (by means of differential amplifiers) the +28 COM, +14 vdc, and +4 vdc outputs from the CMC power supplies and generates a signal VFAIL for an out-of-limits condition or complete failure of any one of these power supplies. Signal VFAIL, conditioned by timing signals, generates signal STRT1 from the logic circuits, provided it is not inhibited by interface signal NHVFAL. Signal STRT1, when applied to priority control, prevents counter instructions from being executed. Simultaneously, if the computer is in the standby mode, an input (FILTIN) is issued to the warning integrator. This input is controlled by signal STNDBY.

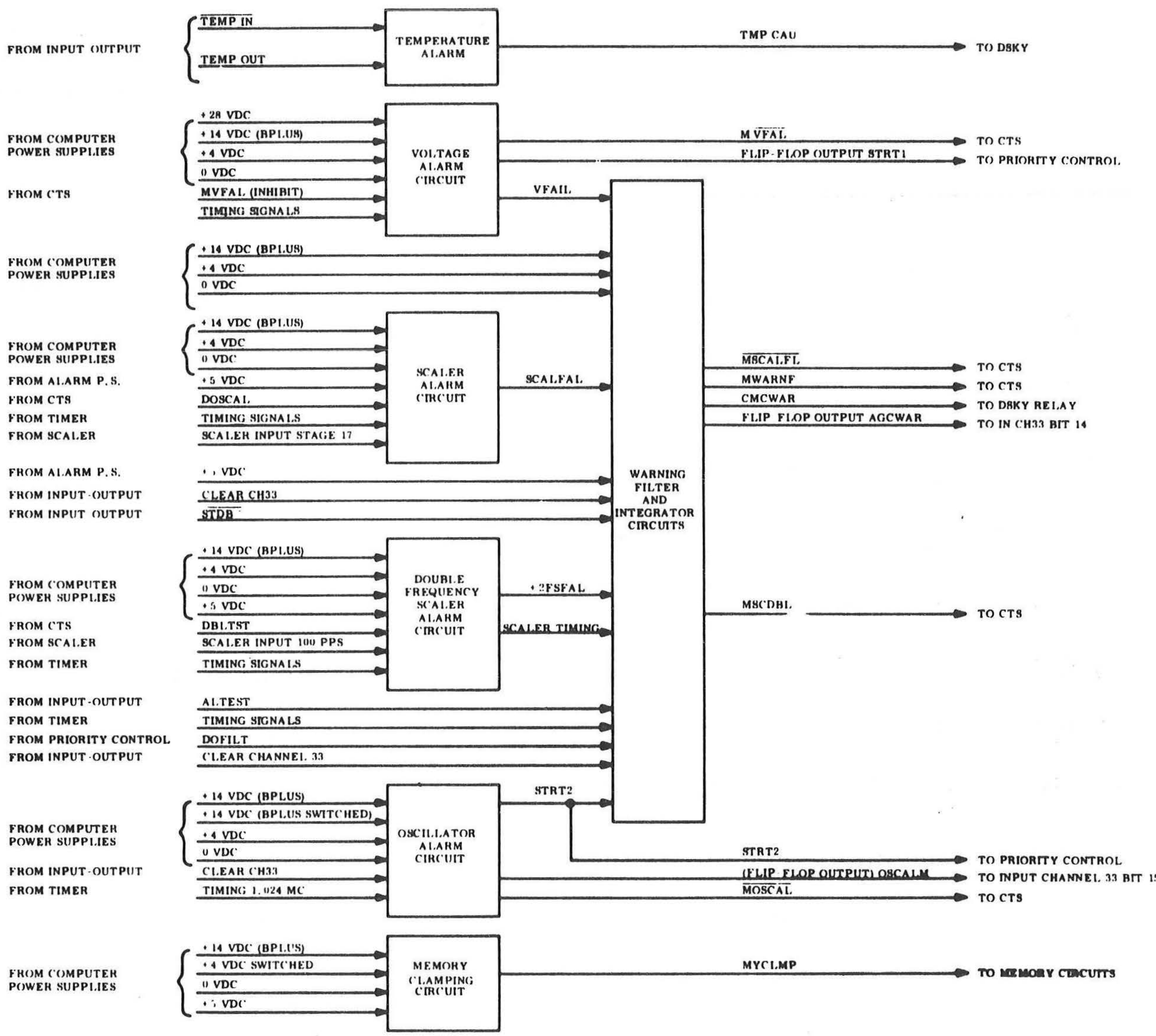


Fig. 2-51. CMC Alarm Detection Circuits Functional Block Diagram

The oscillator alarm circuit generates signal STRT2 if the CMC 2.048 megacycle oscillator should fail or if the CMC is in the low power mode (standby). A delay circuit in the oscillator alarm assures signal STRT2 is applied to priority control to prevent the counter instructions from being executed. This condition remains until the oscillator starts running. Signal STRT2 also causes the generation of signal OSCALM from the logic circuits to input channel 33, bit position 15.

There are two scaler alarm circuits in the CMC: scaler alarm and double frequency scaler alarm. The scaler alarm provides a check on the timer, scaler stage 17 and generates signal SCAFAL when stage 17 fails to produce pulses. Signal SCAFAL generates signal CMCWAR directly from the logic circuits to the input-output channels that interface with relays in the DSKY. Double frequency scaler alarm generates signal 2FSFAL if the 100 pps scaler signal (signal SCASIO from the logic circuits conditioned by timer signals) should fail. Signal 2FSFAL provides an input to signal FILTIN which causes signal CMCWAR to be generated.

The warning integrator initiates the generation of warning signal CMCWAR from the logic circuits. Input signal FILTIN, conditioned by timing signals, represents restart or counter fail signal (DOFILT), voltage fail in standby mode, alarm test signal (ALTEST), or double frequency scalar alarm.

If either CMC power supply is out of limits or fails completely or if the CMC is in the standby mode, the MYCLMP circuit output inhibits access to memory. Operation of the MYCLMP circuit is identical to that of the voltage alarm circuit. It employs a differential amplifier that has a threshold voltage applied to it. If the +4 volt input voltage falls below this threshold signal, MYCLMP goes high indicating an alarm condition.

The incorporation of a +5 vdc source within the alarm detection circuits eliminates the need for more semiconductors, and components normally used where a reference voltage is required.

The IMU stable member temperature is also monitored by the alarm circuits. Signal TEMPIN, an indication that the stable member temperature is outside its design limits, causes signal TMPCAU to be generated and routed to the DSKY for display (TEMP).

2.3.5.2 Caution and Warning Indications

The caution and warning indicators associated with the CSS are the CMC and ISS warning lamps on the MDC and LEB G & N panels; and RESTART, TEMP, GIMBAL LOCK, PROG, and TRACKER on the DSKY. Whenever a failure is sensed, one or more of these lights come on, the MASTER ALARM lamp lights, and an audible tone is introduced into the headsets of all crew members. The tone may be stopped and the MASTER ALARM light put out by pressing the MASTER ALARM pushbutton, but the appropriate warning light remains on until the trouble is cleared up.

Each of the caution and warning indicators are actuated by relays contained in the DSKY. A generalized logic diagram of CMC and DSKY circuits is contained in Fig. 2-52. Each OR gate immediately preceding an indicator is a representation of DSKY relay logic. (Table 2-1 describes some of the caution and warning signals.)

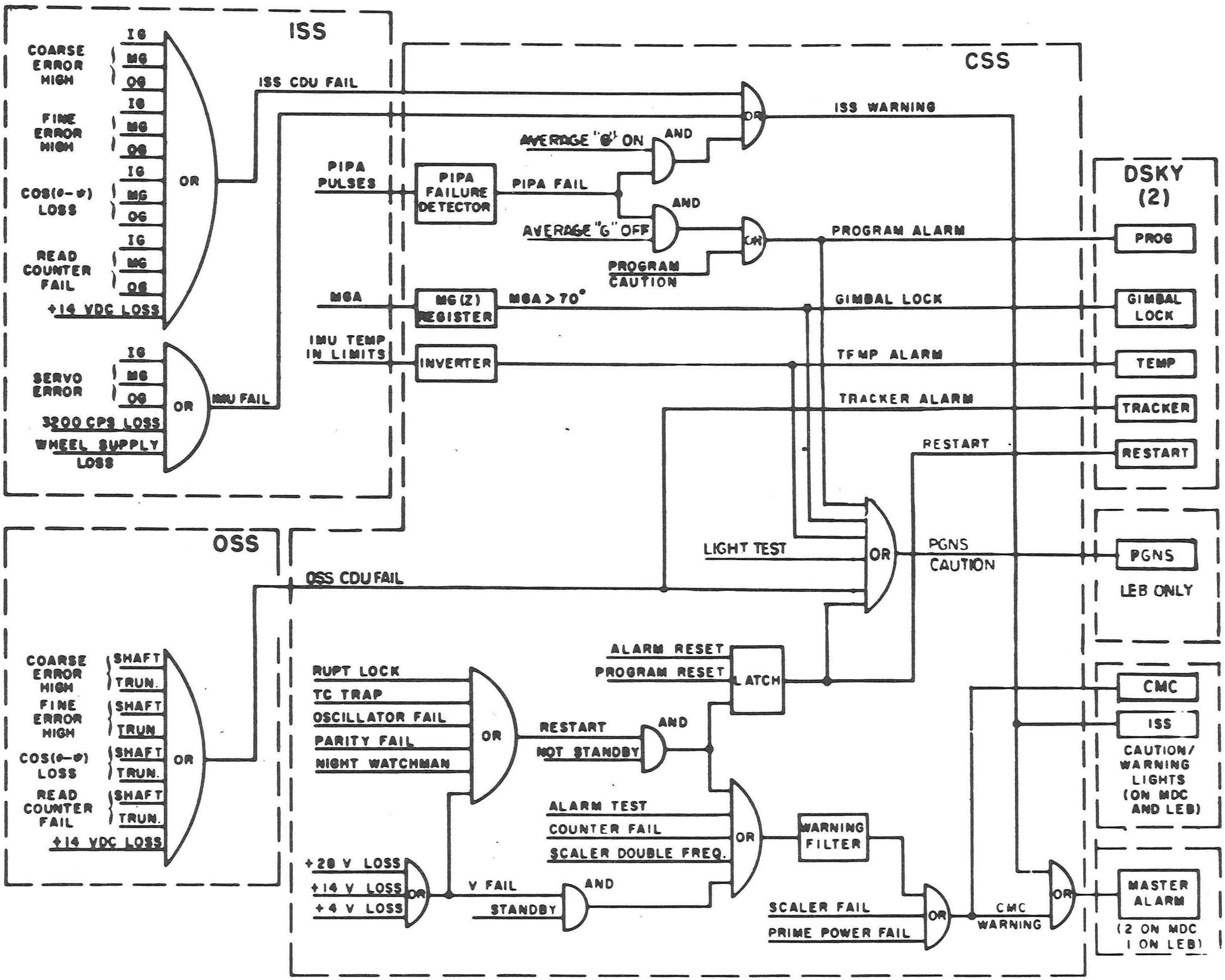


Fig. 2-52. Caution and Warning Indicator Logic Diagram

Signal	Description
Rupt Lock	Occurs if interrupt is too long or too infrequent. The criterion for "too long" is phase dependent varying from 140 ms to 300 ms. Likewise, the criterion for "too infrequent" varies from 140 ms to 300 ms.
TC Trap	Occurs if too many TC or TCF (transfer control) instructions are run or are too infrequent. The criterion for "too many" varies from 5 ms to 15 ms duration and for "too infrequent" it varies from 5 ms to 15 ms absence.
Oscillator Fail	Occurs if CMC 2.048 mc oscillator stops. A 250-millisecond delay keeps the fail signal present after the oscillator starts.
Parity Fail	Occurs when parity test fails. CMC uses odd parity and tests every word read out of memory above address octal 10.
Night Watchman	Occurs if the computer should fail to access address 67 within a period whose duration varies from 0.64 seconds to 1.92 seconds.
Restart	Occurs when any of the preceding signals are present and the CMC is in the operate mode (not in standby). Also is caused by certain routines and can be forced by DSKY entry. It causes the CMC to return to a prior point in the program and lights the RESTART indicator. It is reset by an alarm reset or program reset.
Alarm Test	Test input for checking CMC alarm circuits.
Counter Fail	Occurs if counter increments happen too frequently or else fail to happen following

Table 2-1. Description of Caution and Warning Activation Signals (Sheet 1 of 4)

Signal	Description
	an increment request. "Too frequently" means continuous counter request and/or incrementing for from 0.625 ms to 1.875 ms.
Double frequency scaler fail	Occurs if the 100 pps scaler stage operates at a pulse rate of 200 pps or more.
V Fail	Occurs if the CMC voltages (28, 14, 4) are out of limits. The following criteria apply for V fail: 4V supply > 4.4V 14V supply > 16V 4V supply < 3.65V 14V supply < 12.5V 28V supply < 22.6V
Standby	Turns off the switchable +4 and +14 vdc, thus putting the CMC into a low power mode where only the scaler, timing signals, and a few auxiliary signals are operative. Standby is initiated by first setting the ENABLE STANDBY outbit (Channel 13, bit 11), and then pressing the PRO button on the DSKY for a time, which varies from 0.64 seconds to 1.92 seconds. All CMC alarms are inhibited during the standby mode with the exception of CMC warning, which can be caused by a prime voltage failure or scaler fail; and TEMP caution, which can be caused by temperature alarm issued when IMU temperature is out of limits.
Scaler Fail	Occurs if scaler stage 17 (1.28 sec. period) fails to produce pulses. This provides a check on the timing for all logic alarms.
Prime Power Fail	Occurs if +28 vdc prime power falls below 23 volts.

Table 2-1. Description of Caution and Warning Activation Signals (Sheet 2 of 4)

Signal	Description
ISS CDU Fail	Occurs under the following conditions (but not during CDU zero moding): 1) CDU fine error in excess of 1.0 vrms 2) CDU coarse error in excess of 2.5 vrms 3) Read counter limit cycle in excess of 160 cps 4) Cos$(\theta-\psi)$ below 2.0 volts 5) +14 volt supply ±4 volts
IMU Fail	Occurs under the following conditions (but not during coarse align or the 5 second interval following coarse align): 1) IG Servo Error - Greater than 2.9 milliradians for 2 seconds 2) MG Servo Error - Greater than 2.9 milliradians for 2 seconds 3) OG Servo Error - Greater than 2.9 milliradians for 2 seconds 4) 3200 cps decrease to 50% of nominal level 5) 800 cps wheel supply decrease 50% of nominal level
PIPA Fail	Occurs if no pulses arrive from an accelerometer during a 312.5 micro-second period, or if both plus and minus pulses occur, or if a long duration (1.28s to 3.84s) without at least one plus pulse and one minus pulse arriving. The CMC only generates the ISS warning signal when the accelerometer outputs are being used.

Table 2-1. Description of Caution and Warning Activation Signals (Sheet 3 of 4)

Signal	Description
Gimbal Lock	Occurs when the IMU middle gimbal angle (MGA) exceeds 70°. (When the MGA exceeds 85°, the ISS is downmoded to coarse align and the NO ATT indicator on the DSKY is activated). Gimbal lock is defined as a condition in which the IMU middle gimbal has moved to a position such as to make the outer and inner gimbal axes colinear. When the middle gimbal angle reaches 70°, the CMC issues a warning of the impending gimbal lock (in excess of 85°, where the stabilization loops become unstable).
Temp out of limits	Occurs when stable member temperature is outside the range $126.3^{\circ}F$ to $134.3^{\circ}F$.
OSS CDU Fail	Occurs under the following conditions (but not during CDU zero moding): 1) CDU fine error in excess of 1.0 vrms 2) Read counter limit cycle in excess of 160 cps 3) $\cos(\theta-\psi)$ below 2.0 volts 4) +14 volt supply ±4 volts
Program Caution	Caused by a program alarm. (See paragraph 2.3.5.3 for description.)
Light Test	Tests RESTART and STBY lights.
Alarm Reset	Furnishes a reset from the DSKY for RESTART and OPR ERR indicators.
Program Reset	A reset for the RESTART indicator from the program, issued if the problem which caused the restart has gone away.

Table 2-1. Description of Caution and Warning Activation Signals (Sheet 4 of 4)

2.3.5.3 Program Alarms

The program alarm is a program-controlled alarm that is issued when a program check has failed. The program alarm lights the PROG alarm indicator on the DSKY.

Upon issuance of the program alarm, the CMC also issues a five-digit error code. Some of these error codes are automatically displayed on the DSKY by program action. The other error codes must be displayed manually by keying V5N9E. The error code(ALARM CODE), indicates the specific condition that caused the alarm, and thereby, provides diagnostic data to an information level at which the crew can make effective decisions. The alarm codes are listed in Table 2-2.

The alarm codes are displayed as followed:

R1 = First alarm following error reset

R2 = Second alarm following error reset

R3 = Most recent alarm

Keying the Error Reset button will set R1 and R2 to zero but will <u>not</u> affect R3.

Displayed POODOO alarms are prefixed with a two, for example alarm 01103 is now 21103. Displayed BAILOUT alarms are prefixed with a three, for example alarm 01104 is now 31104.

00110	No marks since last marks reject. Indicates that operator pressed mark reject button unnecessarily.	Key RSET. Continue normal operation.
00112	Marks not being accepted. Indicates mark reject while CMC not accepting marks.	Key RSET. Continue normal operation.
00113	No inbits in low seven bits of channel 16. Not very likely to occur. Can only occur in markrupt program which is entered by mark, mark reject, or DSKY keycode, each of which sets one of the low seven bits of channel 16.	Key RSET. Reattempt the entry into Markrupt program which failed (mark, mark reject, or keycode). If alarm recurs, desired entry is not possible.
00114	Mark made but not desired.	Key RSET. Continue normal operation.
00115	Optics torque request when optics is not in CMC mode.	Set optics mode switch to CMC and optics zero sw to zero.
00116	Optics switched from zero mode before 15 second zeroing time has elapsed.	Set optics zero switch to zero. Key RSET. Wait 15 seconds and continue normal operation.
00117	Optics torque request when optics not available. Occurs when V41 N91 is attempted while CMC has reserved OCDU's for other use.	Key RSET. (V41 N91 cannot be performed at this time.)
00120	Optics torque request with optics not zeroed.	Set optics zero switch to off, then to the zero position. Key RSET. Wait 15 seconds and continue normal operation.

Table 2-2. Computer Alarms (Sheet 1 of 9)

00121	CDUS no good at time of mark. Occurs if a mark is made at the time of a CDU switching transient.	Repeat mark.
00122	Marking not called for. Indicates a mark was made while CMC was not in the mark program.	Key RSET. Continue normal operation.
00124	No solution to TPI search calculation.	Key RSET. Key V32E. Readjust GETI (TPI) and /or change search option.
00205	PIPA saturated. Occurs during average G routine if a PIPA register equals or exceeds 6400 pulses in two seconds. This is equivalent to an acceleration of over 19 G's. Most likely will occur with an ISS warning light.	Switch to SCS control. Follow malfunction procedure for ISS warning light. IMU probably unuseable for velocity measurements.
00206	Zero encode not allowed during coarse align with gimbal lock. In this condition, zero encoding can only be done by first commanding coarse alignment to zero by V41.	Key RSET. Key V41 N20E and load 00000E 00000E 00000E Key V40 N20E.
00207	ISS turn-on not present for 90 seconds.	Key RSET. Reinitiate ISS turn on sequence.
00210	IMU not operating.	Key RSET. Perform ISS turn-on sequence. Reinitiate desired program.

Table 2-2. Computer Alarms (Sheet 2 of 9)

00211	Coarse align error. Occurs when gimbal angles are not within two degrees of commanded position at completion of coarse alignment.	To determine magnitude of error key V06 N20E for display of gimbal angles. If in P51, P52, P53, or P54 continue alignment. Record GYRO torquing angles. Do fine align check in P52 or P54. If doing V41N20, terminate V41. Alignment must be done by an alignment program.
00212	PIPA failure while PIPA's are not in use.	Key RSET. Perform PIPA bias check. If alarm persists GNCS TVC and entry capability may be lost.
00213	IMU not operating with turn on request.	Key RSET. Perform ISS turn on sequence
00214	ISS turned off while in use.	See alarm 00213.
00217	Bad return from stall routines. Indicates ISS mode switching failure.	Key RSET. Reinitiate current program; If alarm recurs, terminate use of ISS.
00220	IMU not aligned - no REFSMMAT.	Key RSET. Perform routine R00 and an IMU alignment program. Reinitiate desired program.
00401	Desired gimbal angles yield gimbal lock	Key RSET. Either select new gimbal angles or maneuver spacecraft to avoid gimbal lock.

Table 2-2. Computer Alarms (Sheet 3 of 9)

00404	Target out of view (90 degree test). Occurs during auto optics positioning if the computed trunnion angle is greater than 90 degrees.	Perform A or B and key RSET: A) Manually maneuver spacecraft until optics can acquire target. Key PRO B) Terminate auto-optics positioning routine. Key V34E.
00405	Two useable stars not available	Perform A, or B: A) Maneuver spacecraft until two useable stars are manually acquired, then key PRO. B) Maneuver spacecraft until two useable stars may be automatically acquired, then key V32E.
00406	Rendezvous navigation program not operating. Occurs if (R21) or (R23) is requested when rendezvous navigation program (P20) is not running.	Key Key Rel. Key RSET. (R22) cannot be performed).
00407	Target out of view (50 degree test). Occurs during auto optics positioning if computed trunnion angle exceeds 50 degrees.	Perform A or B and key RSET: A) Manually maneuver to preferred attitude. 1) key V16N22E for desired gimbal angles 2) V16N92E for desired optics angles B) Automatic maneuver 1) set SC Cont to CMC and/or key V58E
00421	W Matrix overflow. Indicates that W Matrix has been integrated forward without new navigation updates for so long a time that terms in the matrix exceed their scale factors.	Key RSET. Get state vector update from ground (P27).

Table 2-2. Computer Alarms (Sheet 4 of 9)

00600	Imaginary Roots on First Iteration	Reset/V32E Adjust Input Parameters
00601	HP Post CSI Low	See Alarm 600 for Response
00602	HP Post CDH Low	See Alarm 600 for Response
00603	TIG CSI-CDH is Less Than 10 Minutes	See Alarm 600 for Response
00604	TIG CDH-TPI is Less Than 10 Minutes	See Alarm 600 for Response
00605	Iteration Exceeds Loop Maximum	See Alarm 600 for Response
00606	Delta V Exceeds Maximum	See Alarm 600 for Response.
00611	GETI (TPI) does not exist for given elevation angle (E).	Key PRO Key RSET
00612	State vector in wrong sphere of influence at GETI. Occurs during return to earth program if the state vector at GETI is in the moon's sphere of influence.	See alarm 00600
00613	Reentry angle out of limits. Occurs during return of earth program if the desired flight path angle cannot be reached.	See alarm 00605
00777	PIPA fail caused the ISS Warning set by T4RUPT.	Key RSET Perform PIPA Bias Check.

Table 2-2. Computer Alarms (Sheet 5 of 9)

01102	Self test error.	Reinitiate self test. If failure recurs, self test has failed. CMC may not be useable.
01105	Down telemetry too fast. Occurs when end of word pulse rate of downlink exceeds 100 pps.	Key RSET. Notify MSFN.
01106	Up telemetry too fast. Locks out uplink when incoming bit rate exceeds 6400 bits per second.	Request MSFN to retransmit up telemetry data. Key RSET. If alarm recurs, perform CMC update by voicelink.

Note: Alarm 01107 and others are intended for CMC testing and debugging. They are not likely to occur in flight.

01107	Phase table does not agree after restart.	CMC does automatic fresh start. Reinitialize erasable memory.
01301	Arcsine, arccosine input too large. (See note preceding alarm 01107.)	See alarm 31201
01407	Velocity to be gained increasing.	Terminate thrusting Check orbital parameters and reinitiate orbit change targeting and thrust as necessary.
01426	IMU unsatisfactory. Occurs during entry (P61 or P62) if the spacecraft +Y or -Y axis is not within 30 degrees of V X R. This condition may result in an excessive MGA during entry guidance causing a gimbal lock alarm.	Key RSET. If there is sufficient time, realign IMU. If not, the crew has the option to continue with GNCS entry or to switch to SCS or manual entry control.
01427	IMU reversed. Occurs during entry (P61 or P62) if the spacecraft -Y axis is within 30 degrees of V X R.	Key RSET. Continue normal operation but note that FDAI indication is inverted; I.E. 0 degrees roll is lift down and 180° is lift up.

Table 2-2. Computer Alarm (Sheet 6 of 9)

01520	Verb 37 not allowed at this time. Occurs when program change is attempted when it is not allowed.	Key RSET. Do not attempt to change programs until allowed.
01600	Overflow in drift test. For ground test only.	Cannot occur in flight.
01601	Bad IMU torque. For ground test only.	Cannot occur in flight.
01602	Bad optics verification.	Cannot occur in flight.
01703	Insufficient time to integrate state vector. Occurs if the state vector cannot be integrated to GETI defined in P40 or P41.	Key RSET. GETI is automatically slipped to a later time.
03777	ICDU fail caused ISS warning (Channel 30, bit 12).	Use ISS warning malfunction procedure
04777	ICDU and PIPA fail caused ISS warning (Channel 30, bit 12 and Channel 33, bit 13).	Same as 03777.
07777	IMU fail caused ISS warning. (Channel 30, bit 13).	Same as 03777.
10777	IMU and PIPA fail caused ISS warning (Channel 30, bit 13 and Channel 33, bit 13).	Same as 03777.
13777	IMU and ICDU fail caused ISS warning (Channel 30, bits 12 & 13).	Same as 03777.
14777	IMU, ICDU, and PIPA fail caused ISS warning (Channel 30, bit 12 and 13, and Channel 33, bit 13).	Same as 03777.
20430	ACC Overflow in Integration	Reset/Reinitiate Prog
20607	No Solution from time theta or time radius	Reset/Reinitiate Prog
20610	Altitude at ignition less than 400K'.	Reselect P37 and decrease TIG.

Table 2-2. Computer Alarms (Sheet 7 of 9)

21103	Unused CCS branch. Intended for program debugging; not likely to occur in flight.	Key RSET Terminate and reinitiate program. If alarm recurs, perform CMC self check.
21204	NEG or zero Waitlist Call	See alarm 31201
21206	Second job attempts to go to sleep via keyboard and display program. (See note preceding alarm 01107.)	See alarm 31201
21210	Two programs attempting to use stall routine. Certain programs use stall routine to wait for completion of input/output operations. Alarm occurs if a second program tries to use stall routine before first program is done with it.	See alarm 31201
21302	Square root routine called with a negative argument. (See note preceding alarm 01107.)	See alarm 31201
21501	Keyboard and display alarm during internal use. Intended for ground checkout; not likely to occur in flight.	Terminate and reinitiate program. Key RSET. If alarm recurs, perform CMC self check.
21502	Illegal use of flashing display. Intended for ground checkout; not likely to occur in flight.	See alarm 21501
21521	(P01) or P07) Illegally called.	Reset/Call Legal Prog
31104	Delay routine busy. intended for CMC checkout; not likely to occur in flight.	See alarm 01103.

Table 2-2. Computer Alarms (Sheet 8 of 9)

31201	No vacant areas available. Occurs when more than five jobs requiring VAC areas are requested at the same time. (See note preceding alarm 01107.)	Terminate and reinitiate program. Key RSET. If alarm recurs, perform CMC self check.
31202	No core sets available. Occurs when more than seven jobs are requested at one time. (See note preceding alarm 01107.)	See alarm 31201
31203	Waitlist overflow - too many tasks. Occurs when more than seven tasks are requested at one time. (See note preceding alarm 01107.)	See alarm 31201
31207	No vacant areas available for marks. Occurs if SXTMARK is called (R53, R56, and P03) when all five VAC areas are filled. (See note preceding alarm 01107.)	See alarm 31201
31211	Illegal interrupt of extended verb. Occurs when an internal program requests marking while marking system is already in use or an extended verb is active. (See note preceding alarm 01107.)	See alarm 31201

Table 2-2. Computer Alarms (Sheet 9 of 9)

2.4 RENDEZVOUS RADAR TRANSPONDER

The rendezvous radar transponder on the CSM receives from the LM the rendezvous radar (RR) X-band CW signal and retransmits back to RR a phase coherent return signal. The return signal is offset in fundamental carrier frequency from the received signal by 40.8 mc and contains the same modulation components phase related with respect to the received signal.

During the coast phase of the descent to the lunar surface, the LM and CSM maintain continuous radar contact through the rendezvous radar - transponder link. At the end of the lunar stay, the RR is used to track the transponder in the orbiting CSM to obtain orbital parameters, which are used to calculate the launching of the LM into a rendezvous trajectory.

In the rendezvous phase, the LM and CSM again maintain radar contact to obtain information needed for midcourse correction, rendezvous, and docking operations. By accepting the weak RR signal, and retransmitting back to the RR the phase coherent return signal, the range capabilities of the RR are greatly increased as power losses are reduced from fourth power to second power.

2.4.1 RR Transponder Modes

There are three modes of operation of the RR transponder.

2.4.1.1 Signal Search Mode

In the signal search mode the transponder transmits a CW signal. The frequency is swept ± 104 kc about the nominal transmit frequency of 9792 mc with a sawtooth function at a rate of approximately 0.5 cps, and 208 kc total deviation.

The Transponder is in the signal search mode at all times that the transponder is on and no signal is being received from the RR.

2.4.1.2 Transponder Mode

In the transponder mode the transponder provides a CW, sinusoidally phase modulated signal, at a frequency equal to that received from the RR, multiplied by 240/241. The phase modulation is at frequencies of 204.8 kc, 6.4 kc, and 200 cps $\pm$ .0015%.

The transponder is in the transponder mode at all times that a signal is being received from the RR and the power is on. Signals equal to or greater than -123 dbm which fall within the transponder frequency range are automatically detected and acquired by the transponder.

2.4.1.3 Self Test Mode

The self test mode permits testing of the transponder without a signal from the RR. The self test is performed by switching on the systems test panel (101).

SECTION 3

INTERFACE OF THE GNCS WITH OTHER CSM SYSTEMS

3.1 FLIGHT CONTROL INTERFACE

Primary attitude and thrust control, throughout all mission phases, is performed by the GNCS through interfaces with the stabilization and control system (SCS), reaction control system (RCS), and service propulsion system (SPS). In case of GNCS failure, the SCS provides backup attitude and thrust control. During the boost (P11) the GNCS may also be used to control the Saturn autopilot. Flight control operations of the GNCS are performed through the three digital autopilots (DAP's) within the CMC: the reaction control system DAP, the thrust vector control DAP, and the entry DAP.

For DAP operation the spacecraft must be under GNCS control (SC CONT switch set to CMC) and the IMU must be in the inertial mode, except for RCS DAP operation in the FREE mode. The crew controls DAP operation by the selection of the programs which use the DAP's and through the capability of changing DAP coefficients. Changes to DAP data required by normal operations are made through DAP data load routine R03. This routine provides three nouns which display the following information:

Noun 46 - Vehicle configuration, deadband, rate, and quad fail codes.

Noun 47 - Weights of CSM and LM

Noun 48 - Pitch and yaw trim gimbal offset

These parameters may be changed when necessary by normal DSKY operation.

3.1.1 Reaction Control System DAP

The RCS DAP controls spacecraft attitude and attitude rates through commands to the service module RCS jets. The CMC receives attitude data from the IMU through the ICDU's and computes the attitude rates. The CMC generates on-off commands to the RCS jets, based on the attitude and rate errors. A jet selection logic then chooses the jets to be fired.

3.1.1.1 Automatic Control

In the attitude hold mode, vehicle attitude error and body rates are used to compute jet firing commands to maintain the spacecraft within a designated attitude deadband. This deadband is displayed with noun 46 in the bit D position (fourth from left) of register 1. A 0 in bit D designates a ±0.5 degree deadband and a 1 designates a ±5.0 degree deadband. The attitude hold mode is in effect when the CMC is in the HOLD mode and no manual attitude commands are present and in the AUTO mode when no manual or CMC attitude commands are present. In the attitude hold mode, the spacecraft is held about the attitude attained when the CMC MODE was switched to HOLD or upon terminating a manual maneuver during the hold mode.

The automatic attitude maneuver is similar to attitude hold, except that the attitude is held about a desired attitude which is changing from the initial to the final vehicle attitude. This desired attitude is computed from inputs of attitude error and error rate. Automatic commands can be generated only when the CMC MODE switch is set to AUTO and no manual commands are present. The deadband is selected as in the attitude hold mode.

Rate limiting takes place when a high attitude rate exists. Jets are fired to oppose the high rate. When the proper rate limit deadband is entered the attitude hold function takes over.

The Barbeque Mode Routine (R64) may be called during the AUTO DAP mode which allows the crew to perform PTC (X AXIS ROLL), a restricted form of ORBRATE, and deadband changing without doing a direct erasable load. SEE 3.1.1.5, 5.2.3.37A, and Table 5-5.

3.1.1.2 Manual Commands

The translation and rotation hand controls interface directly with the CMC and have priority, at all times, over automatic commands. In the auto or hold modes, the vehicle moves in accordance with the manual commands and establishes an attitude hold upon completion of the manual maneuver. To return to automatic maneuvering the crew must recall it through the DSKY. In the auto and hold modes the rotational hand controller provides for a predetermined rate on each axis. Qualitatively, the action of the DAP after receiving a new RHC command is (1) to rate damp, i.e., drive S/C rate about each control axis to within a deadband of the command rate, and (2), once this is done, to incorporate in the forward loop an extra integration that will eliminate residual rate errors.

In the free mode, jet firing is made only in response to the manual controls. Both the rotation and translation controllers provide acceleration commands. This is the only mode in which the minimum impulse controller can be used. It fires a single rotational pulse of 14 milliseconds duration each time the control is moved from the null position. It must be returned to null before another pulse can be fired.

The auto, hold, and free modes are selected by the CMC MODE switch and require the SC Cont switch to be set to CMC.

3.1.1.3 DAP Data Load

The crew must select the deadband and rate for RCS DAP controlled maneuvers and must indicate to the CMC the vehicle configuration and failed thruster quads. The latter function permits the insertion of pseudo quad failures to provide single jet maneuvers. These crew selections are made by use of noun 46 in routine R03. This noun displays two 5-digit code words in registers 1 and 2. Table 3-1 defines each of the digits, which are designated A through E from left to right.

The crew can also update the CSM and/or LM vehicle weight values used in acceleration prediction. This update is also accomplished in routine R03, by noun 47. Register 1 displays CSM weight and register 2 displays LM weight.

Noun 48 is concerned with the TVC DAP only.

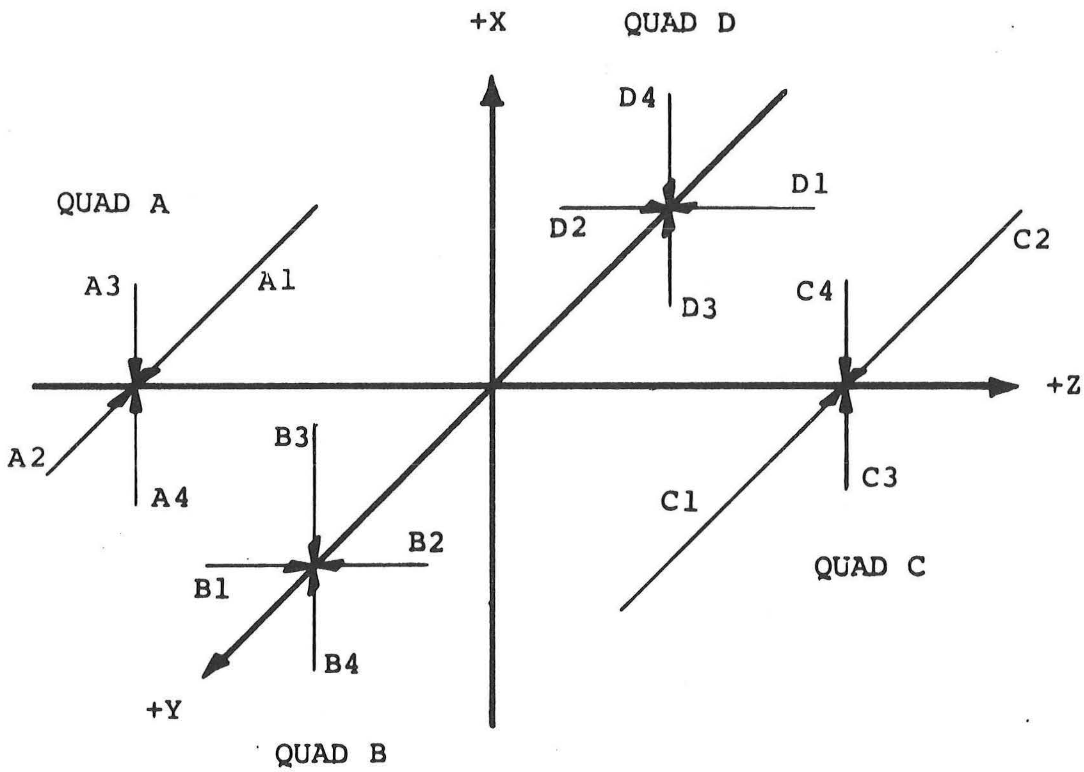
3.1.1.4 Jet Selection Logic

The direction of thrust of the SM RCS jets is illustrated in Fig. 3.1. These jets can be grouped according to their rotational effect, as shown in Table 3-2. There is one pair of jets each for the plus and minus yaw and pitch rotations and two pair each for plus and minus roll. Similarly, the jets are paired for translations, two pairs for each X direction, and one pair for each Y and Z direction. A single jet firing results in both rotation and translation. To conserve propellants, this combined type of maneuver is used whenever possible.

Register	Digit*	Code Name	Description
R1	A	Vehicle configuration	0 = No DAP 1 = CSM 2 = CSM/LM 3 = CSM/SIVB/LM (S IVB Control) 6 = CSM/LM (ascent only)
	B	X translation, quad AC	0 = fail quad AC 1 = use quad AC
	C	X translation, quad BD	0 = fail quad BD 1 = use quad BD
	D	Deadband	0 = ±0.5 deg 1 = ±5.0 deg
	E	Rate	0 = 0.05 deg/sec 1 = 0.2 deg/sec 2 = 0.5 deg/sec 3 = 2.0 deg/sec
R2	A	Quad AC roll	0 = fail quad AC (use BD) 1 = use quad AC (not BD)
	B	Quad A	0 = fail quad A 1 = use quad A
	C	Quad B	0 = fail quad B 1 = use quad B
	D	Quad C	0 = fail quad C 1 = use quad C
	E	Quad D	0 = fail quad D 1 = use quad D

*Digits are lettered from left to right.

Table 3-1. Noun 46 DAP Data Code.



Note: Arrows indicate thrust direction, not exhaust direction.

Fig. 3-1. Thrust Direction of SM RCS Jets

Group	Jet	Quad	Rotation	Translation
Pitch Jets	C3	C	+ (pitch)	+X
	A4	A	-	+X
	A3	A	+	-X
	C4	C	-	-X
Yaw Jets	D3	D	+ (yaw)	+X
	B4	B	-	+X
	B3	B	+	-X
	D4	D	-	-X
Roll (BD) Jets	B1	B	+ (roll)	+Z
	D2	D	-	+Z
	D1	D	+	-Z
	B2	B	-	-Z
Roll (AC) Jets	A1	A	+ (roll)	+Y
	C2	C	-	+Y
	C1	C	+	-Y
	A2	A	-	-Y

Table 3-2. Rotation and Translation Effect of SM RCS Jet Firing

Entire quads may be failed by the N46 load (see Table 3-1) . The CMC does not fire jets in failed quads. Translation commands which would require use of a failed quad are commanded only if they do not interfere with any rotational maneuver. When a rotation is commanded requiring use of a failed quad, a single jet rotation is made by firing the remaining jet of the rotation pair for a longer period of time. In the case of the roll quads, if a quad is failed the other pair of jets may be used. By loading in quad failures, the astronaut has the capability of commanding single jet rotations for the conservation of fuel.

All jet firings are limited to a minimum of 14 milliseconds. This is to ensure at least a minimum impulse and a rate reversal in the limit cycle.

3.1.1.5 BARBEQUE MODE ROUTINE (R64)

This routine allows the crew to have the DAP maintain control rate about the vehicle X axis or the Y RCS control axis. This routine is called via extended verb V79E. Once N79 is configured as desired the PRO on FL V06N79 will:

1). change the DAP deadband to that specified in R2 of N79.
2). generate a commanded rate (specified in R1 of N79) about the vehicle X axis or Y RCS control axis (specified in R3 of N79).

The maneuver commands will be communicated to the DAP if the S/C CONT is in CMC and CMC MODE is AUTO. The mode of operation of R64 can be varied as shown in Table 5-5,page 5-180B.

3.1.2 Thrust Vector Control DAP

The thrust vector control (TVC) DAP is used during SPS thrusting. The CMC generates vehicle commands and compares these commands with the IMU-measured vehicle attitude to generate attitude errors about the vehicle pitch, yaw, and roll axes. To produce these attitude error signals, first the CMC-generated increments in attitude command are transformed into equivalent angular increments of the IMU gimbals. Then the accumulated IMU gimbal angle increments are compared with the measured gimbal angles. The resulting angle errors are then transformed into pitch, yaw, and roll errors about the vehicle body axes.

Three independent control signals are generated by the CMC, one about each body axis. Roll control is achieved by a separate roll program which controls the firing of RCS roll jets. Pitch and yaw control is achieved through identical independent pitch and yaw autopilot programs which command deflections of the gimbaled SPS engine.

Uncertain initial conditions and different vehicle configurations greatly affect TVC DAP performance. Errors in the estimated position of the vehicle center of gravity can produce a misalignment of the thrust vector and a consequent torquing motion. Off nominal RCS performance during ullage can create turning rates of up to one deg/sec at SPS ignition. There are also uncertainties in the displacement of propellant slosh masses. The difference in characteristics between a CSM alone and a CSM/LM configuration requires separate autopilot programs. The main differences include: the much lower bending mode frequencies of the CSM/LM, the difference in moment of inertia and moment arm from engine gimbal to vehicle center of gravity, and additional vehicle mass and propellant slosh masses of the CSM/LM configuration.

The initial parameters used by the TVC DAP are loaded in routine R03. Noun 46 loads the vehicle configuration (see Table 3-1); noun 47, the CSM and /or LM vehicle weights; and noun 48, the pitch and yaw trim angles.

The pitch and yaw autopilots perform identical functions consisting of a dynamic filtering operation on the sampled attitude error and generating a suitable command to the gimbal servo. A digital to analog converter (DAC) changes the gimbal servo command to an analog voltage which it maintains for each sampling period. The DAC output is quantized with increments of 0. 0237 degrees. The command and feedback signals are quantized with increments of 0. 011 degrees. For the LM attached configuration each filter is updated every 80 milliseconds, for the CSM alone each is updated every 40 milliseconds.

The roll autopilot maintains vehicle roll attitude by maintaining the IMU outer gimbal angle close to a preselected value. Prior to thrusting, the vehicle may be rolled to a preferred orientation. The outer gimbal angle corresponding to the orientation at engine turn on and is maintained throughout the thrust. The inner and middle gimbal angles are near zero at ignition, under nominal conditions; thus, control of the outer gimbal angle is equivalent to roll control. With a large initial middle gimbal angle some roll motion occurs but is not significant.

The maximum firing time of any one firing of the roll jets is 2. 5 seconds. There is a minimum of 1/2 second delay between firings to increase accuracy of rate estimation. Long maneuvers are, therefore, broken into 2. 5 second firings, 1/2 second apart. Two-jet firing is used and for consecutive firing alternate jet pairs are fired. The roll inertia is continually recomputed during firing. The roll limit angle rate is 0. 1 deg/sec and the roll deadband is ±5 degrees.

The TVC DAP produces only roll commands to the RCS and no pitch or yaw RCS maneuvers can be made during TVC DAP control. However, for emergency purposes, turning the translation control clockwise, during a GNCS controlled SPS burn, terminates attitude control by the TVC DAP. The rotation control must then be used for TVC. Automatic control cannot be reestablished for that burn. The thrust will continue until VG is nulled or thrust is manually terminated.

3.1.3 Entry DAP

The entry DAP is initiated by DSKY entry after crew verification of CM/SM separation and continues operating until drogue chute deployment. During this time, it provides an attitude hold from start until receipt of inputs from the crew of entry roll attitude commands to maneuver the CM to the entry trim attitude from the separation attitude. The entry DAP also holds entry attitude with respect to the relative velocity vector, begins rate damping at 0.05g, follows roll commands from entry guidance beginning at 0.2g, and maintains attitude hold and rate damping until autopilot is disabled. The entry DAP also provides a display on the FDAI error needles consisting of roll, yaw, and pitch attitude errors prior to atmospheric entry (at 0.05g) and only roll error thereafter. This display is updated every 0.2 seconds. The entry DAP recognizes no mode except automatic. Manual take over does not affect DAP action or its displays.

When SM/CM separation occurs, a delay is needed to obtain adequate clearance between the CM and SM before starting a maneuver to reorient the CM to the entry attitude. During the time from separation until entry DAP initiation by DSKY entry, the CM attitude control is disabled to prevent any firing which could caus recontact of the CM and SM. After initiation, the entry conditions are established by commanded attitude angles: roll as specified by DSKY entry, zero beta, and trim angle of attack.

Outside the atmosphere the DAP controls attitude in all axes. Inside the atmosphere only roll attitude control is used. Rate damping is used for pitch and yaw.

The terminal phase of extra-atmospheric return to the earth at a specified landing point is achieved by entry guidance, using atmospheric aerodynamic lift. The guidance equations determine proper orientation of the lift vector relative to the trajectory plane as the means of control in achieving the desired landing point. The component of lift in the plane of the relative velocity and the position vector controls the down range flight. Cross range is controlled by the out-of-plane component of lift. By rolling the CM about the velocity vector, orientation of the lift vector is achieved such that the desired in-plane component obtains. The out-of-plane component of lift causes lateral drift of the vehicle. This sidewise motion is used for plane changing, if any is needed. Otherwise lateral drift is an unwanted by-product of the steering, and is constrained by causing the CM to roll so as to reverse the sign of the out-of-plane component of lift. Since the in-plane component is the fundamental controlled quantity, it is important that its sign be unchanged during lateral reversals or switchings. In effect this demands that the CM roll predominantly through the smaller of the two possible angles at lateral switching time. In certain critical cases entry guidance insists on rolling over the top without regard for the angle size and informs the DAP. Thus entry guidance provides a single output quantity, commanded roll angle roll C, to be achieved by the CM.

Before entering the atmosphere, all attitude errors will be nulled. When the 0.05g level is sensed by entry guidance, a switch is set. The DAP then changes from pitch and yaw attitude control to rate damping. The roll system is already operating and is ready to accept commands from entry guidance.

Inside the atmosphere the CM is aerodynamically stable. Since stability is no problem, simple rate dampers are used in pitch and yaw. Also aerodynamic forces can be used to do most of the work during a coordinated turn. The roll axis torque is mostly inertia, having negligible damping and cross-coupling terms. Hence a simple predictive autopilot is used.

In entry guidance, control is based on components of lift in and normal to the trajectory plane. These components are specified in terms of an angle defined the same as the roll angle R but having the desired value (Roll C). If the CM is to achieve the desired lift direction then the bank angle (β) must be zero. Thus, one property of the entry DAP is to keep $\beta = 0$ and another is to have R agree with Roll C. A third property of the atmospheric DAP is to enforce the proportionality between yaw and roll rate necessary to produce coordinated roll.

In the atmosphere, aerodynamic forces tend to keep β essentially zero, and the angle of attack (α) assumes a trim angle of about -20 degrees, so that only roll control is needed. The required coordinated roll maneuvers are achieved by the angular rate autopilots already required to damp pitch and yaw body rates.

The pitch and yaw rate damping is performed in a discontinuous manner by producing a control action each time new input data are available. The pitch and yaw autopilots are exercised each 0.1 second immediately after the measurement of angular velocity. As long as the pitch rate is less than 2 deg/sec no action is taken. When the sampled pitch rate exceeds 2 deg/sec jets are fired to produce an opposing torque. The jets continue to fire until the sampled pitch rate becomes less than 2 deg/sec.

The yaw axis requirements are different than pitch. The CM must roll about the velocity vector in order to maintain nominal trim attitude and to keep the stagnation point in a fixed area on the heat shield. During periods of angular acceleration in roll, a corresponding acceleration in yaw is established and supported by aerodynamic forces. These forces encourage the CM to make a coordinated turn. Most of the work is done by the aerodynamics with the yaw jets firing only when needed to keep the CM within the central band. This keeps yaw oscillations damped to within ±2 deg/sec.

Every two seconds during the entry phase, entry guidance provides the roll command, Roll C. It examines current vehicle position and velocity, and landing point position. From this it calculates the required lift vector orientation and issues the Roll C command to achieve the orientation. The roll autopilot uses the Roll C command, present roll attitude, and roll rate to determine firing time for the thrusters.

The crew has no control over entry DAP operation except to load initial conditions and to monitor the entry on the DSKY, the FDAI, and EMS. The crew may take over entry control manually, but having done so, cannot return to automatic control.

3.1.4 Transition Between DAP's

Transition between DAP's is effected by discretes or by major program commands. The entry DAP is activated 0.5 seconds after the PRO keycode response to V50 N25 checklist code 00041 request.

Just prior to SPS TVC burn sequence initiation, the RCS is holding the initial thrusting attitude in the narrow deadband, the preselected trim has been commanded to the engine and confirmed by the crew, and the crew has accepted the thrusting parameters. At a prescribed time before ignition time the crew initiates ullage and the RCS DAP holds attitude in the narrow deadband. At time of ignition the RCS DAP ceases and the TVC DAP controls engine excursion. Ullage is ended by the major program 2 seconds after engine on.

At commanded engine cut-off, engine gimbal commands are stored for trim reference for subsequent burns, and TVC DAP operation ceases. RCS DAP operation is simultaneously initiated in the wide deadband mode.

3.1.5 Saturn Control Function

There are two modes of Saturn guidance takeover operation. They are the automatic mode and the manual mode.

The automatic mode provides the CMC with the backup capability of issuing steering commands to the IU autopilot during program (P11) operation. The Auto mode is selected by placing the LV GUIDANCE switch ,on the MDC, to the CMC position. The CMC then issues steering commands based on desired attitude (a function of the pitch polynomial), the measured attitude, and the existing attitude error at takeover. and an erasable constant called the Saturn Scale Factor. Returning the switch to the IU position while still in (P11) takes the CMC out of the Saturn steering loop.

The Manual mode provides the crew with a capability of issuing RHC commands, through the CMC, to the Saturn IU. To initiate this mode the crew must first set the CONFIG window of Noun 46 (R1) to a 3. This is done by means of V48E(R03). Then the crew must execute a V46E. The manual takeover mode is entered once each 100 MS by means of the Time 5 clock mechanism. Since the ICDU error counters also drive the FDAI attitude error needles, these needles will be driven by the RHC commands. Because the RHC commands are implied rate commands and the needles are designed to indicate attitude errors, the magnitude of the needle deflection is not meaningful and the sign of the needle deflection is opposite of the RHC deflection.

3.2 G & C CONTROLS AND DISPLAYS

The G and C controls and displays interface directly or indirectly with the GNCS. Most of these controls and displays are located on the left side of the main panel.

3.2.1 Entry Monitor System

The entry monitor system (EMS) provides a backup means for the crew to monitor entry performance and midcourse ΔV maneuvers. The EMS delta V monitoring capability is used for SCS controlled ΔV maneuvers. The desired ΔV is preset into the EMS. The EMS integrates acceleration from ullage to SPS tailoff and decrements the ΔV counter. When the counter reaches zero the EMS provides a backup SPS off command.

During entry the EMS monitors the entry, starting when 0.05g is sensed. During program P61 the DSKY displays (V06 N63) the predicted range to go from the 0.05g altitude to the landing point and the inertial velocity at the 0.05g altitude. At this time the astronaut initializes the EMS by inserting the DSKY displayed parameters. The EMS accelerometer is running but its output is not being integrated for velocity and range.

When the EMS accelerometer senses 0.05g the 0.05G indicator lights. This should occur at the same time that the GNCS senses 0.05g and transfers from program P63 to P64. The astronaut, at this time, sets the ENTRY-0.05G and EMS ROLL switches on. The EMS then starts integrating the acceleration to update the range and velocity initially set in during P61.

Ten seconds after 0.05g is attained one of the two corridor lamps lights to indicate the required roll attitude; the top light indicates lift up and the bottom lift down. The G-V trace on the plotter provides continuous acceleration and velocity readings with respect to the entry corridor. The slope of the trace dictates the required roll attitude. The scroll is inscribed with high g and exit rays and is driven at a rate proportional to the acceleration along the velocity vector. A scribe is driven vertically in proportion to the G_T component of sensed acceleration. From the plotter the crew can detect GNCS failures that would result in atmospheric exits at supercircular speeds or excessive load factors. If the trace becomes tangent to any of the rays the crew must take over manual control of the entry.

The EMS also provides a roll attitude indication. This consists of a dial and pointer and the two corridor lamps. The pointer indicates maximum lift up when pointing up (0°) and maximum lift down at 180°.

The RANGE/ΔV display, during entry, indicates the range to go to touch down. This display is in nautical miles from 0 to 3500.

3.2.2 Flight Director Attitude Indicator (FDAI)

There are two identical FDAI's which indicate spacecraft attitude, attitude errors, and attitude rate. The total attitude is displayed on the attitude ball and is obtained, depending on FDAI switching, from either the IMU or the GDC (gyro display coupler) which couples the BMAG's to the display system. Pitch and yaw are indexed on the ball and are read under an inverted wing symbol in the center. Roll can be determined from the ball, but is more easily read by a roll index around the periphery of the ball.

The FDAI attitude error needles indicate the difference between actual and desired spacecraft attitude. The attitude error may be obtained from the following sources, depending on various switch positions: BMAG 1, GDC-attitude set difference, IMU-attitude set difference, the ICDU's.

The attitude rate display uses signals derived only from the BMAG's.

The switching for the source of the FDAI inputs is described in paragraph 3.2.7.

3.2.3 Gimbal Position and Fuel Pressure Indicator

The SPS gimbal position indication shares a meter with the S-II and S-IVB fuel pressure, since SPS gimbal position is not needed until after S-IVB separation. After separation, the astronaut must switch to the gimbal position indicator (GPI) position. The GPI provides thumbwheels for setting in gimbal trim positions for SCS controlled ΔV maneuvers.

The GPI is monitored during the gimbal drive test prior to a GNCS controlled SPS thrust.

3.2.4 Attitude Set Control Panel

The attitude set control panel (ASCP) provides a means of positioning resolvers for each body axis by the use of thumbwheels. Indicators readout the dialed angles. The input signals to the resolvers are either from the IMU or the GDC. The output signals are the difference between the desired angles set in and the actual angles from the IMU or GDC.

3.2.5 Rotational Hand Control

There are two three-axis rotational hand controls (RHC) which can be mounted on the couch armrests or at the navigation station. The controls are connected in parallel. They are used for manual attitude control. Each axis of control performs three functions:

1. Breakout switches close when the control is moved 1.5 degrees from its rest position. These switches are used: for on-off commands to the CMC, for SCS minimum impulse, for acceleration commands, to cage the BMAG's, and to enable proportional rate commands in the electronics. Which of these functions are performed depends on external switching (see paragraph 3.2.7).
2. Transducers produce AC signals proportional to control displacement. These signals are used to command spacecraft rotation rates during SCS attitude control and to command SPS engine gimbal trim during manual thrust vector control. The transducers can be used individually or in any combination simultaneously.
3. Direct switches close when the control is moved to 11 degrees from null.

These switches are enabled by the ROT CONTR PWR - DIRECT switches and produce acceleration commands directly to the RCS jet solenoids.

3.2.6 Translation Control

The translation control provides for acceleration along one or more of the spacecraft axes. It consists of a T-handle which is moved parallel to the desired thrust direction. Switch closures supply the translation commands to the CMC and reaction jet and engine control. The T-handle may also be rotated. In the clockwise direction it transfers spacecraft control from the CMC to the SCS. In the counterclockwise direction it initiates a manual abort during launch. In both directions a detent is provided at 12 degrees so that the handle will not return to null when the hand is removed.

3.2.7 G and C Switching Interfaces

The G and C functional switching affects spacecraft control and displays. Some switching is critical for GNCS operations.

3.2.7.1 CMC ATT Switch

This switch must be in the IMU position at all times to enable FDAI motor excitation and body to Euler transformation in the GDC. The GDC position is not mechanized.

3.2.7.2 FDAI SCALE Switch

This is a three position switch which controls the full-scale deflection values of the attitude error and rate display of the FDAI as follows:

Up position - ± 5 degree attitude error
± 1 degree per second rate

Center position - ± 5 degree attitude error
± 5 degree per second rate

Down position - ± 15 degree yaw and pitch and ± 50 degree roll attitude error

± 10 degrees per second yaw and pitch and ± 50 degrees per second roll rate

This switch is independent of other panel switching. Scale selection is made for both FDAI's and cannot be selected for individual FDAI' s.

3.2.7.3 FDAI SELECT Switch

This is a three position switch that selects on which FDAI the selected inputs will be displayed.

1. In the 1/2 (up) position both FDAI's receive inputs. FDAI 1 displays GNCS input; IMU gimbal angles drive the ball and CMC signals drive the error needles. FDAI 2 displays SCS inputs; the GDC drives the ball and BMAG 1 drives the needles. Both FDAI's receive rate data from BMAG 2 (or BMAG 1 in the backup rate mode). If BMAG 1 is in backup (BMAG mode switch set to RATE 1) then it cannot supply attitude errors and FDAI 2 needles will be at null. With the FDAI SELECT switch in this position (1/2), the FDAI SOURCE and the ATT SET switches are not functional for display switching.

2. In the 2 (center) position only FDAI 2 is enabled. The attitude and error sources are controlled by the FDAI SOURCE and ATT SET switches. The rate source is from the BMAG selected by the BMAG MODE switches.

3. In the 1 (down) position only FDAI 1 is enabled. Signal sources are selected as in the 2 position.

3. 2. 7. 4 FDAI SOURCE Switch

This is a three position switch which selects the FDAI input signal source. It has no function if the FDAI SELECT switch is set to the 1/2 position. The sources selected are displayed on the FDAI selected by the FDAI SELECT switch in either position 1 or 2.

1. In the CMC (up) position the GNCS provides the attitude and attitude error display on the selected FDAI.

2. In the ATT SET (center) position, the ATT SET switch determines input source (see paragraph 3.2.7.5) for selected FDAI.

3. In the GDC (down) position, the SCS provides the input: the GDC attitude and BMAG 1 attitude error. If any BMAG MODE switch is set to RATE 1, the attitude error for that channel will not be available.

3.2.7.5 ATT SET Switch

This two position switch controls the interface of the IMU or GDC with the ASCP resolvers for display purposes, provided the FDAI SOURCE switch is set to ATT SET and the FDAI SELECT switch is set to 1 or 2.

1. In the IMU (up) position the error needles display the difference between the IMU gimbal angles and the ASCP resolver angles. The errors can be used to align the ASCP resolvers to the IMU gimbals. The attitude error display can be used for manually maneuvering around the IMU; however, the displayed errors are not converted to body axes. The total attitude display is derived from the IMU.

2. In the GDC (down) position the error needles display the difference between the GDC resolvers and the ASCP resolvers. The errors can be used to align the GDC or to manually maneuver the spacecraft. Total attitude from the GDC is displayed.

In either position the display is made on the FDAI selected by the FDAI SELECT switch.

3.2.7.6 MANUAL ATTITUDE Switches

These three switches, are three-position switches which enable various functions during SCS control. There is one switch each for the roll, pitch, and yaw axes; however, they all function identically.

1. In the ACCEL CMD (up) position the breakout switches of the RHC are enabled to the RCS solenoid drivers. Closing the breakout switches provides acceleration commands to the RCS. When the breakout switches are closed a free drift condition is created. These switches must not be in this position during GNCS controlled manuevers.

2. In the RATE CMD (center) position proportional rate control is provided if the SC CONT switch is in SCS and the RHC breakout switches are closed. If the breakout switches are open, the SCS will hold any inertial attitude selected within the established deadband. The switches should be kept in the RATE CMD position during GNCS control.

3. In the MIN IMP (down) position the SCS is in a free drift condition with no attitude or rate damping inputs to the RCS. The breakout switches of the RHC command 15 millisecond impulses when they are closed.

3.2.7.7 LIMIT CYCLE Switch

In the up position this switch enables SCS automatic pseudo-rate feedback in the SCS attitude control system. During automatic SCS control, this function generates short duration on-off pulses to the RCS, thus conserving fuel. This switch should be OFF when making a manual manuever.

3.2.7.8 ATT DEADBAND Switch

This switch controls the attitude deadband during SCS control (SC CONT switch in SCS position) . The MAX and MIN position indicate selection of maximum or minimum deadband, the values of which are determined by the position of the RATE switch as follows:

LOW rate - MAX attitude deadband is ± 4.2 degrees
LOW rate - MIN attitude deadband is ± 0.2 degrees
HIGH rate - MAX attitude deadband is ± 8 degrees
HIGH rate - MIN attitude deadband is ± 4 degrees

3.2.7.9 RATE Switch

This switch determines the maximum proportional rates attainable during SCS control. These rates can only be obtained for any axis if the MANUAL ATTITUDE switch for the axis is in RATE CMD position. Maximum rates in HIGH position are 7 degrees per second in pitch and yaw and 20 in roll. Maximum rates in LOW position are 0.65 degrees per second in all axes. This switch also sets the deadband as indicated in preceding paragraph.

3.2.7.10 TRANS CONTR PWR Switch

In the on (up) position this switch applies MNA and MNB 28 VDC to the redundent switches in the translation hand control. In the OFF (down) position, power is removed from the translation control.

3.2.7.11 ROT CONTR PWR - NORMAL Switches

These two switches control the 28 VDC and AC input to the rotational hand controls. The switches are identical, one for each hand control. In the AC/DC position AC power is applied to the proportional control of the hand control and 28 VDC to the breakout switches. In the AC position only the AC power is applied. In the OFF (center) position no power is applied.

3.2.7.12 ROT CONTR PWR - DIRECT Switches

These two identical (one for each rotation control) switches control application of 28 VDC to the direct switches in the rotation control. In the MNA/MNB (up) position, power from both busses is applied. In the down position, switch 1 applies MNA power to hand control #1 and switch 2 applies MNB power to hand control #2. The center position is OFF.

3.2.7.13 SC CONT Switch

This switch selects either CMC or SCS control of the spacecraft. In the CMC (up) position, the spacecraft is under CMC control, unless the translation control is turned clockwise. The type of control is determined by the CMC MODE switch and the CMC program. If any of the MANUAL ATTITUDE switches are in the ACCEL CMD position the RCS engine for that axis will not be controlled by the CMC but will receive commands only from the RHC breakout switches.

In the SCS (down) position, the spacecraft is under SCS control, with the same exception for MANUAL ATTITUDE switches in the ACCEL CMD position.

3.2.7.14 CMC MODE Switch

This switch selects one of three CMC modes.

1. The AUTO (up) position permits the CMC to control the spacecraft by its program. In this position the only normal crew inputs to spacecraft control is through the DSKY. Manual RCS commands override the CMC auto mode. After such manual commands a DSKY entry is required to return the CMC to auto mode, otherwise attitude hold is maintained. The MANUAL ATTITUDE switches must not be in ACCEL CMD position during this mode.

2. In the HOLD (center) position, the CMC performs an attitude hold function. Automatic CMC control is disabled except to hold the attitude within the programmed deadband. If the attitude is changed manually while in this mode, the CMC will hold to the new attitude. The MANUAL ATTITUDE switches must not be in ACCEL CMD position during the mode.

3. In the FREE (down) position, only the manual controls can cause jet firing. This position enables the minimum impulse controller on the navigation panel in the LEB.

For this switch to be functional the SC CONT switch must be set to the CMC position.

3.2.7.15 BMAG MODE Switches

These switches select the rate and attitude sensors (BMAG's) in each axis. There is one each for roll, pitch, and yaw axis; all are functionally the same.

1. In the RATE 2 (up) position, rate damping only is provided from BMAG 2. BMAG 1 is caged and, hence, no SCS automatic hold is available. BMAG 2 also supplies rate for FDAI display and for GDC calculation of attitude.

2. In the ATT 1/RATE 2 (center) position, BMAG 2 provides rate as above and BMAG 1 provides attitude error for SCS attitude hold.

3. In the RATE 1 (down) position BMAG 1 is caged to provide the rate data normally provided by BMAG 2; for FDAI display, for GDC calculation of attitude, and for rate control. No SCS attitude hold is available.

3.2.7.16 SPS THRUST Switch

This switch directly enables the SPS engine but does not necessarily disable it. In the DIRECT ON (up) position, it provides the 28 vdc ground to energize the SPS solenoids directly to bypass the SCS thrust on-off electronics. To perform this function at least one of the ΔV THRUST switches (A or B) must be set to NORMAL. In the NORMAL (down) position the SPS THRUST switch removes the ground from the driver side of the SPS solenoid, but does not deenergize the propellant valves.

For manual thrust off, the ΔV THRUST switches must be set to OFF.

3.2.7.17 DIRECT ULLAGE Switch

This momentary pushbutton switch provides backup for the CMC and translation control + X ullage translation prior to an SPS thrust.

3.2.7.18 THRUST ON Switch

This momentary pushbutton switch provides manual backup start capability for the SPS turn on.

3.2.7.19 ΔV THRUST Switches

These two switches provide redundant enabling of SPS thrust turn on by the SCS logic or the SPS THRUST switch. The enabling is accomplished in the NORMAL position of either switch A or B. The A and B indicate that the MNA and MNB dc bus, respectively, provides the power. With both of these switches in the OFF position the SPS is disabled. Therefore, they are used for manual SPS cutoff.

3.2.7.20 GDC ALIGN Switch

This momentary pushbutton switch enables the GDC total attitude resolvers to be aligned with the ASCP resolvers. To display the GDC position on the FDAI, the FDAI SOURCE, FDAI SELECT, and ATT SET switches should be set to display GDC-ASCP difference. The GDC ALIGN pushbutton must be held until alignment is complete. After alignment the FDAI needles should be at zero and the ball should agree with the ASCP dials.

3.2.7.21 SCS TVC Switches

These two switches, one for pitch axis and one for yaw axis, set the SCS configuration for SPS thrust vector control. In the AUTO (up) position, an automatic SCS controlled ΔV maneuver is enabled, using the rate and attitude outputs of the BMAG's. In this position, clockwise rotation of the translation control switches control to a rate-damped MTVC. In the RATE CMD (center) position, MTVC is provided in which the RHC output is summed with the BMAG rate output to control SPS engine gimbals. In the ACCEL CMD (down) position, MTVC is provided in which only the RHC controls the SPS engine gimbals.

3.2.7.22 SPS GIMBAL MOTORS Switches

These four switches are used to drive the SPS gimbals manually. The SPS engine gimbal is provided with redundant drive loops; hence, there are two switches for each of the two axes. The four switches are functionally the same. The START (up) position is a momentary position, spring-loaded to the center position. This position is used to start the gimbal motors. In the center position, the motors keep running. And the bottom position is OFF. The gimbal trim is monitored on the gimbal position indicator.

3.2.7.23 IMU CAGE Switch

This is a guarded switch which is used to drive the IMU gimbals to zero. This switch is only used in the emergency of a tumbling IMU or CMC failure. It should not be used except in emergency because the gimbal drive rates are high enough to drive the gyros into their stops, since there is no CDU rate limiting. This can cause permanent gyro bias shifts.

3.2.7.24 ENTRY-EMS ROLL Switch

This on-off switch enables roll stability inputs to the EMS, generated by the GDC. A valid entry roll display will be provided only if the 0.05 G switch is also on.

3.2.7.25 ENTRY - 0.05 G Switch

This on-off switch initiates the SCS for entry. All BMAG's are caged. Roll rate to yaw rate coupling is engaged in the yaw channel of the ECA and in the EDA to display stability axis yaw rate on the FDAI. SCS attitude hold capability is disabled. The GDC is configured for entry. The GDC driven FDAI is driven in roll only.

3.2.7.26 LV/SPS IND (SII/SIVB) Switch

In the SII/SIVB (up) position, the gimbal position and fuel pressure indicator displays S-II and S-IV B booster fuel pressure. In the GPI (down) position, the SPS gimbal position is displayed.

3.2.7.27 TVC GMBL DRIVE Switches

These two switches select the SPS gimbal drive servo loops. There is one switch for each axis (PITCH and YAW). In the AUTO (center) position automatic switchover, for overcurrent sensing, from primary to redundant loop is provided. In the 1 (up) position, the primary loop is selected with no automatic switchover capability. In the 2 (down) position the redundant loop is selected with no automatic switchover capability.

3.2.7.28 FCSM Switches

The two FCSM switches enable the flight combustion stability monitor (FCSM), one switch for each of the redundant SPS channels, A and B. In the SPS A or SPS B (up) position the FCSM is enabled and provides automatic SPS engine cutoff in case of rough firing. The RESET/OVERRIDE (down) position disables the FCSM and resets it for future use. the FCSM should be enabled prior to any GNCS controlled SPS thrusting maneuver.

3.2.7.29 LAUNCH VEHICLE - GUIDANCE Switch

This switch selects the control for the Saturn. In the IU (up) position the Saturn instrumentation unit controls the Saturn In the CMC (down) position the GNCS controls the Saturn. The CMC sends steering commands to the IU during boost stages S-IC, SII, SIVB when (P11) is in operation.

3.2.7.30 TVC SERVO POWER Switches

These switches are on panel 7 to the left of the MDC. They are used to select the source (AC1/MNA or AC2/MNB) for the TVC servo loops. These switches must be on for any TVC maneuver.

3.2.7.31 AUTO RCS SELECT Switches

These 16 switches, on panel 8, apply 28 vdc to the high side of the RCS automatic solenoids and 28 vdc enabling power to the SCS solenoid drivers. The MNA and MNB positions select the respective busses for operating power. In the OFF (center) position automatic jet firing is disabled. There is one switch for each of the RCS thrusters. Above each switch is the SM RCS jet designation for the switch. Below each switch is the translation direction of its corresponding SM jet and, in the case of the 12 right hand switches, the CM RCS jet designation for the switch.

3.3 POWER DISTRIBUTION

Power for the GNCS is redundantly supplied by dc busses A and B and essential ac busses 1 and 2.

The dc power (27.5 vdc) is supplied through four pairs of circuit breakers, located on panel 22 of the MDC, to filters in the PSA (see Fig. 3-2). The optics and IMU operate power is routed through G/N POWER switches on panel 99 in the LEB before filtering. One circuit breaker in each pair connects to main bus A and the other to main bus B. The IMU HTR circuit breakers apply ISS standby power; the IMU circuit breakers apply ISS operate power; the COMPUTER circuit breakers apply CSS operate power; and the OPTICS circuit breakers apply OSS power.

Essential ac busses 1 and 2 provide 115-v, 400-cps, 3-phase power. The GUIDANCE/NAVIGATION - POWER circuit breakers AC1 and AC2 on panel 22 of the MDC (see Fig. 3-2) apply phase B from the ac busses, through the G/N PWR switch on the same panel, to the OSS reticle dimmer. LEB AC2 circuit breaker applies phase A from ac bus 2 to the LEB LIGHTS NUMERICS control where it is transformed to about 5 vac for LEB DSKY lighting. The L MDC - AC1 circuit breaker applies phase A from ac bus 1 to INTERIOR LIGHTS - NUMERICS control where it is transformed to 5 vac for MDC DSKY lighting.

Table 3-4 gives some values of GNCS power consumption during normal conditions.

Equipment	Average Power Consumption (Watts)
ISS (Standby)	43.1
ISS (Operate)	271.7
ISS (Fine Align)	287.9
CMC (Standby)	10.0
CMC (Operate)	110.0
OSS	136.6
Eyepiece Heaters	7.5 (max)

Table 3-4. GNCS Power Consumption

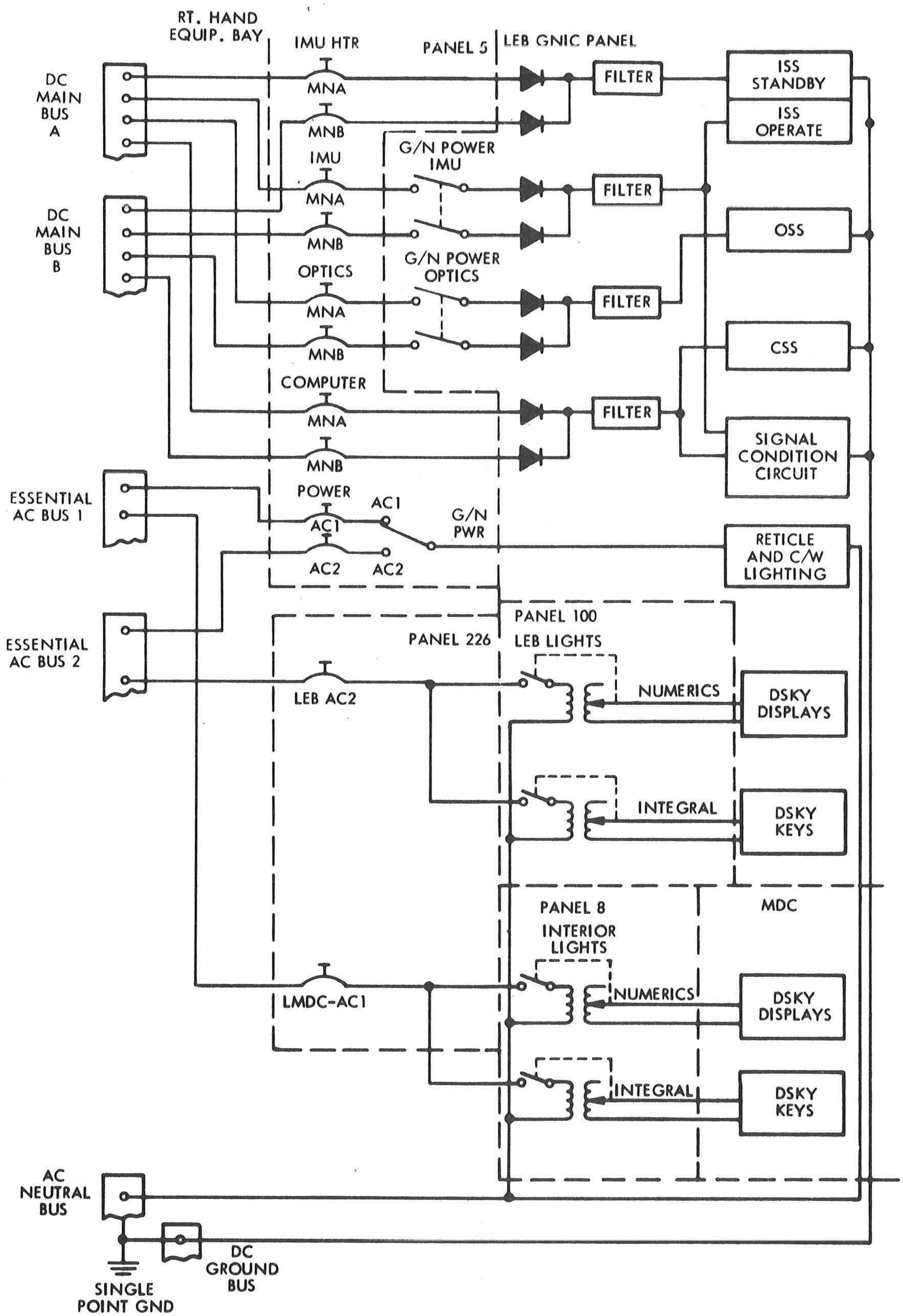


Fig. 3-2. GNCS Power Distribution

3.4 TELEMETRY SUBSYSTEM

3.4.1 Downlink

The GNCS telemetry downlink data consists of three types of signals: discretes, coded analog data, and CMC digital downlink data. The GNCS supplies the pulse code modulator (PCM) with CMC serial digital data and analog data from the signal conditioner (SC). The PCM digital multiplexer codes the SC analog signals into parallel digital data. The PCM codes the various data into serial format for transmission to earth.

The GNCS analog signals and some discretes must be converted to a common impedance and voltage range (0 to 5 vdc) to be accepted by the PCM multiplexer. This is done by the GNCS signal conditioner (Fig. 3-3). The signal conditioner also provides isolation between the circuit being monitored and the telemetry system. The PCM multiplexer transforms the conditioned signals into an eight bit telemetry word suitable for multiplexing and transmission. The GNCS operational signal conditioner consists of four modules:

1. DAC PIPA temperature and 2.5 volt bias signal conditioner.
2. IRIG and PIPA signal conditioner.
3. Gimbal resolver signal conditioner.
4. 120 volt PIPA supply signal conditioner.

The signal conditioner receives a 28 volt dc B+ supply voltage and 2.5 volt dc conditioning voltage from the signal conditioner power supply. The 28 volt dc B+ is applied to each module. The 2.5 volt dc bias voltage

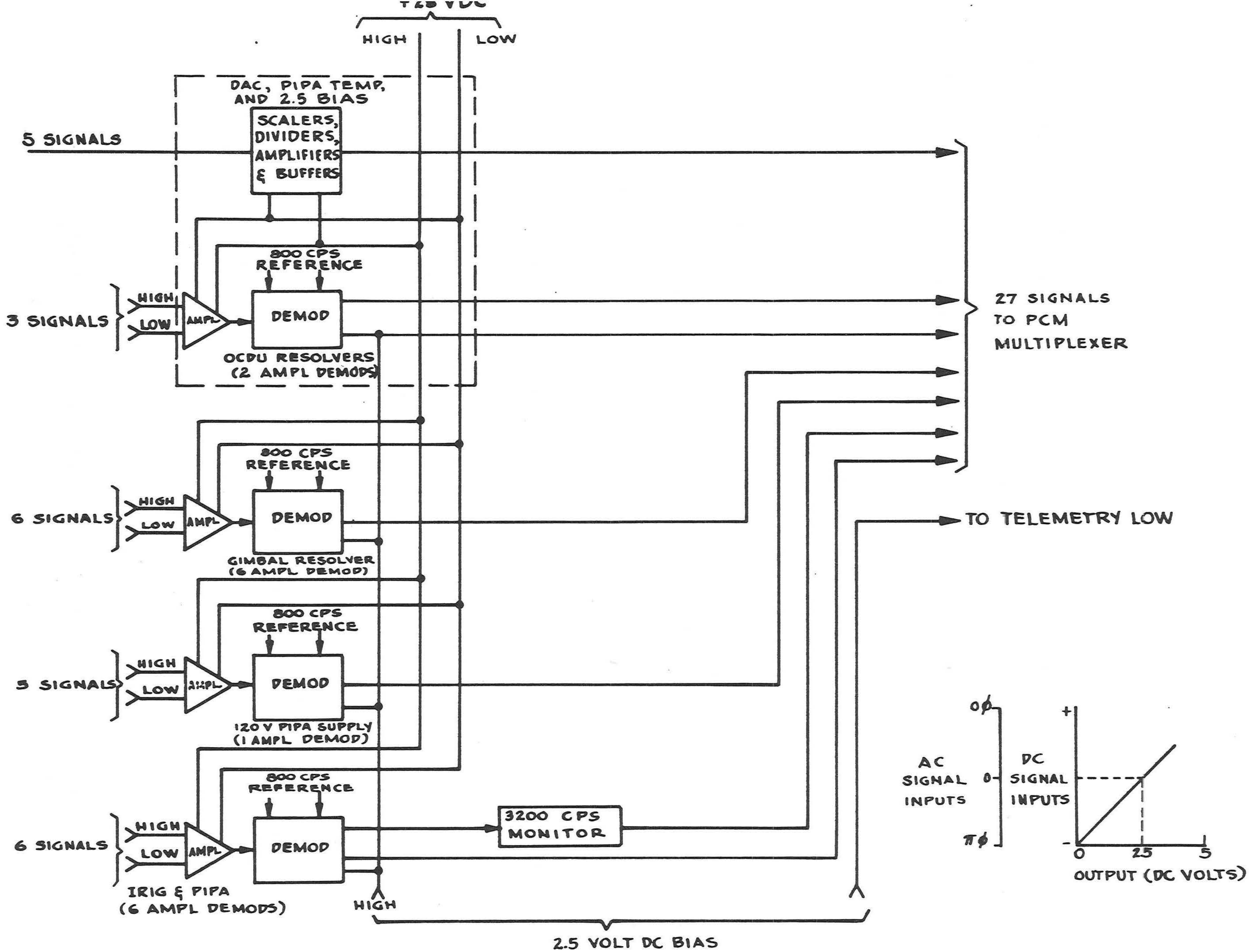


Fig. 3-3. Signal Conditioner Functional Block Diagram

is connected in series with the demodulated outputs of each module and is also monitored directly by the PCM multiplexer. The 2.5 volt dc bias high is connected to the signal low and becomes the reference point for the 0 to 5 volt signal outputs of the demodulators. In this manner, a zero-phase ac signal, after conditioning, is represented as a dc voltage value above the 2.5 volt reference. A pi-phase signal, after conditioning, is represented as a dc voltage value below the 2.5 volt reference. Bipolar dc signals from GNCS which may be positive or negative and have a zero volt reference after conditioning are represented in a similar manner. Positive voltages are represented as a voltage value above the 2.5 volt reference and negative voltages are represented as a voltage value below the 2.5 volt reference.

Discrete signals are telemetered as single bits within eight bit words. The GNCS, CMC, and ISS discretes are developed to their proper 5 vdc level by the signal conditioner. Table 3-4 lists the signals monitored by the signal conditioner.

The CMC digital downlink is transmitted at a rate of 50 words per second on the high bit rate and 10 words per second on the low bit rate. Each word consists of 33 bits, the first bit is a word-order code, the next 16 bits are the contents of one CMC register, and the last 16 bits are the contents of another 16 bit register. (Because the PCM telemetry format requires data in multiples of 8-bit words, the CMC downlink program repeats the 7 most significant bits from the first 16-bit register, after the 33-bit transmission, in order to fill the 40-bit downlink allocation.) In this

Measurement No.	Description
CG 0001V	Computer digital data (40 bit)
CG 1040V	+120 vdc PIPA supply dc level
CG 1110V	2.5 vdc telemetry bias
CG 1201V	ISS 28 vrms, 800 cps, 1%, zero phase
CG 1331V	3.2 kc, 28 volt supply
CG 1513X	+28 vdc IMU standby
CG 1523X	+28 vdc CMC operate
CG 1533X	+28 vdc optics operate
CG 2001V	X PIPA signal generator in phase output
CG 2021V	Y PIPA signal generator in phase output
CG 2041V	Z PIPA signal generator in phase output
CG 2112V	Inner gimbal 1X resolver sine output
CG 2113V	Inner gimbal 1X resolver cosine output
CG 2117V	Inner gimbal servo in phase error
CG 2142V	Middle gimbal 1X resolver sine output
CG 2143V	Middle gimbal 1X resolver cosine output
CG 2147V	Middle gimbal servo in phase error
CG 2172V	Outer gimbal 1X resolver sine output
CG 2173V	Outer gimbal 1X resolver cosine output
CG 2177V	Outer gimbal servo in phase error
CG 2300T	PIPA temperature
CG 3721V	Shaft CDU DAC output
CG 3722V	Trunnion CDU DAC output
CG 5040X	CMC warning

Table 3-4. GNCS Telemetry Measurement List

manner the contents of 100 CMC registers are transmitted in one second at the high bit rate and in 5 seconds at the low rate.

The downlink format is controlled by a CMC program which loads the next 2 registers to be transmitted into channels 34 and 35. This program is entered on an interrupt caused by an "endpulse" from the telemetry system. There are five different downlink lists in the Colossus program for use in different mission phases.

The general CMC downlink format is shown in Table 3-5. Each list contains 100 words (i.e. 200 CMC registers) and requires 2 seconds to transmit. The first word in any list contains the ID and sync registers and has a word order code bit of zero. The ID register marks the beginning of a list and also identifies which list is being transmitted. The sync register always contains the same 16 bits. These bits (1111 110 111 000 000) are used to sync certain remote site downlink processing equipment. The next 12 words (24 registers) are snapshot data. These twelve words have word order code bits of one. Since certain data on the downlink are only meaningful when considered in multi-register arrays (e.g. state vectors) and since the programs which compute these arrays are not synchronized with a downlink program, a "snapshot" is taken of these words so that changes in their values will not occur while these arrays are being transmitted to the ground.

When a "snapshot" is taken several words are stored at the time the first word is transmitted. The other words in the downlist are read at the time of transmission and therefore the only time homogeneity for them is between the two registers making up a single word. The next 31 words (62 registers) contain regular data and have word order code bits of one. Since both registers of a word are loaded at the same time, no synchronization problems can arise on double precision parameters. The next 6 words (12 registers)

Downlink Word No.	Order Code	Contents of First Register	Contents of Second Register
1	0	ID	Sync
2	1	Snapshot data which may vary with different lists	
↓	↓		
13	1		
14	1	Regular data which probably is different for different lists	
↓	↓		
44	1		
45	1	DSPTAB registers	
↓	↓		
50	1		
51	0	TIME 2	TIME 1
52	1	Snapshot data which may vary with different lists	
↓	↓		
63	1		
64	1	Regular data which probably is different for different lists	
↓	↓		
90	1		
91	1	Channel 11	Channel 12
92	1	Channel 13	Channel 14
93	1	Channel 30	Channel 31
94	1	Channel 32	Channel 33
95	1	Regular data which probably is different for different lists	
↓	↓		
100	1		

Table 3-5. General CMC Downlink Format

have word order code bits of one and transmit the contents of the latching relays in the DSKY. As such they indicate all displays and certain other functions handled through the latching DSKY relays. All downlink lists contain DSPTAB registers in this position in the list.

The next downlink word contains the double precision contents of the CMC clock. This word has a word order code bit of zero and always retains the position indicated in all lists. This starts the second half of the downlist which is similar in format to the first half. The next 12 words (24 registers) contain more snapshot data. The following 27 words (54 registers) contain more regular data. The next four words (8 registers) contain the contents of channels 11, 12, 13, 14, 30, 31, 32, and 33, in that order. They contain the status of a number of discrete interfaces of the CMC. These words have word order bits of one and are in the same position on all downlink lists. The last 6 words (12 registers) contain more regular data. Tables 3-6, 3-7, 3-8, 3-9, and 3-10 contain the five downlink lists.

3.4.2 Uplink

By means of the CMC uplink, the ground can insert data or instructions into the CMC in the same manner as the crew does using the DSKY keyboard. The crew can block the uplink by placing the UP TLM - CM switch on the MDC or the UP TELEMETRY switch in the LEB to the BLOCK position. The CMC update program (P27) is selected by the crew by DSKY entry or by the ground by uplink transmission. The update program can only be selected from programs P00, and P02.

There are four categories of CMC update:

1. To provide an octal increment to the CMC lift off time (V70).

2. To provide an octal increment to the CMC clock only (V73).

3. To provide load capability for a block of sequential erasable locations (up to 18 locations) (V71).

4. To provide load capability for individual specified locations (from 1 to 9 locations) (V72).

The entry may be manual or automatic. During automatic update, the UPLINK ACTY light is lighted. Manual update is selected by keying V70E, V71E, V72E, or V73E followed by keying the required data (in octal) into register R1. This is done with a flashing V21 N01 display that also displays the calculated machine address in R3.

TABLE 3-6

CSM POWERED DOWNLIST

(P11, P40, P41, P47 and P61)

WORD NO.		REGISTER	DESCRIPTION		
I. D. WORDS					
01	A	CMPOWEDL	DOWNLIST IDENTIFICATION		
	B	LOWIDCOD	SYNCHRONIZATION BITS		
SNAPSHOT SECTION OF DOWNLIST					
02	A	RN	CSM STATE VECTOR	X POSITION	MSB
	B	RN +1			LSB
03	A	RN +2		Y POSITION	MSB
	B	RN +3			LSB
04	A	RN +4		Z POSITION	MSB
	B	RN +5			LSB
05	A	VN		X VELOCITY	MSB
	B	VN +1			LSB
06	A	VN +2		Y VELOCITY	MSB
	B	VN +3			LSB
07	A	VN +4		Z VELOCITY	MSB
	B	VN +5			LSB
08	A	PIPTIME	STATE VECTOR TIME		MSB
	B	PIPTIME +1			LSB

TABLE 3-6

09	A	CDUX	ACTUAL ICDU ANGLES	X	
	B	CDUY		Y	
10	A	CDUZ		Z	
	B	CDUT	ACTUAL OCDU TRUNION ANGLE		
11	A	ADOT (OR OGARATE)	RCS DAP MEASURED BODY RATE ABOUT ROLL CONTROL AXIS (OR OUTER		MSB
	B	ADOT +1 (OR OGARATE +1)	GIMBAL ANGLE RATE DURING TVC DAP USE)		LSB
12	A	ADOT +2 (OR OMEGAB)	RCS DAP MEASURED BODY RATES ABOUT CONTROL AXES (OR TVC DAP BODY AXIS	PITCH	MSB
	B	ADOT +3 (OR OMEGAB +1)	ATTITUDE RATES)		LSB
13	A	ADOT +4 (OR OMEGAB +2)		YAW	MSB
	B	ADOT +5 (OR OMEGAB +3)			LSB
	REGULAR SECTION OF DOWNLIST				
14	A	AK	CONTROL AXIS ATTITUDE ERROR	X	
	B	AK1		Y	
15	A	AK2		Z	
	B	RCS FLAGS			
16	A	THETADX	DAP DESIRED ICDU ANGLES	X	
	B	THETADY		Y	
17	A	THETADZ		Z	
	B	GARBAGE			
18	A	TIG	TIME OF IGNITION	MSB	
	B	TIG +1		LSB	
19	A	DELLT4	TRANSFER TIME FROM IGNITION TO INTERCEPT	MSB	
	B	DELLT4 +1		LSB	

TABLE 3-6

20	A	RTARG	AIM POINT POSITION VECTOR (IN REFERENCE COORDINATES)	X MSB
	B	RTARG +1		LSB
21	A	RTARG +2		Y MSB
	B	RTARG +3		LSB
22	A	RTARG +4		Z MSB
	B	RTARG +5		LSB
23	A	TGO	TIME TO GO TO ENGINE CUTOFF	MSB
	B	TGO +1		LSB
24	A	PIPTIME1	TIME AT WHICH PIPAS WERE READ ASSOCIATED WITH DELTA V'S	MSB
	B	PIPTIME1 +1		LSB
25	A	DELV	TWO SECOND ACCUMULATION OF PIPA COUNTS DELTA V X(SM)	MSB
	B	DELV +1		LSB
26	A	DELV +2	DELTA V Y(SM)	MSB
	B	DELV +3		LSB
27	A	DELV +4	DELTA V Z(SM)	MSB
	B	DELV +5		LSB
28	A	PACTOFF	TOTAL PITCH TRIM GIMBAL ANGLE	
	B	YACTOFF	TOTAL YAW TRIM GIMBAL ANGLE	
29	A	PCMD	SPS PITCH COMMAND	
	B	YCMD	SPS YAW COMMAND	
30	A	CSTEER	CROSS PRODUCT STEERING CONSTANT	MSB
	B	GARBAGE		LSB
31	A	CSI∆V	COELLIPTIC SEQUENCE INITIATION DELTA V's (VX, VY, VZ)	MSB
	B	CSI∆V+1		LSB
32	A	CSI∆V + 2		MSB
	B	CSI∆V + 3		LSB
33	A	CSI∆V + 4		MSB
	B	CSI∆V + 5		LSB

TABLE 3-6

34	A	REFSMMAT	REFSMMAT (TRANSFORMATION MATRIX BETWEEN STABLE MEMBER AND REFERENCE COORDINATES)
	B	REFSMMAT +1	
35	A	REFSMMAT +2	
	B	REFSMMAT +3	
36	A	REFSMMAT +4	
	B	REFSMMAT +5	
37	A	REFSMMAT +6	
	B	REFSMMAT +7	
38	A	REFSMMAT +8	
	B	REFSMMAT +9	
39	A	REFSMMAT +10	
	B	REFSMMAT +11	
	FLAGWORDS		
40	A	FLAGWRD0	FLAGWORD 0
	B	FLAGWRD1	FLAGWORD 1
41	A	FLAGWRD2	FLAGWORD 2
	B	FLAGWRD3	FLAGWORD 3
42	A	FLAGWRD4	FLAGWORD 4
	B	FLAGWRD5	FLAGWORD 5
43	A	FLAGWRD6	FLAGWORD 6
	B	FLAGWRD7	FLAGWORD 7
44	A	FLAGWRD8	FLAGWORD 8
	B	FLAGWRD9	FLAGWORD 9

DISPLAY TABLES

45	A	DSPTAB +0	DSKY DISPLAY RELAY CONFIGURATION			
	B	DSPTAB +1				
46	A	DSPTAB +2				
	B	DSPTAB +3				
47	A	DSPTAB +4				
	B	DSPTAB +5				
48	A	DSPTAB +6				
	B	DSPTAB +7				
49	A	DSPTAB +8 D				
	B	DSPTAB +9 D				
50	A	DSPTAB +10 D	DSKY DISPLAY RELAY CONFIGURATION			
	B	DSPTAB +11 D				
CMC CLOCK (AND START OF SECOND HALF OF DOWNLIST)						
51	A	TIME2	TIME OF CMC CLOCK			MSB
	B	TIME1				LSB
SNAPSHOT SECTION OF DOWNLIST						
52	A	R-OTHER	LM STATE VECTOR	X	POSITION	MSB
	B	R-OTHER +1				LSB
53	A	R-OTHER +2		Y	POSITION	MSB
	B	R-OTHER +3				LSB
54	A	R-OTHER +4		Z	POSITION	MSB
	B	R-OTHER +5				LSB
55	A	V-OTHER		X	VELOCITY	MSB
	B	V-OTHER +1				LSB

56 A	V-OTHER +2		Y VELOCITY	MSB
B	V-OTHER +3			LSB
57 A	V-OTHER +4		Z VELOCITY	MSB
B	V-OTHER +5			LSB
58 A	T-OTHER	STATE VECTOR TIME		MSB
B	T-OTHER +1			LSB
59 A THRU 63 B		SAME AS 09 A THRU 13 B		
REGULAR SECTION OF DOWNLIST				
64 A THRU 67 B		SAME AS 14 A THRU 17 B		
68 A	RSBBQ	RESTART B BANK and SUPERBANK		
B	RSBBQ + 1	RESTART Q REGISTER		
69 A	CADRFLSH	FCADR ADDRESS OF LAST PRIORITY DISPLAY		
B	CADRFLSH +1	FCADR ADDRESS OF LAST MARK DISPLAY		
70 A	CADRFLSH +2	FCADR ADDRESS OF LAST NORMAL DISPLAY		
B	FAILREG	ALARM CODE OF FIRST ALARM		
71 A	FAILREG +1	ALARM CODE OF SECOND ALARM		
B	FAILREG +2	ALARM CODE OF LAST ALARM		
72 A	CDUS	ACTUAL OCDU SHAFT ANGLE		
B	PIPAX	ACTUAL PIPA COUNTS	X	
73 A	PIPAY		Y	
B	PIPAZ		Z	
74 A	ELEV	ELEVATION ANGLE		MSB
B	ELEV +1			LSB

TABLE 3-6

75	A	CENTANG	CENTRAL ANGLE OF TRANSFER		MSB
	B	CENTANG +1			LSB
76	A	OFF SET POINT	DISTANCE FROM ACTIVE TO PASSIVE VEHICLE		MSB
	B	OFF SET POINT + 1			LSB
77	A	FLAGWRD10	FLGWRD 10		
	B	FLAGWRD11	FLGWRD 11		
78	A	TEVENT	TIME OF EVENT		MSB
	B	TEVENT +1			LSB
79	A	PCMD	SPS PITCH COMMAND		
	B	YCMD	SPS YAW COMMAND		
80	A	OPTMODES	OPTICS MODE		
	B	HOLDFLAG	HOLDFLAG		
81	A	LM MASS	LM CURRENT MASS		
	B	CM MASS	CM CURRENT MASS		
82	A	DAPDATR1	RCS-CSM DAP INTERFACE DATA		
	B	DAPDATR2			
83	A	ERRORX	RCS DAP ATTITUDE ERROR	X	
	B	ERRORY		Y	
84	A	ERRORZ		Z	
	B	GARBAGE	(THETA DX)		
85	A	WBODY (OR OMEGAC)	DESIRED BODY RATES FOR RCS DAP (OR TVC DAP BODY AXIS RATE COMMANDS)	ROLL	MSB
	B	WBODY +1 (OR OMEGAC +1)			LSB
86	A	WBODY +2 (OR OMEGAC +2)		PITCH	MSB
	B	WBODY +3 (OR OMEGAC +3)			LSB

TABLE 3-6

87	A	WBODY +4 (OR OMEGAC +4)		YAW	MSB
	B	WBODY +5 (OR OMEGAC +5)			LSB
88	A	REDOCTR	REDO COUNTER (NUMBER OF RESTARTS)		
	B	THETAD	DESIRED FINAL CDU ANGLES	OGA	
89	A	THETAD +1		IGA	
	B	THETAD +2		MGA	
90	A	IMODES30	IMU STATUS BITS		
	B	IMODES33	G+N STATUS BITS		
		CHANNELS			
91	A	CHANNEL 11	INPUT AND OUTPUT CHANNELS (SEE TABLES 6-1 AND 6-2)		
	B	CHANNEL 12			
92	A	CHANNEL 13			
	B	CHANNEL 14			
93	A	CHANNEL 30			
	B	CHANNEL 31			
94	A	CHANNEL 32			
	B	CHANNEL 33			
95	A	VG TIG	VELOCITY TO BE GAINED	X	MSB
	B	VG TIG +1			LSB
96	A	VG TIG +2		Y	MSB
	B	VG TIG +3			LSB
97	A	VG TIG +4		Z	MSB
	B	VG TIG +5			LSB
98	A	CDH△VX			
	B	CDH△VX			
99	A	CDH△VY			
	B	CDH△VY			
100	A	CDH△VZ			
	B	CDH△VZ			

TABLE 3-7

CSM COAST AND ALIGN DOWNLIST

(P00, P01, P02, P03, P06, P07, P51, P52, P53, and P54)

WORD NO.	REGISTER	DESCRIPTION		
I. D. WORDS				
01 A	CMCSTADL	DOWNLIST IDENTIFICATION		
B	LOWIDCOD	SYNCHRONIZATION BITS		
SNAPSHOT SECTION OF DOWNLIST				
02 A THRU 13 B		SAME AS CSM POWERED DOWNLIST		
REGULAR SECTION OF DOWNLIST				
14 A THRU 18 B		SAME AS CSM POWERED DOWNLIST		
19 A	STARID1	STAR 1 IDENTIFICATION NUMBER		
B	STARID2	STAR 2 IDENTIFICATION NUMBER		
20 A	MARKTIME1	STAR 1 SIGHTING DATA	TIME OF MARK	MSB
B	MARKTIME1 + 1			LSB
21 A	MARKTIME1 + 2		YCDU ANGLE	
B	MARKTIME1 + 3		OPTIC SHAFT ANGLE	
22 A	MARKTIME1 + 4		ZCDU ANGLE	
B	MARKTIME1 + 5		OPTICS TRUNNION ANGLE	
23 A	MARKTIME1 + 6		XCDU ANGLE	
B	MARKTIME1 + 7	(NOT USED)GARBAGE		
24 A	MARKTIME2	STAR 2 SIGHTING DATA	TIME OF MARK	MSB
B	MARKTIME2 + 1			LSB
25 A	MARKTIME2 + 2		YCDU ANGLE	
B	MARKTIME2 + 3		OPTICS SHAFT ANGLE	
26 A	MARKTIME2 + 4		ZCDU ANGLE	

26 B	MARKTIME2 + 5		OPTICS TRUNNION ANGLE	
27 A	MARKTIME2 + 6		XCDU ANGLE	
B	MARKTIME2 + 7	NOT USED	GARBAGE	
28 A	HAPO	APOGEE		MSB
B	HAPO +1			LSB
29 A	HPER	PERIGEE		MSB
B	HPER +1			LSB
30 A	PACTOFF	SPS ENGINE GIMBAL-ACTUATOR TRIM ANGLE ESTIMATES		MSB
B	YACTOFF			LSB
31 A	VG TIG	VELOCITY TO BE GAINED		X MSB
B	VG TIG +1			LSB
32 A	VG TIG +2			Y MSB
B	VG TIG +3			LSB
33 A	VG TIG +4			Z MSB
B	VG TIG +5			LSB
34 A THRU 39 B		SAME AS CSM POWERED DOWNLIST		
FLAGWORDS				
40 A THRU 44 B		SAME AS CSM POWERED DOWNLIST		
DISPLAY TABLES				
45 A THRU 50 B		SAME AS CSM POWERED DOWNLIST		
CMC CLOCK (AND START OF SECOND HALF OF DOWNLIST)				
51 A	TIME2	TIME OF CMC CLOCK		MSB
B	TIME1			LSB

SNAPSHOT SECTION OF DOWNLIST				
52 A THRU 63 B			SAME AS CSM POWERED DOWNLIST	
REGULAR SECTION OF DOWNLIST				
64 A THRU 73 B			SAME AS CSM POWERED DOWNLIST	
74 A	OGC		GYRO TORQUING ANGLES IN R55, DESIRED GIMBAL ANGLES	X MSB
B	OGC	+1	IN P52 AND P54	X LSB
75 A	IGC			Y MSB
B	IGC	+1		Y LSB
76 A	MGC			Z MSB
B	MGC	+1		Z LSB
77 A	FLAGWRD10		FLGWRD 10	
B	FLAGWRD11		FLGWRD 11	
78 A	TEVENT		TIME OF EVENT	MSB
B	TEVENT	+1		LSB
79 A	LAUNCHAZ		LAUNCH AZIMUTH	MSB
B	LAUNCHAZ	+1		LSB
80 A THRU 90 B			SAME AS CSM POWERED DOWNLIST	
CHANNELS				
91 A THRU 94 B			SAME AS CSM POWERED DOWNLIST	
DISPLAY TABLES				
95 A THRU 100 B			SAME AS 44A THRU 50B	

TABLE 3-8

CSM ENTRY AND UPDATE DOWNLIST
(P27, P62, P63, P64, P65, P66, P67)

WORD NO.		REGISTER	DESCRIPTION	
I. D. WORDS				
01	A	CMENTRDL	DOWNLIST IDENTIFICATION	
	B	LOWIDCOD	SYNCHRONIZATION BITS	
SNAPSHOT SECTION OF DOWNLIST				
02 A THRU 13 B			SAME AS CSM POWERED DOWNLIST	
REGULAR SECTION OF DOWNLIST				
14 A THRU 17 B			SAME AS CSM POWERED DOWNLIST	
18	A	CMDAPMOD	ENTRY DAP MODE	
	B	PREL	ROLL RATE	
19	A	QREL	PITCH RATE	
	B	RREL	YAW RATE	
20	A	L/D1	LIFT TO DRAG RATIO	MSB
	B	L/D1 +1		LSB
21	A	UPBUFF	UPDATE VERIFY BUFFERS	
	B	UPBUFF +1		
22	A	UPBUFF +2		
	B	UPBUFF +3		
23	A	UPBUFF +4		
	B	UPBUFF +5		
24	A	UPBUFF +6		
	B	UPBUFF +7		

25	A	UPBUFF +8 D	UPDATE VERIFY BUFFERS	
	B	UPBUFF +9 D		
26	A	UPBUFF +10 D		
	B	UPBUFF +11 D		
27	A	UPBUFF +12 D		
	B	UPBUFF +13D		
28	A	UPBUFF +14 D		
	B	UPBUFF +15 D		
29	A	UPBUFF +16 D		
	B	UPBUFF +17 D		
30	A	UPBUFF +18 D		
	B	UPBUFF +19D		
31	A	COMPNUMB	DESIRED NUMBER OF UPDATE COMPONENTS	
	B	UPOLDMOD	PROGRAM INTERRUPTED BY P27	
32	A	UPVERB	UPDATE VERB	
	B	UPCOUNT	OCTAL IDENTIFIER OF NEXT UPDATE QUANTITY	
33	A	PAXERR1	ROLL ERROR FOR ENTRY DAP	
	B	ROLLTM	ROLL ANGLE FOR ENTRY DAP	
34	A	LATANG	LATERAL RANGE	MSB
	B	LATANG +1		LSB
35	A	RDOT	ALTITUDE RATE	MSB
	B	RDOT +1		LSB
36	A	THETAH	ANGLE BETWEEN PRESENT POSITION AND TARGET VECTOR	MSB
	B	THETAH +1		LSB

37 A	LAT (SPL)	LATITUDE OF ENTRY TARGET		MSB
B	LAT (SPL) +1			LSB
38 A	LNG (SPL)	LONGITUDE OF ENTRY TARGET		MSB
B	LNG (SPL) +1			LSB
39 A	ALPHA/180	ATTITUDE FROM ENTRY DAP		PITCH
B	BETA/180			YAW
FLAGWORDS				
40 A THRU 44 B		SAME AS CSM POWERED DOWNLIST		
DISPLAY TABLES				
45 A THRU 50 B		SAME AS CSM POWERED DOWNLIST		
CMC CLOCK (AND START OF SECOND HALF OF DOWNLIST)				
51 A	TIME2	TIME OF CMC CLOCK		MSB
B	TIME1			LSB
SNAPSHOT SECTION OF DOWNLIST				
52 A	PIPTIME1	TIME AT WHICH PIPAS WERE READ ASSOCIATED WITH DELTA V'S		MSB
B	PIPTIME1 +1			LSB
53 A	DELV	TWO SECOND ACCUMULATION OF PIPA COUNTS	DELTA V X (SM)	MSB
B	DELV +1			LSB
54 A	DELV +2		DELTA V Y (SM)	MSB
B	DELV +3			LSB
55 A	DELV +4		DELTA V Z (SM)	MSB
B	DELV +5			LSB
56 A	TTE	TIME OF FREE FALL TO EMS ENTRY ALTITUDE		MSB
B	TTE +1			LSB

57 A	VI0	PREDICTED VELOCITY AT EMS ENTRY ALTITUDE		MSB
B	VI0 +1			LSB
58 A	VPRED	PREDICTED VELOCITY AT 400,000 FEET ABOVE FISCHER RADIUS		MSB
B	VPRED +1			LSB
59 A THRU 63 B		SAME AS CSM POWERED DOWNLIST		
REGULAR SECTION OF DOWNLIST				
64 A	AK	CONTROL AXIS ATTITUDE ERROR		X
B	AK1			Y
65 A	AK2			Z
B	RCS FLAGS			
66 A	ERRORX	RCS DAP ATTITUDE ERRORS	X	
B	ERRORY		Y	
67 A	ERRORZ		Z	
B	THETADX	DAP DESIRED ICDU ANGLES	X	
68 A	THETADY		Y	
B	THETADZ		Z	
69 A	CMDAPMOD	ENTRY DAP MODE		
B	PREL	ROLL RATE		
70 A	QREL	PITCH RATE		
B	RREL	YAW RATE		
71 A THRU 80 B		SAME AS 21 A THRU 30 B		
81 A	LMMASS	LM CURRENT WEIGHT		
B	CSMMASS	CSM CURRENT WEIGHT		

82	A	DAPDATR1	RCS-CSM DAP INTERFACE DATA
	B	DAPDATR2	
83	A	ROLL TM	ROLL ANGLE
	B	ROLL C	ROLL COMMAND
84	A	OPTMODES	OPTICS MODE
	B	HOLDFLAG	HOLDFLAG
85 A THRU 90 B			SAME AS CSM POWERED DOWNLIST
CHANNELS			
91 A THRU 94 B			SAME AS CSM POWERED DOWNLIST
95	A	RSBBQ	RESTART BBANK
	B	RSBBQ +1	RESTART Q REGISTER
96	A	CADRFLSH	FCADR ADDRESS OF LAST PRIORITY DISPLAY
	B	CADRFLSH +1	FCADR ADDRESS OF LAST MARK DISPLAY
97	A	CADRFLSH +2	FCADR ADDRESS OF LAST NORMAL DISPLAY
	B	FAILREG	ALARM CODE OF FIRST ALARM
98	A	FAILREG +1	ALARM CODE OF SECOND ALARM
	B	FAILREG +2	ALARM CODE OF LAST ALARM
99	A	FLGWRD 10	FLGWRD 10
	B	FLGWRD 11	FLGWRD 11
100	A	GAMMAEI	FLIGHTPATH ANGLE AT 400,000 FEET
	B	RANGE FOR INITIALIZATION	RANGE ANGLE FROM EMS ALTITUDE ABOVE FISCHER RADIUS TO TARGET

TABLE 3-9

CSM RENDEZVOUS AND PRETHRUST DOWNLIST

(P17, P20, P21, P23, P30, P31, P32, P33, P34, P35, P37 P38, P39, P72, P73, P74, P75, P76, P77, P78, and P79)

WORD NO.	REGISTER	DESCRIPTION	
I. D. WORDS			
01 A	CMRENDDL	DOWNLIST IDENTIFICATION	
B	LOWIDCOD	SYNCHRONIZATION BITS	
SNAPSHOT SECTION OF DOWNLIST			
02 A THRU 13 B		SAME AS CSM POWERED DOWNLIST	
REGULAR SECTION OF DOWNLIST			
14 A THRU 22 B		SAME AS CSM POWERED DOWNLIST	
23 A	VHFTIME	TIME OF VHF MARK	MSB
B	VHFTIME +1		LSB
24 A	MARK TIME	TIME OF OPTICS MARK	MSB
B	MARK TIME+1		LSB
25 A	CDUY	YCDU ANGLE	
B	CDUS	OCDU SHAFT ANGLE	
26 A	CDUZ	ZCDU ANGLE	
B	CDUT	OCDU TRUNNION ANGLE (THIS VALUE IS PROPERLY STORED IN R57 OF P23).	
27 A	CDUX	XCDU ANGLE	
B	RM	VHF RANGE FROM CSM TO LM	

28	A	VHFCNT	NUMBER OF VHF MARKS		
	B	MARKCNT	NUMBER OF OPTICS MARKS		
29	A	TTPI	TIME OF TRANSFER PHASE INITIATION		MSB
	B	TTPI +1			LSB
30	A	ECSTEER	CROSS PRODUCT STEERING CONSTANT		MSB
	B	GARBAGE			LSB
31	A	DELVTPF	MAGNITUDE OF DELTA V AT INTERCEPT		MSB
	B	DELVTPF +1			LSB
32	A	CDH TIME	TIME OF IGNITION OF CDH MANEUVER		
	B	CDH TIME + 1			
33	A	CSI TIME	TIME OF IGNITION FOR CSI MANEUVER		
	B	CSI TIME + 1			
34	A	TPF TIME	TIME OF INTERCEPT		MSB
	B	TPF TIME +1			LSB
35	A	DELVSLV	DELTA V IN LOCAL VERTICAL COORDINATES	X	MSB
	B	DELVSLV +1			LSB
36	A	DELVSLV +2		Y	MSB
	B	DELVSLV +3			LSB
37	A	DELVSLV +4		Z	MSB
	B	DELVSLV +5			LSB

38 A	RANGE	CALCULATED RANGE TO THE LM		MSB
B	RANGE +1			LSB
39 A	RRATE	CALCULATED RANGE RATE BETWEEN CM AND LM		MSB
B	RRATE +1			LSB
FLAGWORDS				
40 A THRU 44 B		SAME AS CSM POWERED DOWNLIST		
DISPLAY TABLES				
45 A THRU 50 B		SAME AS CSM POWERED DOWNLIST		
CMC CLOCK (AND START OF SECOND HALF OF DOWNLIST)				
51 A	TIME2	TIME OF CMC CLOCK	MSB	
B	TIME1		LSB	
SNAPSHOT SECTION OF DOWNLIST				
52 A THRU 63 B		SAME AS CSM POWERED DOWNLIST		
REGULAR SECTION OF DOWNLIST				
64 A THRU 73 B		SAME AS CSM POWERED DOWNLIST		
74 A	CDH DELTA ALTITUDE			MSB
B	CDH DELTA ALTITUDE			LSB
75 A thru 76 B	SAME AS CSM POWERED LIST			
77 A	DELVEET 3	TPI DELTA V (IN REFERENCE COORDINATES)	X	MSB
B	DELVEET 3 + 1			LSB
78 A	DELVEET 3 + 2		Y	MSB
B	DELVEET 3 + 3			LSB
79 A	DELVEET 3 + 4		Z	MSB
B	DELVEET 3 + 5			LSB

80 A THRU 90 B		SAME AS CSM POWERED DOWNLIST			
CHANNELS					
91 A THRU 94 B		SAME AS CSM POWERED DOWNLIST			
95 A	RTHETA	ANGLE BETWEEN LOCAL HORIZONTAL PLANE AND EITHER: +X AXIS (IN R31)		MSB	
B	RTHETA +1	OR SXT LINE OF SIGHT (IN R34)		LSB	
96 A	LAT (SPL)	LATITUDE OF TARGET	MSB		
B	LAT (SPL) +1		LSB		
97 A	LNG (SPL)	LONGITUDE OF TARGET	MSB		
B	LNG (SPL) +1		LSB		
98 A	VPRED	PREDICTED ENTRY VELOCITY AT ENTRY INTERFACE	MSB		
B	VPRED +1		LSB		
99 A	GAMMAEI	FLIGHTPATH ANGLE AT ENTRY INTERFACE	MSB		
B	GAMMAEI +1		LSB		
100 A	FLAGWRD 10	FLGWRD 10			
B	FLAGWRD 11	FLGWRD 11			

TABLE 3-10

CSM PROGRAM 22 DOWNLIST

WORD NO.	REGISTER	DESCRIPTION
I. D. WORDS		
01 A	CMPG22DL	DOWNLIST IDENTIFICATION
B	LOWIDCOD	SYNCHRONIZATION BITS
SNAPSHOT SECTION OF DOWNLIST		
02 A THRU 13 B		SAME AS CSM POWERED DOWNLIST
REGULAR SECTION OF DOWNLIST		
14 A THRU 17 B		SAME AS CSM POWERED DOWNLIST
18 A	SVMRKDAT	LANDING SITE MARK DATA
B	SVMRKDAT +1	
19 A	SVMRKDAT +2	
B	SVMRKDAT +3	
20 A	SVMRKDAT +4	
B	SVMRKDAT +5	
21 A	SVMRKDAT +6	
B	SVMRKDAT +7	
22 A	SVMRKDAT +8	
B	SVMRKDAT +9	
23 A	SVMRKDAT +10	
B	SVMRKDAT +11	

24	A	SVMRKDAT	+12	
	B	SVMRKDAT	+13	
25	A	SVMRKDAT	+14	
	B	SVMRKDAT	+15	
26	A	SVMRKDAT	+16	
	B	SVMRKDAT	+17	
27	A	SVMRKDAT	+18	
	B	SVMRKDAT	+19	
28	A	SVMRKDAT	+20	LANDING SITE MARK DATA
	B	SVMRKDAT	+21	
29	A	SVMRKDAT	+22	
	B	SVMRKDAT	+23	
30	A	SVMRKDAT	+24	
	B	SVMRKDAT	+25	
31	A	SVMRKDAT	+26	
	B	SVMRKDAT	+27	
32	A	SVMRKDAT	+28	
	B	SVMRKDAT	+29	
33	A	SVMRKDAT	+30	
	B	SVMRKDAT	+31	
34	A	SVMRKDAT	+32	
	B	SVMRKDAT	+33	
35	A	SVMRKDAT	+34	
	B	SVMRKDAT	+35	GARBAGE

36 A	LANDMARK	LANDMARK IDENTIFICATION	
B	GARBAGE		
37 A THRU 39 B		SPARE	
FLAGWORDS			
40 A THRU 44 B		SAME AS CSM POWERED DOWNLIST	
DISPLAY TABLES			
45 A THRU 50 B		SAME AS CSM POWERED DOWNLIST	
CMC CLOCK (AND START OF SECOND HALF OF DOWNLIST)			
51 A	TIME2	TIME OF CMC CLOCK	MSB
B	TIME1		LSB
SNAPSHOT SECTION OF DOWNLIST			
52 A	LAT	LANDMARK LATITUDE	MSB
B	LAT +1		LSB
53 A	LONG	LANDMARK LONGITUDE	MSB
B	LONG +1		LSB
54 A	ALT	LANDMARK ALTITUDE	MSB
B	ALT +1		LSB
55 A THRU 58 B		SPARE	
59 A THRU 63 B		SAME AS POWERED LIST	

REGULAR SECTION OF DOWNLIST

64 A THRU 73 B		SAME AS CSM POWERED DOWNLIST		
74 A	8NN	NUMBER OF VALID MARKS		
B	GARBAGE			
75 A	FLGWRD 10	FLGWRD 10		
B	FLGWRD 11	FLGWRD 11		
76 A	RLS	LANDING SITE VECTOR	X	MSB
B	RLS +1			LSB
77 A	RLS +2		Y	MSB
B	RLS +3			LSB
78 A	RLS +4		Z	MSB
B	RLS +5			LSB
79 A		SPARE		
B		SPARE		
80 A THRU 90 B		SAME AS CSM POWERED DOWNLIST		
CHANNELS				
91 A THRU 94 B		SAME AS CSM POWERED DOWNLIST		
95 A THRU 100 B		SPARE		

3.5 CMC INPUT/OUPUT CHANNEL INTERFACE

The CMC interfaces with the rest of the GNCS and the other spacecraft systems in three basic ways:

1. Program interrupts
2. Counter interrupts
3. Input/output channels

The program interrupts inform the CMC that certain conditions exist which demand the interruption of its present course of action according to a predetermined order of priorities. The counter interrupts inform the CMC that one of many variables it has stored in its erasable memory requires an incremental change. These counter interrupts do not cause an interrupt in the program being processed but they do cause a 12 μsec suspension of the program during which time the counter interrupt is processed.

The input/output channels of the CMC make available to the various programs information about spacecraft conditions and provide the CMC with a means of communicating with other spacecraft systems. There are nine output channels (Nos. 5, 6, 10, 11, 12, 13, 14, 34 and 35), and six input channels (Nos. 15, 16, 30, 31, 32, and 33) in the CMC. Each of these channels contains up to 15 bits of information. These bits of information are referred to as discretes. The input and output channels are described in the following paragraphs and interface drawings showing the path taken by each of these discretes. Also included in these drawings are all circuit breakers and switches which play a part in the completion of an action called for by the issuance or acceptance of a discrete by the CMC.

3.5.1 Channel 5 and Channel 6

These two output channels (Fig. 3-4) have eight bit positions each, and are associated with the reaction control system (RCS) jets. These channel outputs are used to control the translational and rotational motion of the spacecraft. A logic one in any of the bit positions causes the appropriate RCS jet to be fired.

3.5.2 Channel 10

This output channel (Fig. 3-5) utilizes all 15 bit positions. By varying the discretes in the 15 bit positions of channel 10, the CMC has the capability of turning on four condition indicators (PROG, TRACKER, GIMBAL LOCK, and NO ATT), on the DSKY and also turning on a combination of electroluminescent lamps in each of the 21 display register positions (including VERB, NOUN, and PROG) to form any decimal digit. The three sign indicator positions associated with the three data registers are also controlled by a combination of bits in this channel.

3.5.3 Channel 11

This output channel is used primarily to provide the CMC with additional interface with the display and keyboard. Bit 1 (Fig. 3-6) is routed to a relay in the DSKY to provide an ISS warning indication. Bit positions 2 through 7 (Fig. 3-7) are routed to the DSKY relays and provide the remainder of the inputs to the DSKY condition indicators as well as providing for the flashing of the VERB and NOUN registers. Bit 8 is a spare. Bit 9 is for ground use. Bit 10 is set by an error reset signal. Bits 11 and 12 are spares. Bit position 13 (Fig. 3-8) of channel 11 provides for on/off control of the SPS engine.

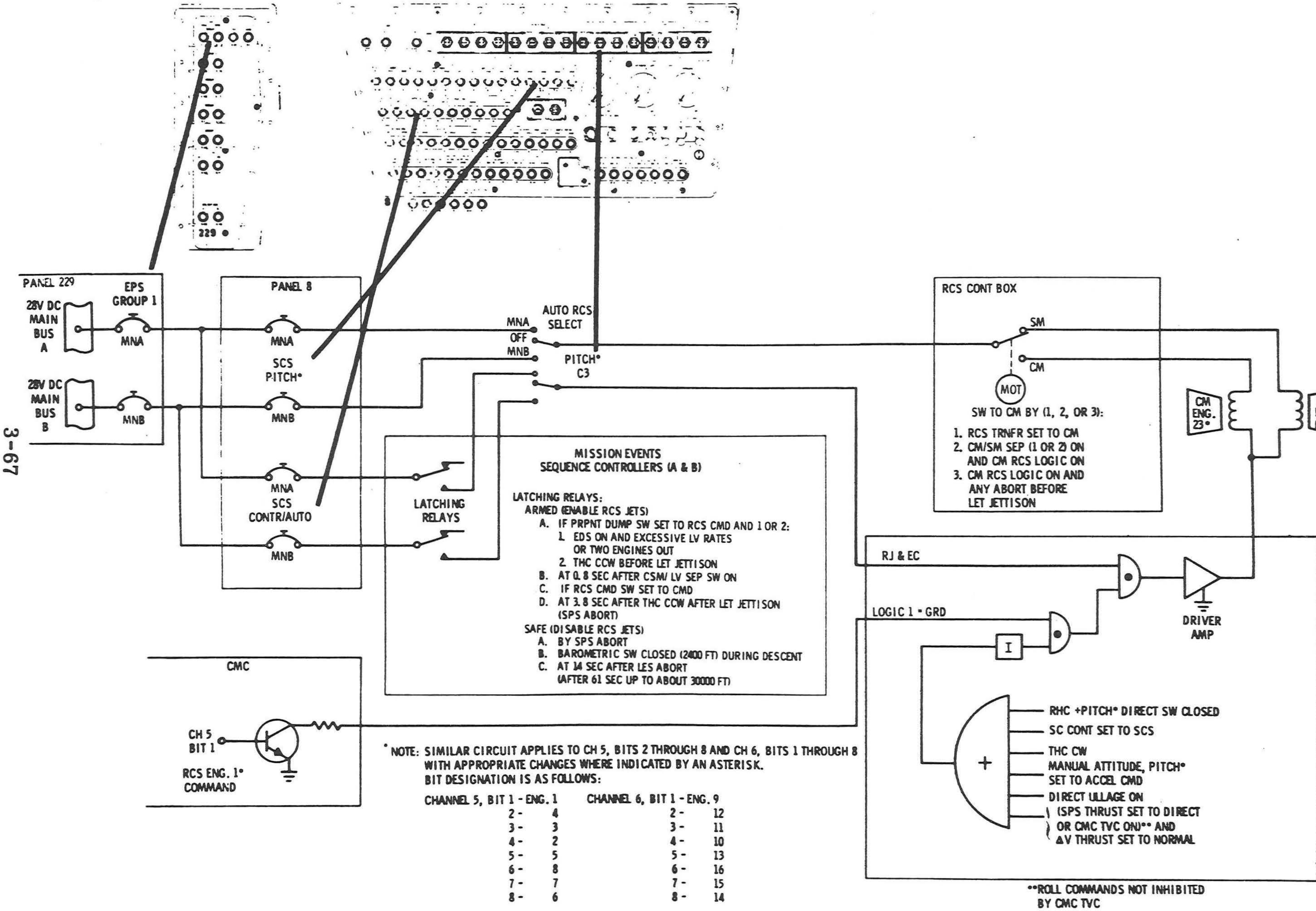


Fig. 3-4. Channels 5 and 6, RCS Jet Commands

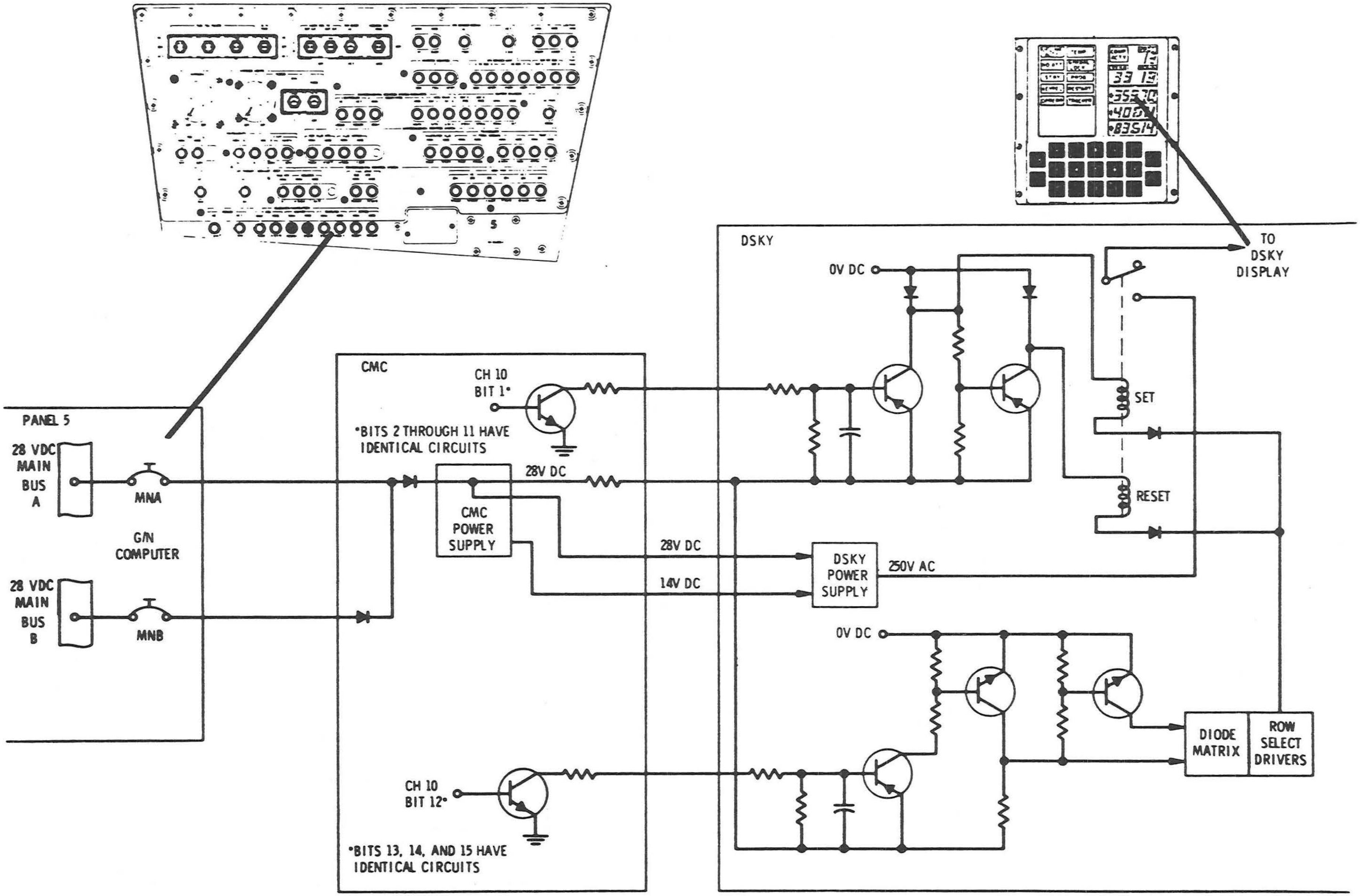


Fig. 3-5. Channel 10, DSKY Relay Commands

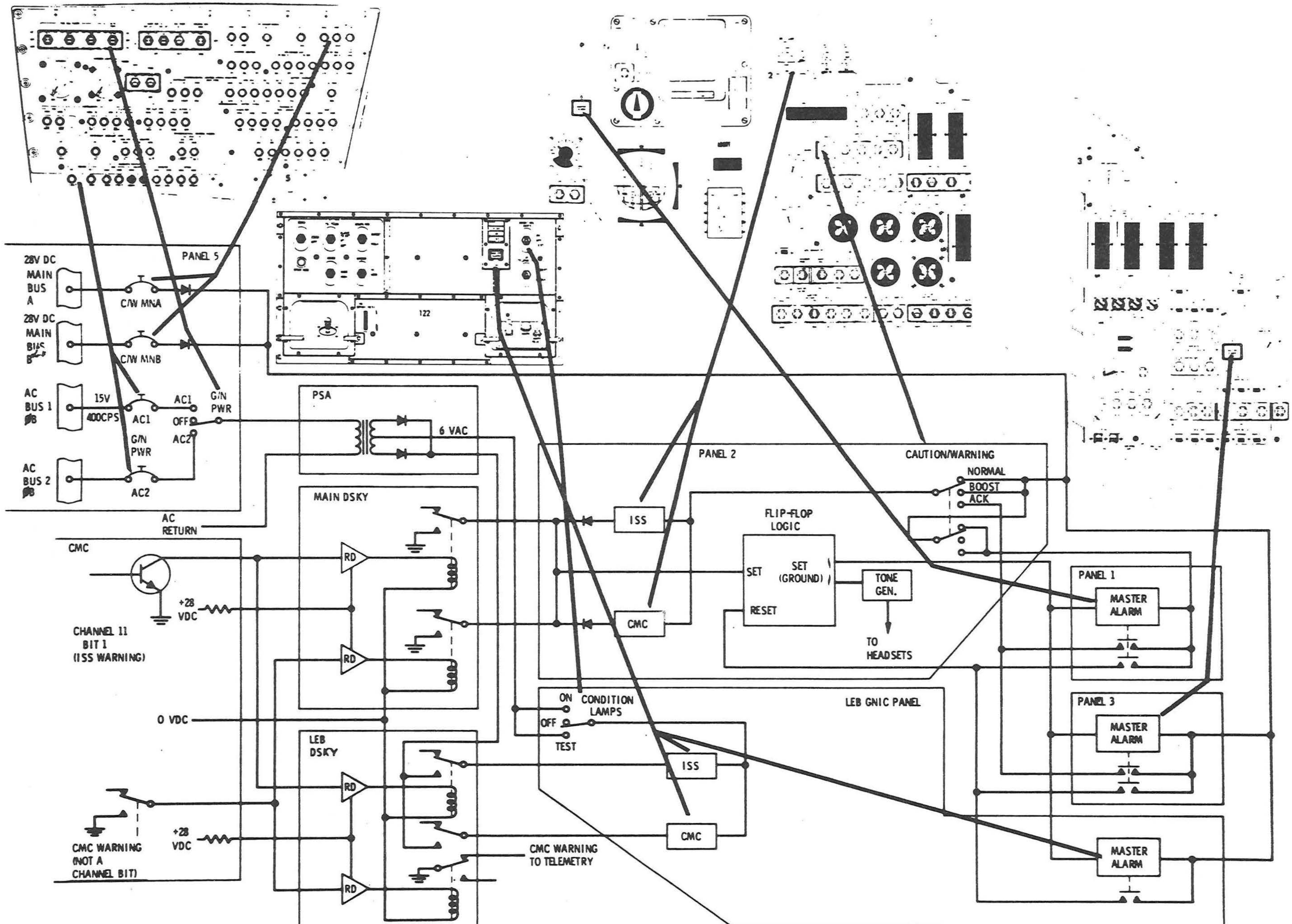


Fig. 3-6. Channel 11 Bit 1, ISS Warning, and CMC Warning

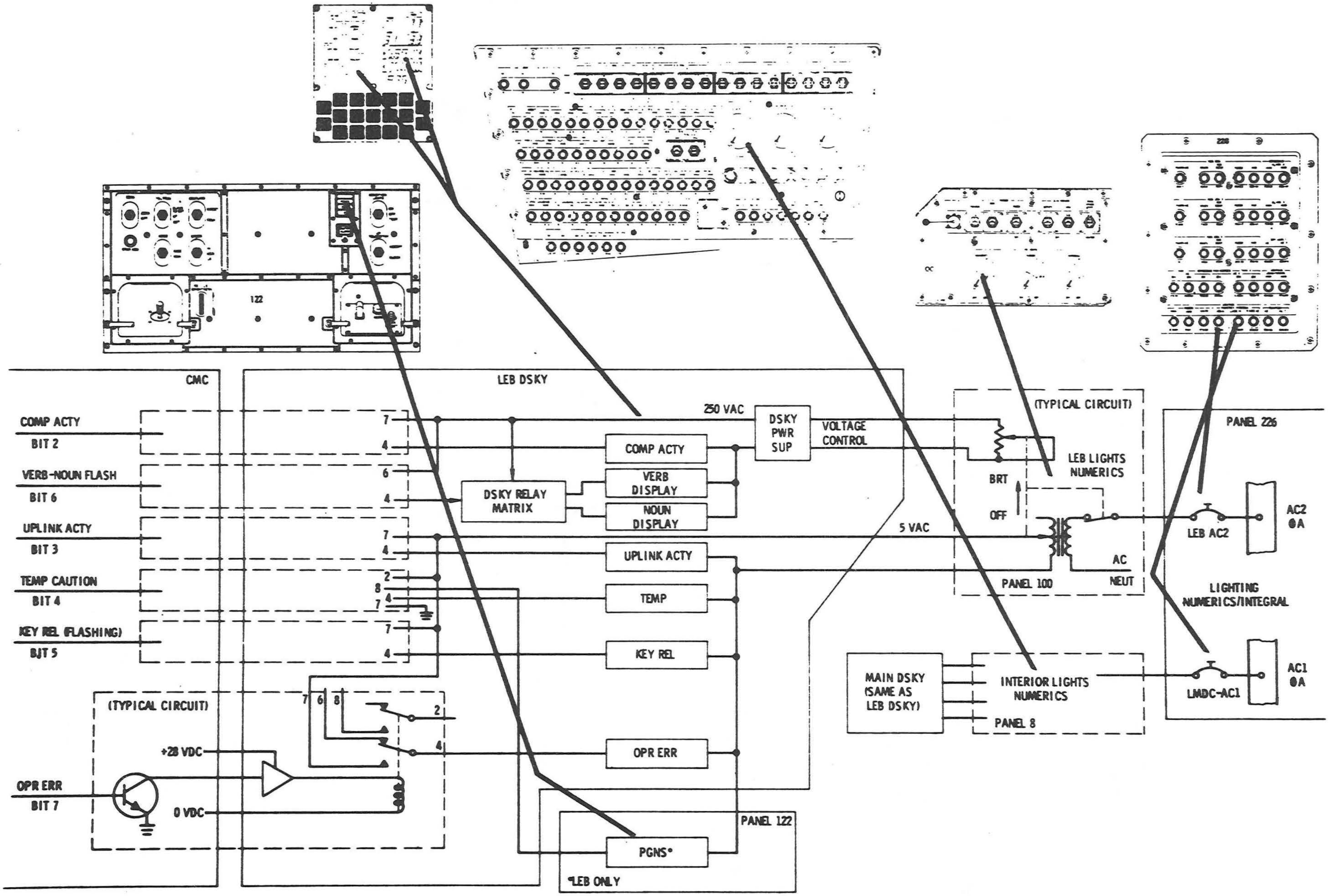


Fig. 3-7. Channel 11 Bits 2 thru 7, DSKY Indicators

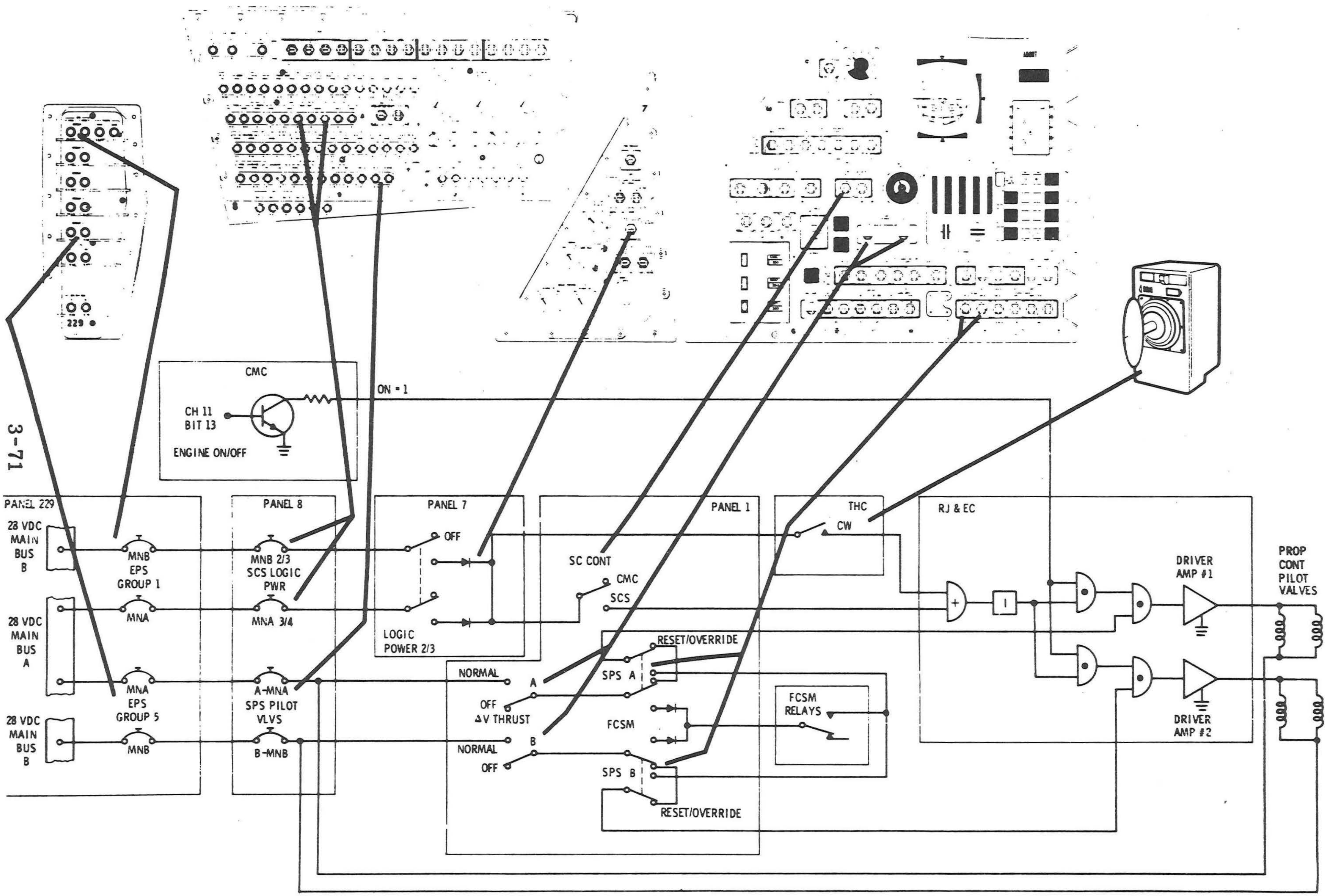


Fig. 3-8. Channel 11 Bit 13, Engine On/Off

3.5.4 Channel 12

Output channel 12 interfaces primarily with the other portions of the GNCS. Bits 1, 2, 4, 5 and 6 of channel 12 (Figs. 3-9, 3-10, and 3-11) interface with the CDU's and are used to control ISS and OSS operation. Bits 3 and 7 are spares. Bits 8 and 9 (Figs. 3-12 and 3-13) also interface with the CDU's and are used to enable CMC thrust vector control and SIVB takeover. Bits 10 and 11 are provided for CMC control of optics moding. Bit 11 is set to 1 in preparation for TVC. Bit 12 is a spare. Bits 13 and 14 (Fig. 3-14) operate DSKY relays which provide discretes to the Saturn instrumentation unit for control of the SIVB. Bit 15 (Fig. 3-15) provides an ISS moding discrete to complete the ISS turn on delay.

3.5.5 Channel 13

The bit positions of this output channel are used by the CMC for internal control of the CMC. Bits 1 through 4 are used for VHF Ranging. Bits 5 and 6 are used internally to control receipt of uplink data. Bit positions 7 and 8 of this channel are used by the CMC to control the processing of data in the interface circuits in the CMC. Bit 7 is associated with downlink and bit 8 is associated with BMAG counter control. Bit 9 is a spare. Bit positions 10 through 15 of this channel are also used for controlling interface circuits internal to the CMC. Bit 10 generates a signal which inhibits RESTRT in the ALARM circuit. This allows various caution indicators on the DSKY to be tested. A one in bit position 11 enables the standby circuits. Bit positions 12, 13, 14 reset the interface circuits which control the rotation, translation, and minimum impulse program interrupts. Bit position 15 of channel 13 is used by the CMC for the generation of a signal, T6RUPT, which enables the decrementing of the TIME6 counter for reaction control program termination. There are no interface drawings for channel 13 since they are used internally in the CMC.

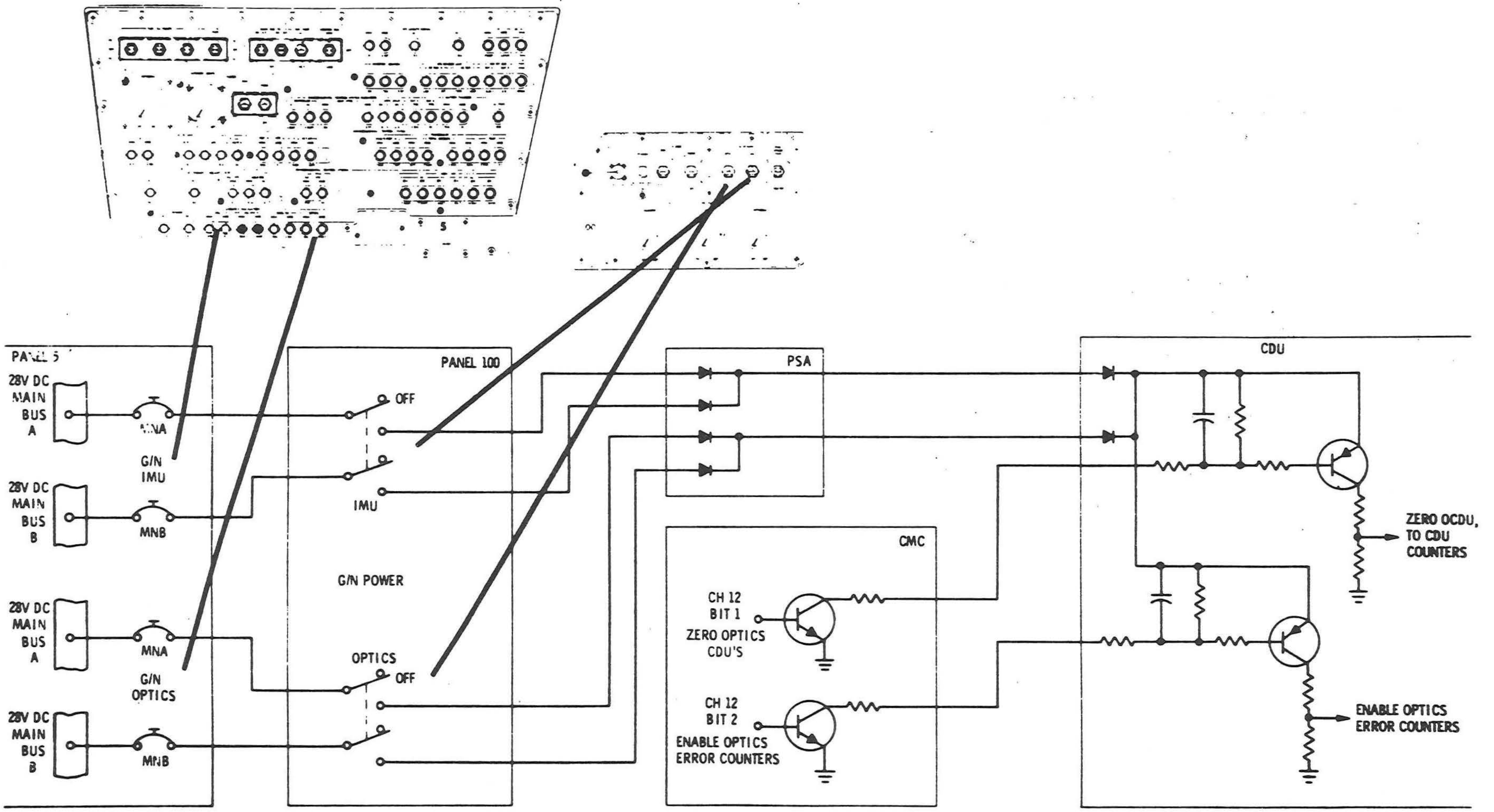


Fig. 3-9. Channel 12 Bits 1 and 2, Zero OCDU's and Enable Optics Error Counters

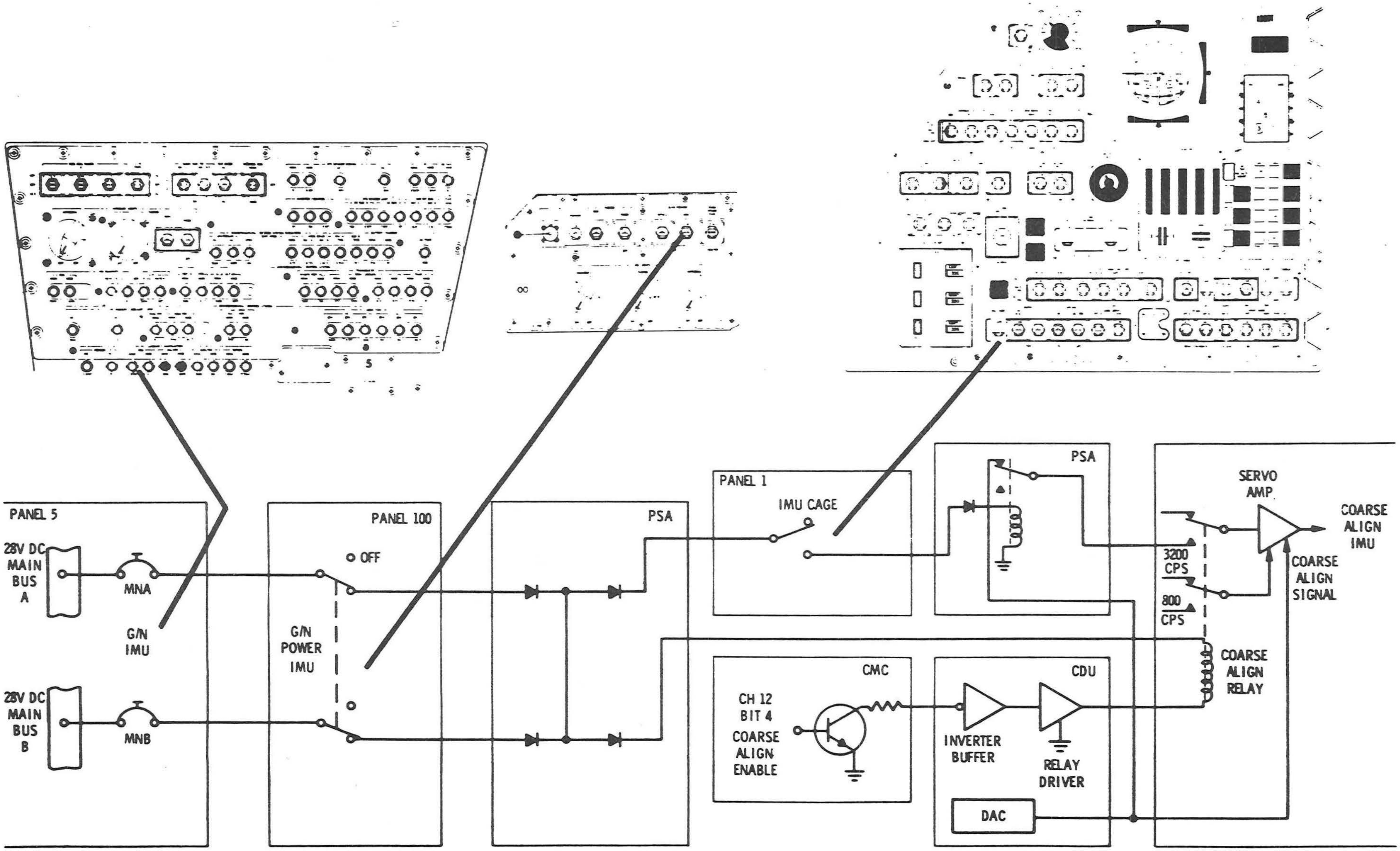


Fig. 3-10. Channel 12 Bit 4, Coarse Align Enable

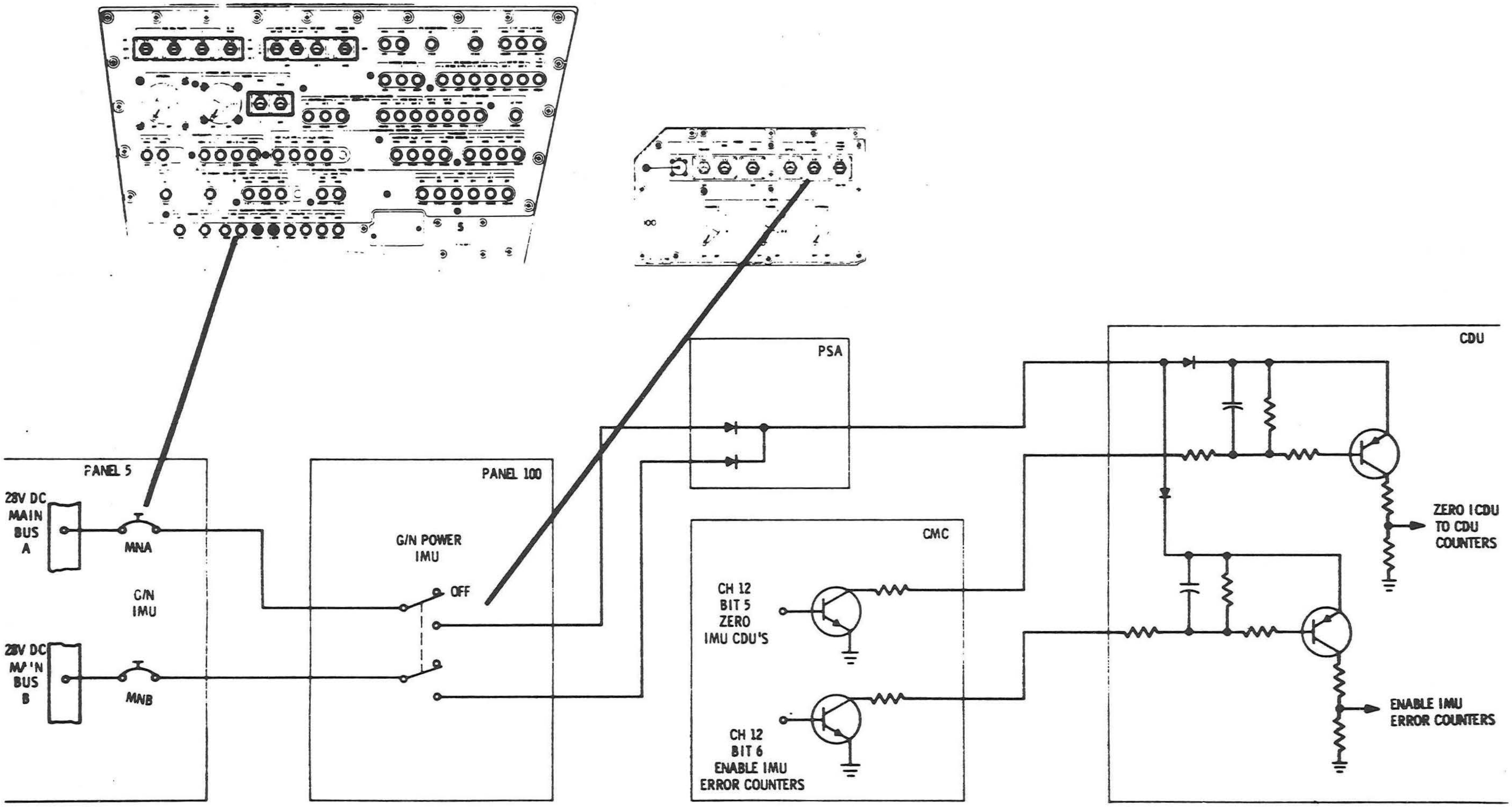


Fig. 3-11. Channel 12 Bits 5 and 6, Zero ICDU's and Enable IMU Error Counters

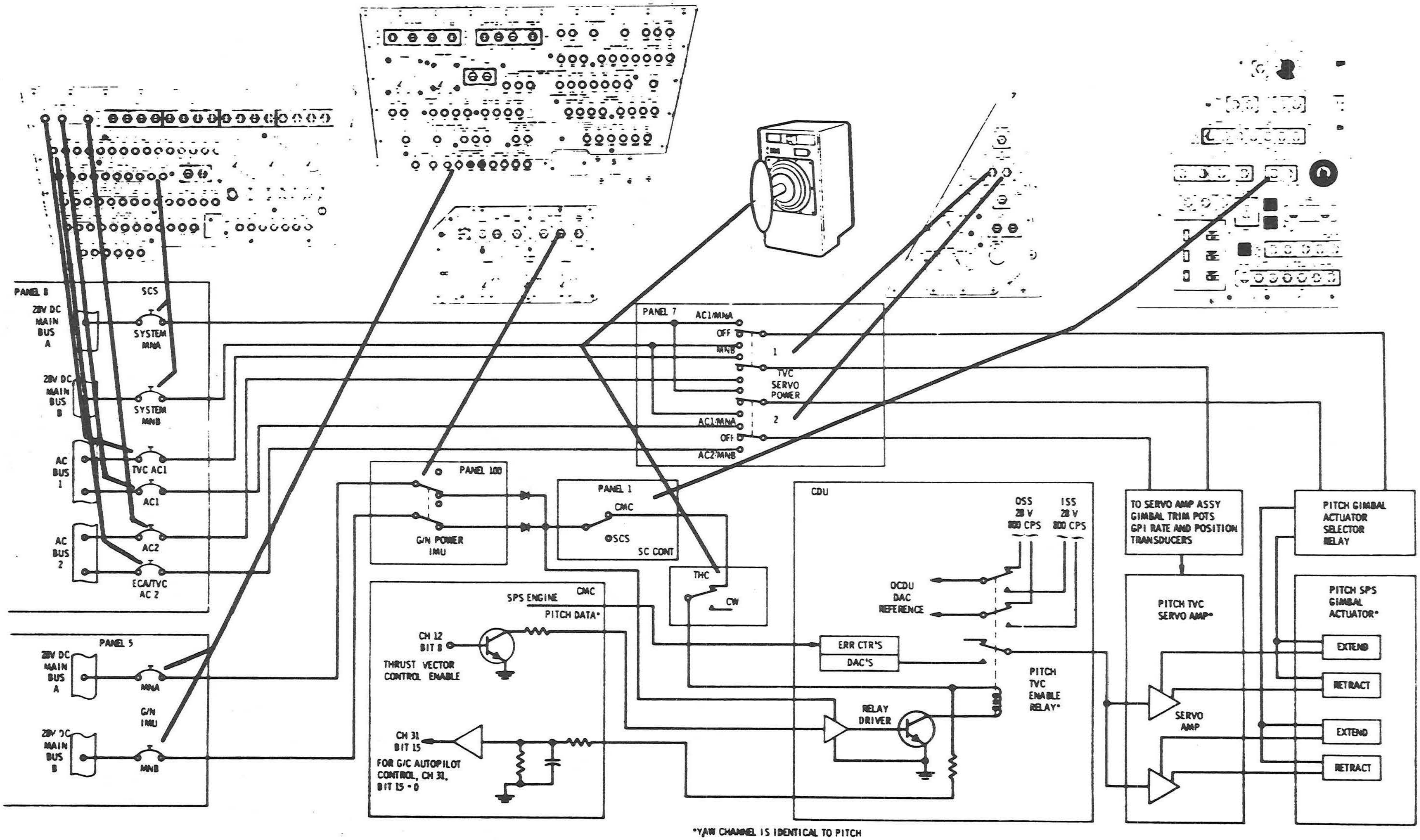


Fig. 3-12. Channel 12 Bit 8, TVC Enable and Channel 31 Bit 15, CMC Spacecraft Control

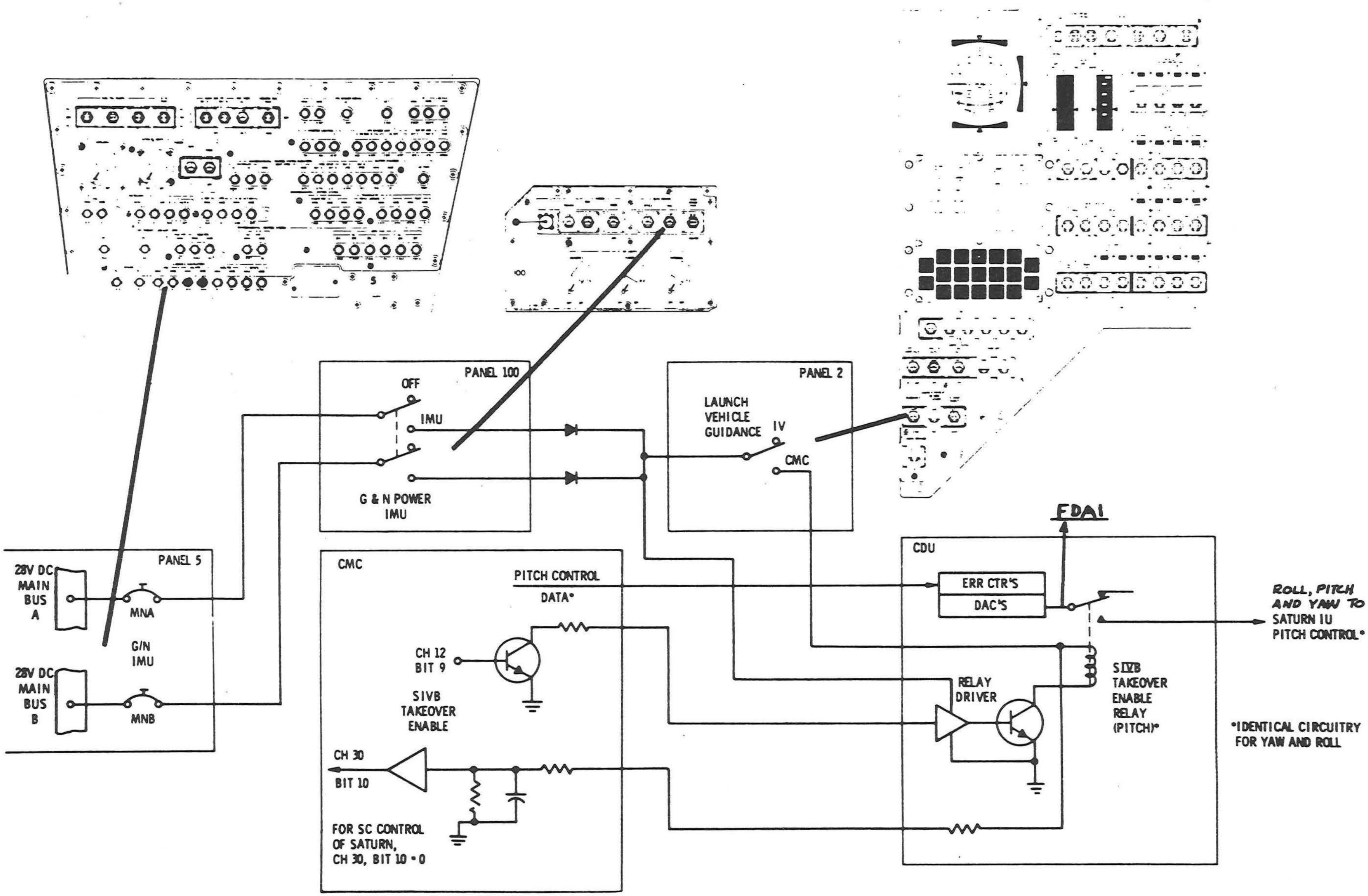


Fig. 3-13. Channel 12 Bit 9, SIVB Takeover Enable and Channel 30 Bit 10, SC Control of Saturn

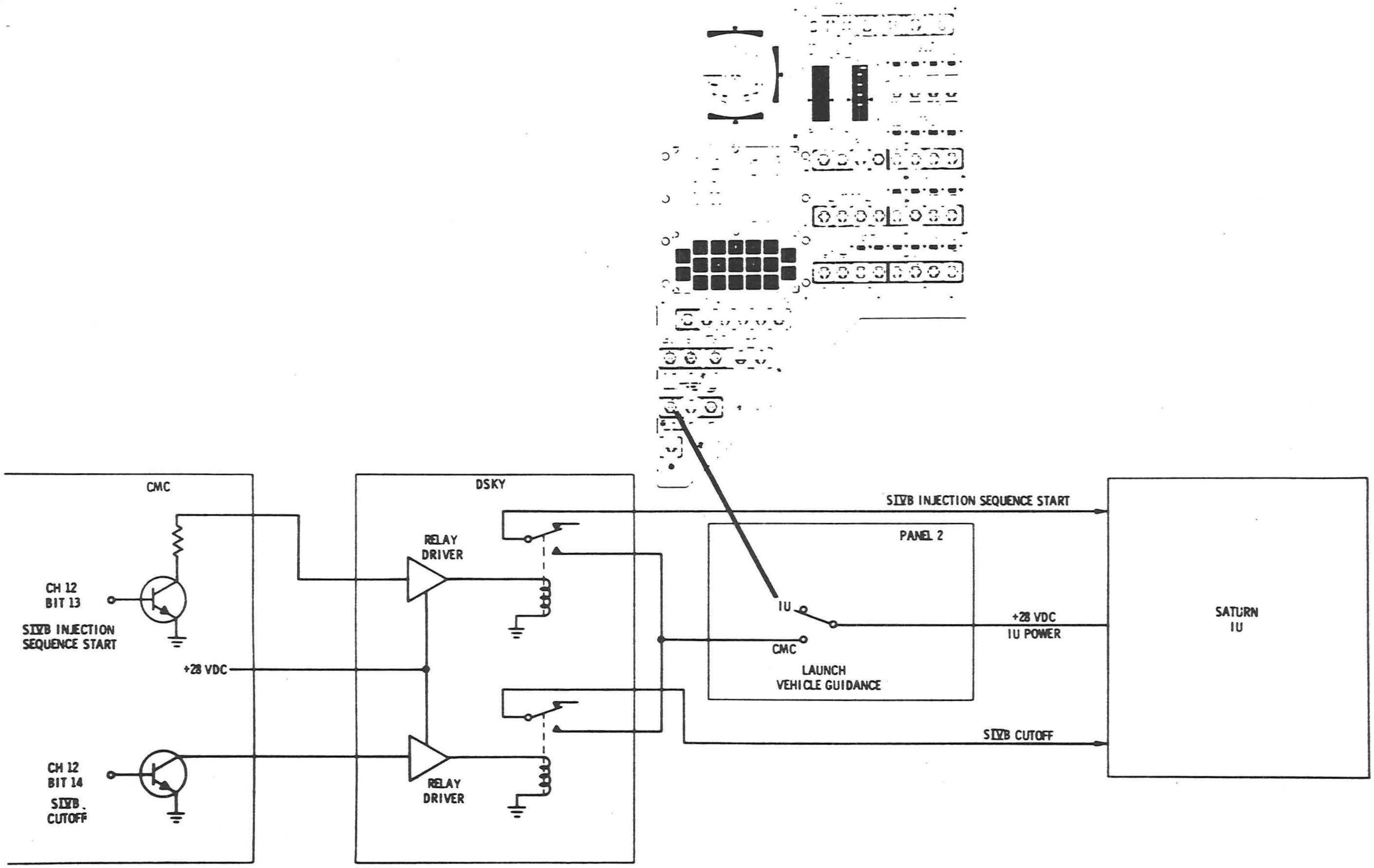


Fig. 3-14. Channel 12 Bits 13 and 14, SIVB Injection Sequence Start and SIVB Cutoff

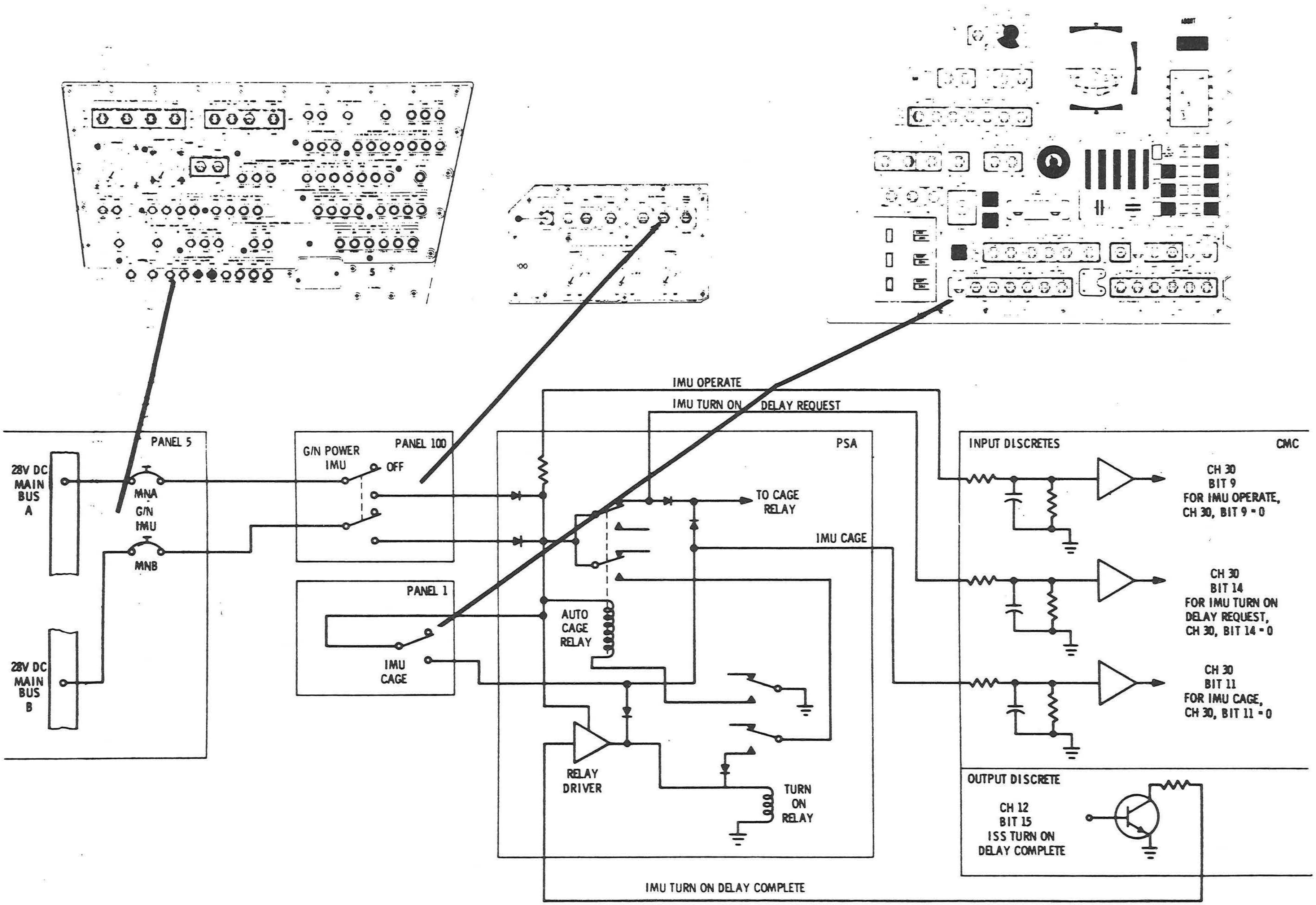


Fig. 3-15. Channel 12 Bit 15, ISS Turn On Delay Complete and Channel 30 Bits 9, 11, and 14, IMU Operate, IMU Cage, and IMU Turn On Delay Request

3.5.6 Channel 14

Channel 14 controls various areas of the CMC for the transfer of data from counters in memory to various GNCS and spacecraft systems. Bit position 1 enables the crosslink control logic which provides a serial data word to the crosslink equipment. Bits 2 through 5 are spares. Bit positions 6 through 10 are used by the CMC to control the torquing of the gyros during fine alignment of the IMU. Bit positions 11 and 12 control the interface circuits in the CMC used to drive the optics in shaft and trunnion. Bit positions 13, 14 and 15 control the interface circuits used to drive the IMU gimbals during coarse align.

3.5.7 Channel 15

This input channel is the interface between the CMC and the main panel DSKY key codes. Whenever any key on the DSKY, except the PRO key, is pressed a five bit key code is sent to the CMC through channel 15, bits 1 through 5. These 5 bit positions are the only ones used in this channel.

3.5.8 Channel 16

The first 5 bit positions of channel 16 interface with the LEB DSKY in the same way channel 15 does with the main DSKY. Bit positions 6 and 7 (Fig. 3-16) are the inputs from the MARK and MARK REJECT buttons. The rest of the bits in this channel are not used.

3.5.9 Channel 30

This input channel provides the CMC with information pertaining to the status of the ISS, OSS and other spacecraft systems, the status of certain switches, and the status of the launch vehicle. Bit 1 (Fig. 3-17) is an indication of the presence of ullage from the Saturn IU. Bit 2 (Fig. 3-18) indicates the status of the CM/SM SEP switches. Bit 3 (Fig. 3-19) indicates the status

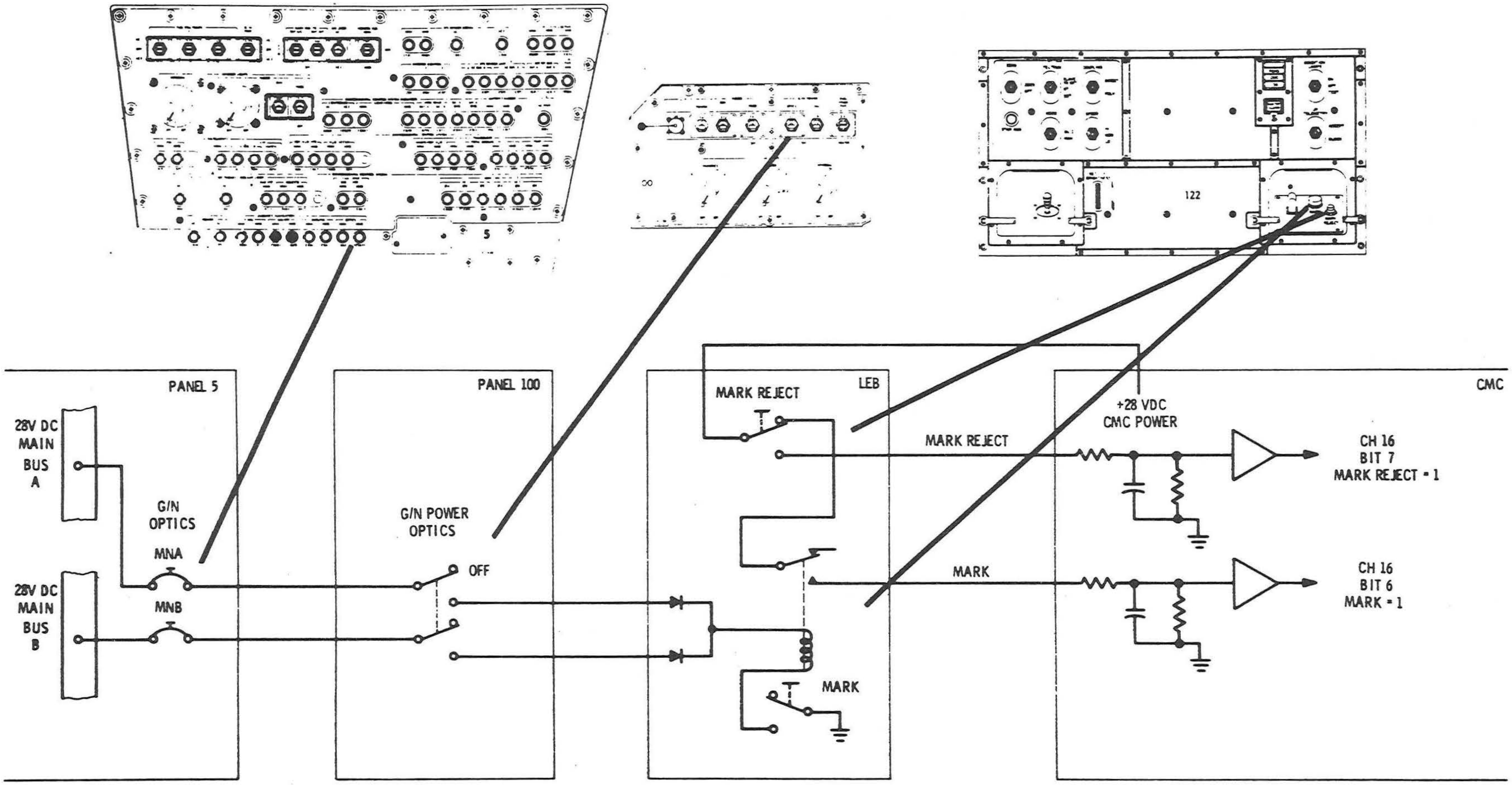


Fig. 3-16. Channel 16 Bits 6 and 7, Optics Mark and Mark Reject

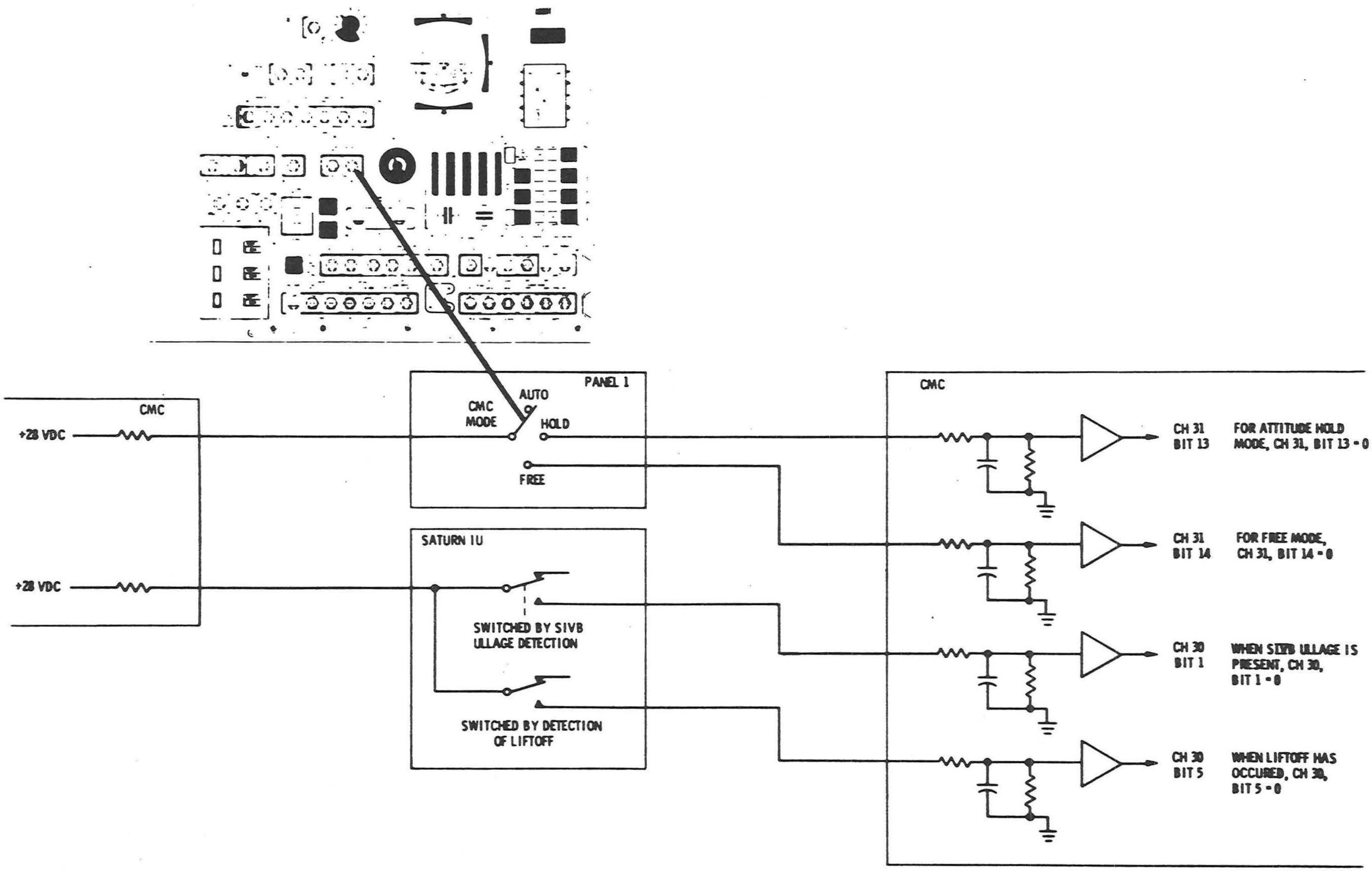


Fig. 3-17. Channel 30 Bits 1 and 5, SIVB Ullage and Liftoff and Channel 31 Bits 13 and 14, CMC SC Control Modes

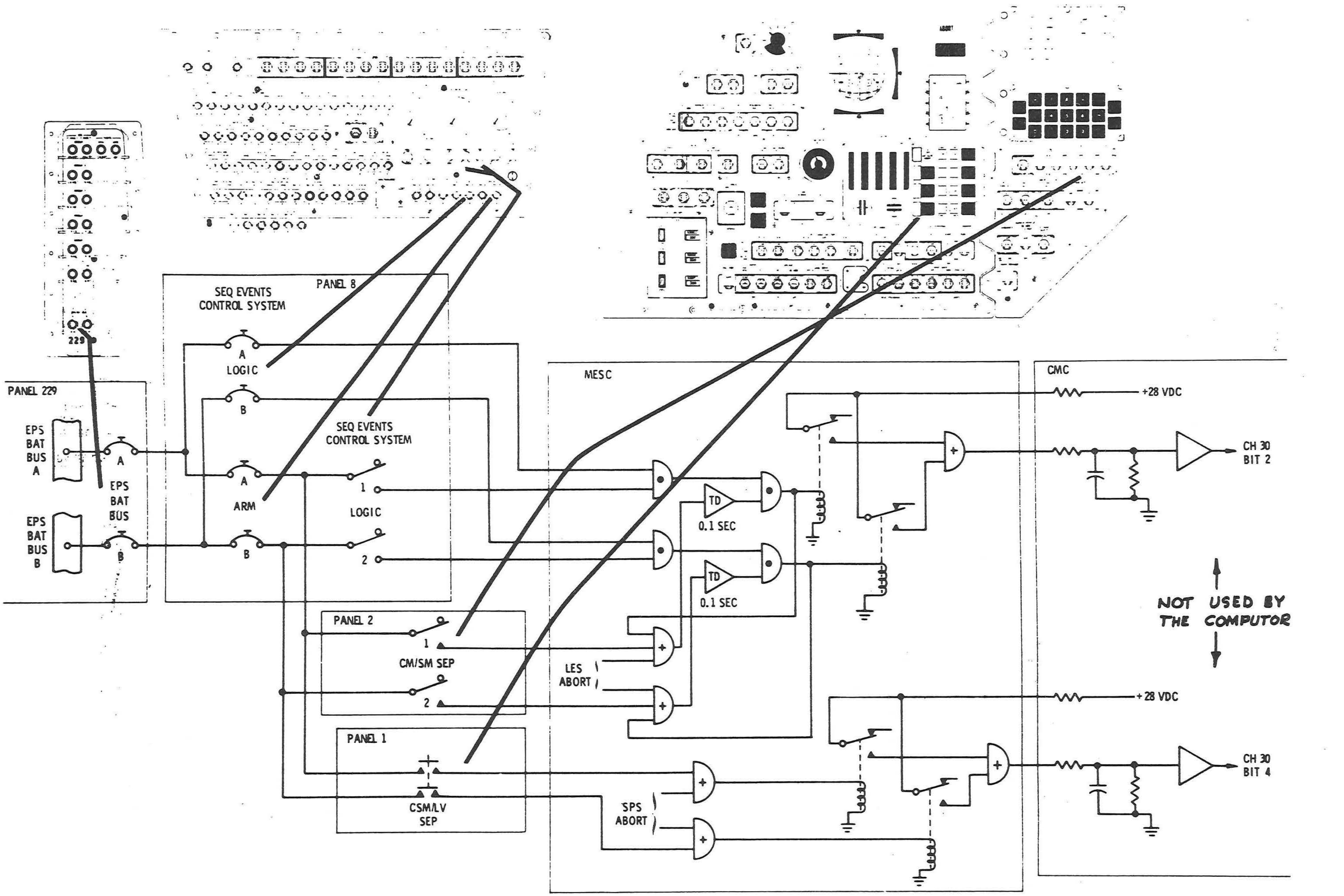


Fig. 3-18. Channel 30 Bits 2 and 4, SM Separate and SIVB Separate

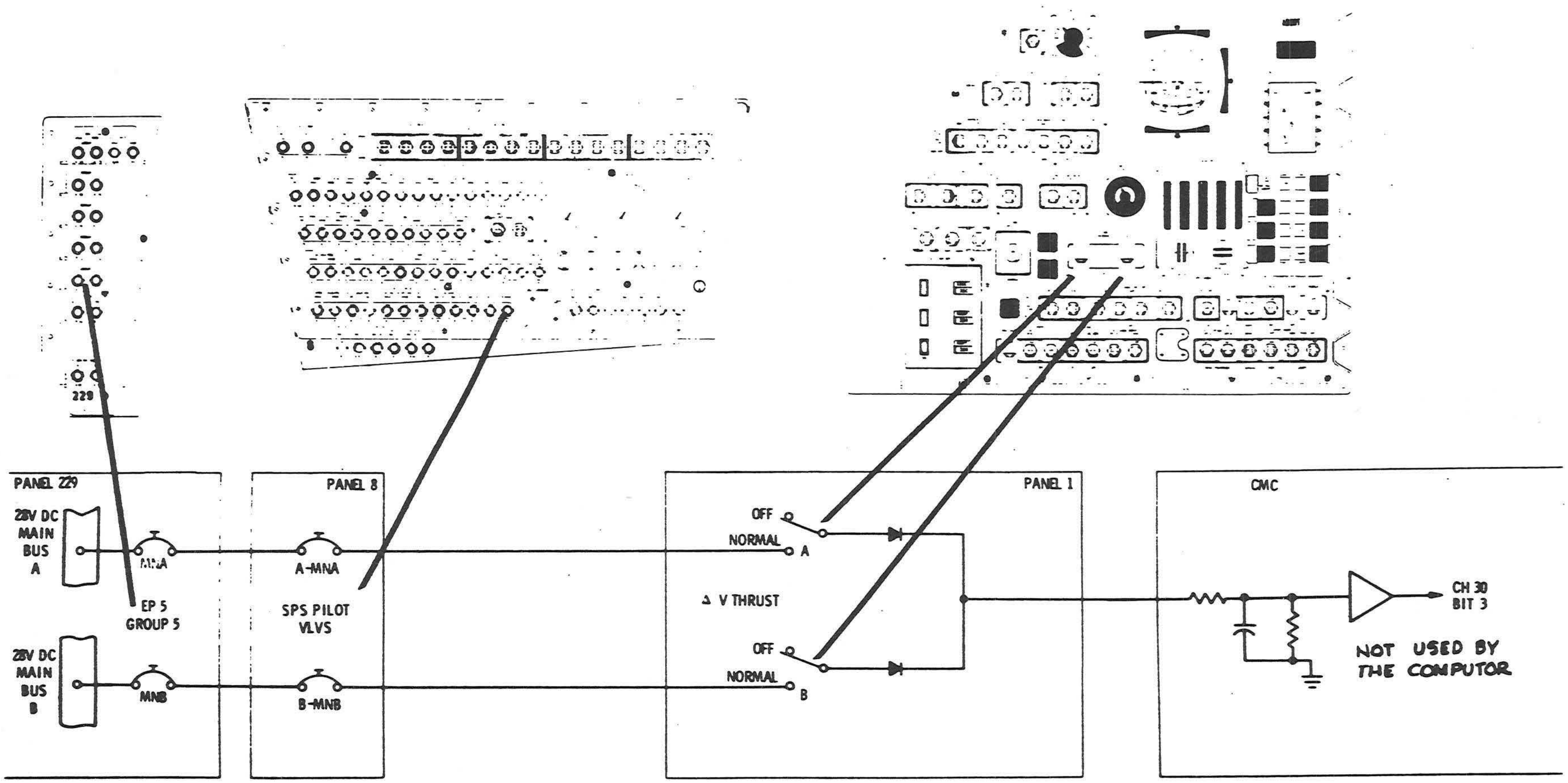


Fig. 3-19. Channel 30 Bit 3, SPS Ready

of the Δ V THRUST switch. Bit 4 (Fig. 3-18) indicates the status of the ABORT SIVB SEPARATE. Even though Bits 2, 3, and 4 are provided to the CMC, they are not used by the computer. Bit 5 (Fig. 3-17) indicates detection of liftoff by the Saturn IU. Bit 6 is a spare. Bit 7 (Fig. 3-20) is an indication of the status of the optics CDU. Bit 8 is a spare. Bit 9 (Fig. 3-15) is the means by which the CMC is informed that the IMU has been turned on. Bit 10 (Fig. 3-13) informs the CMC that the LAUNCH VEHICLE GUIDANCE switch has been placed in the CMC position. Bit 11 (Fig. 3-15) is the means by which the CMC is informed that the IMU CAGE switch has been placed to the on position. Bit positions 12 and 13 (Figs. 3-21 and 3-22) are inputs to the CMC from the CDU and IMU fail detect circuitry. Bit 14 (Fig. 3-15) of this channel is the input to the CMC that requests a 90 second delay during IMU turn on. Bit 15 (Fig. 3-23) of channel 30 is the input to the CMC from the IMU temperature monitoring circuit.

3.5.10 Channel 31

This channel provides the CMC with translation and rotation information. Bit positions 1 through 6 (Fig. 3-24) are inputs of rotational hand control commands in pitch, yaw, and roll. Bit positions 7 through 12 (Fig. 3-25) are inputs to the CMC from the translation hand control for X, Y, and Z axis translation. The last three bits in this channel, bits 13 and 14 (Fig. 3-17) and 15 (Fig. 3-12) provide the CMC with the status of the SC CONT switch and the CMC MODE switch.

3.5.11 Channel 32

The first six bits of this channel, bits 1 through 6 (Fig. 3-26), are inputs from minimum impulse control in the LEB. Bits 7 through 10 are spares.

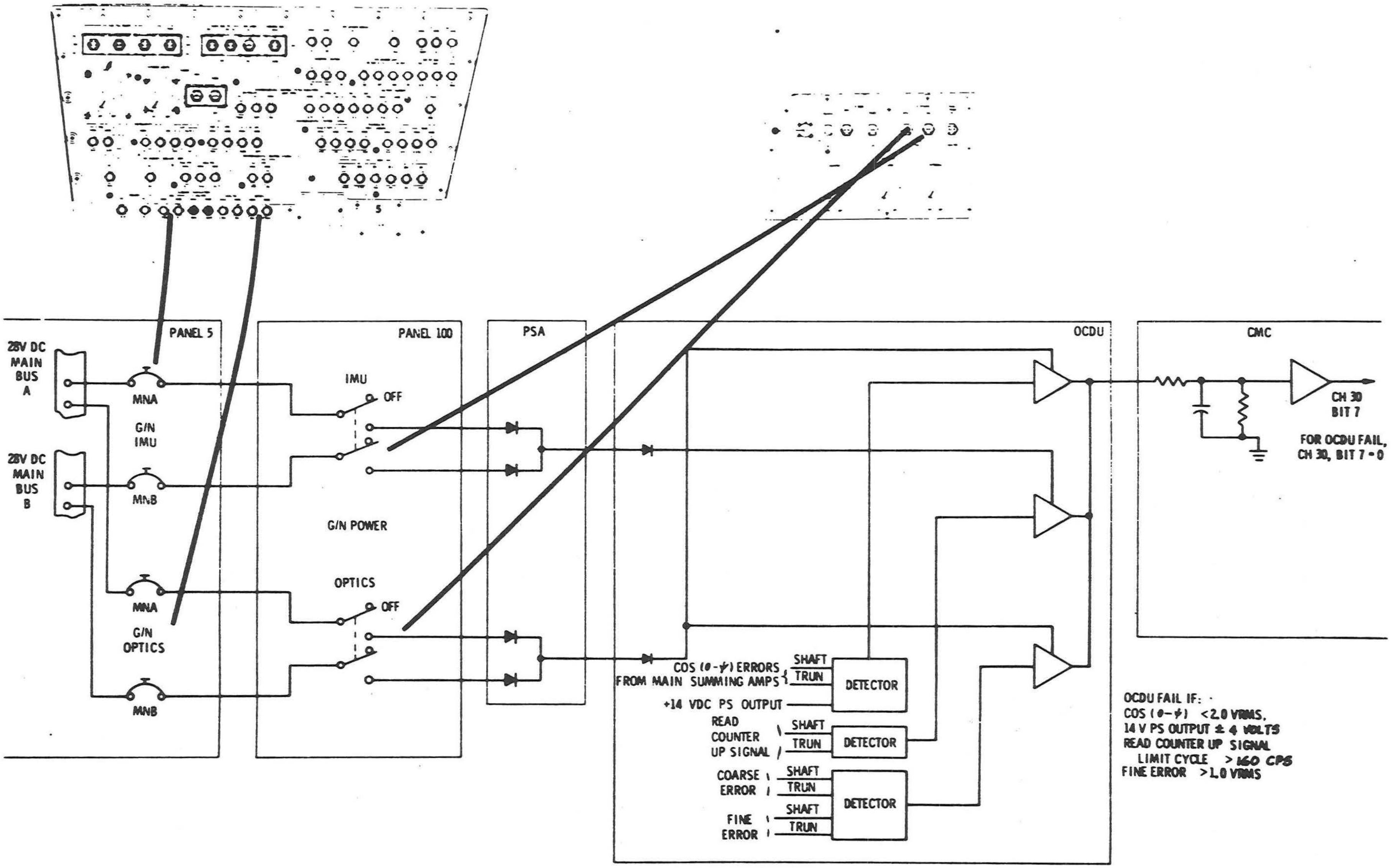


Fig. 3-20. Channel 30 Bit 7, OCDU Fail

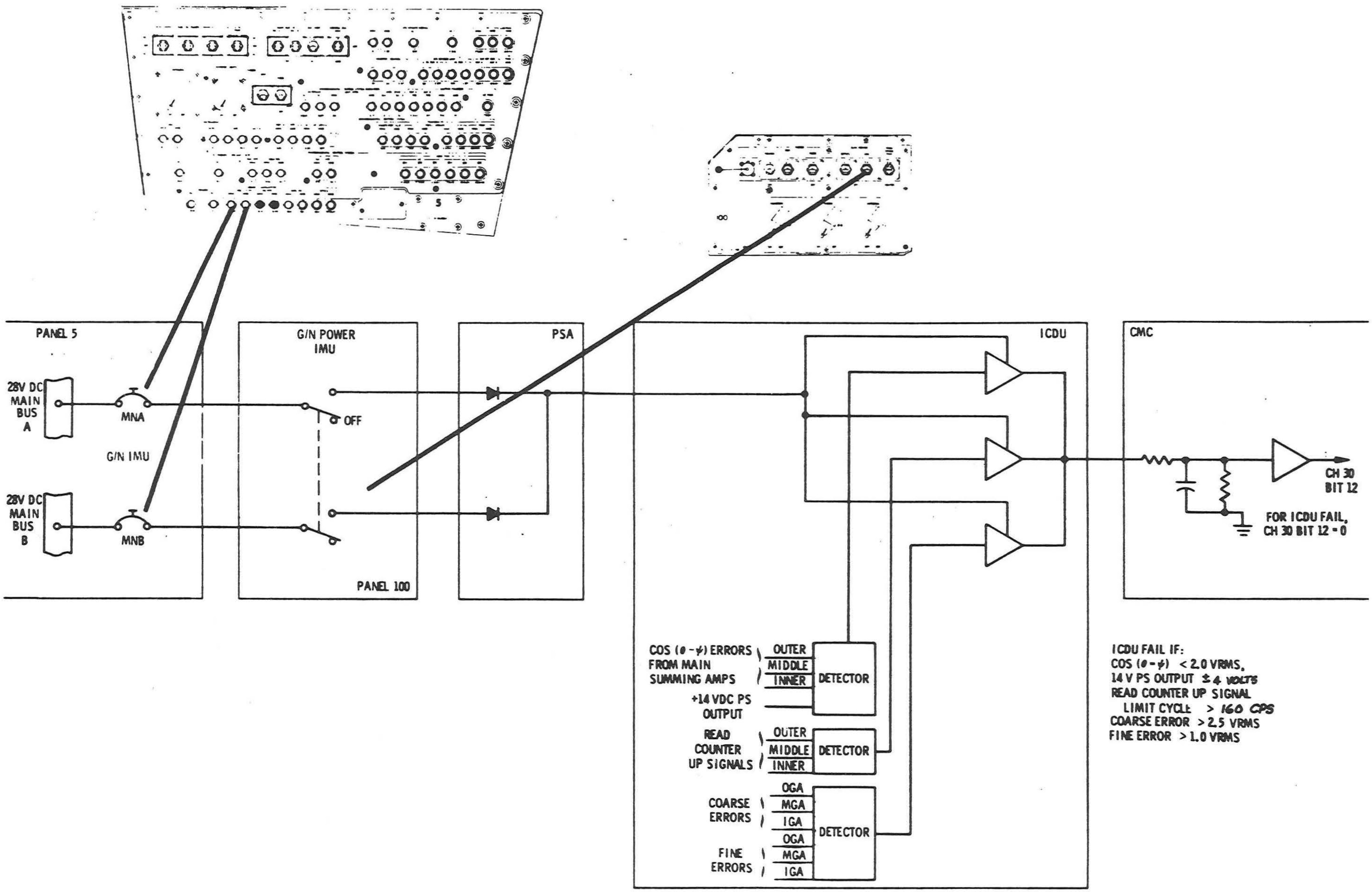


Fig. 3-21. Channel 30 Bit 12, ICDU Fail

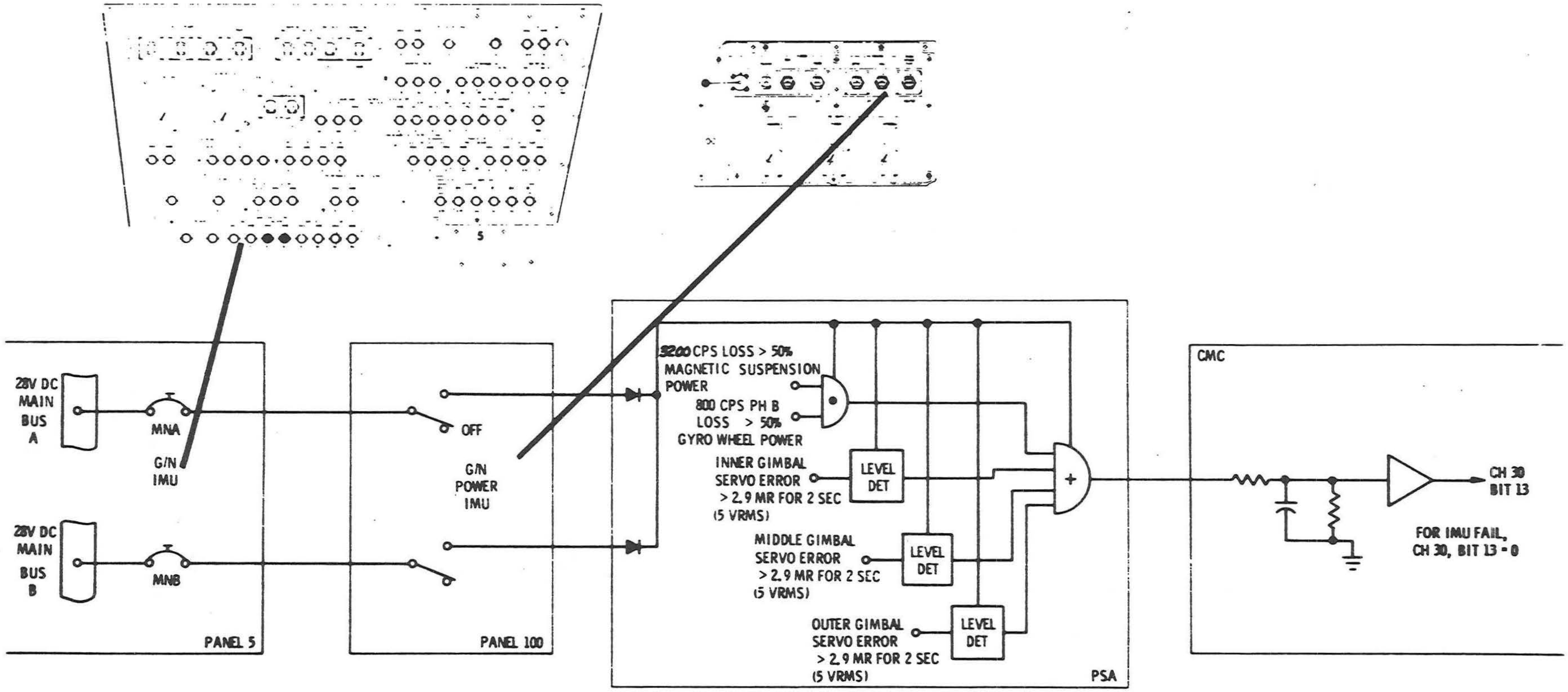


Fig. 3-22. Channel 30 Bit 13, IMU Fail

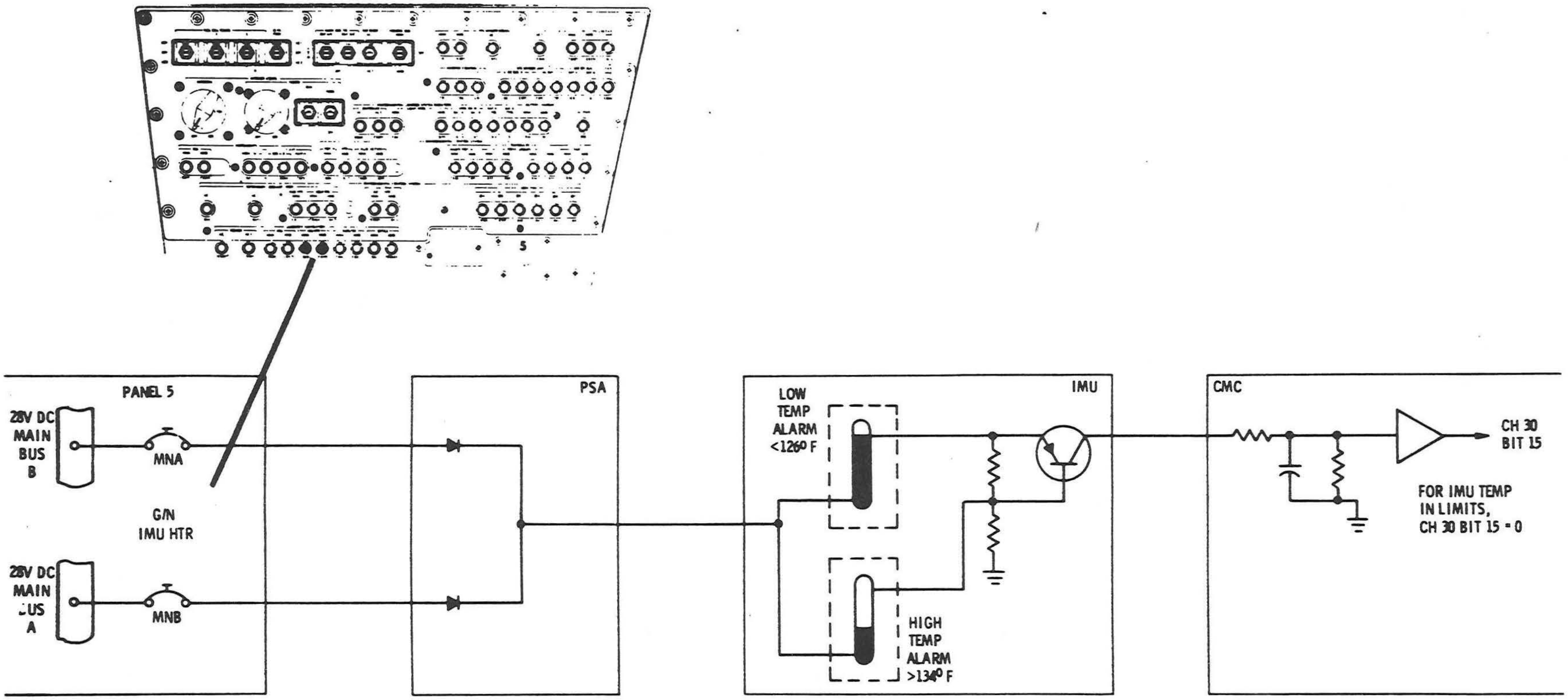


Fig. 3-23. Channel 30 Bit 15, IMU Temperature Within Limits

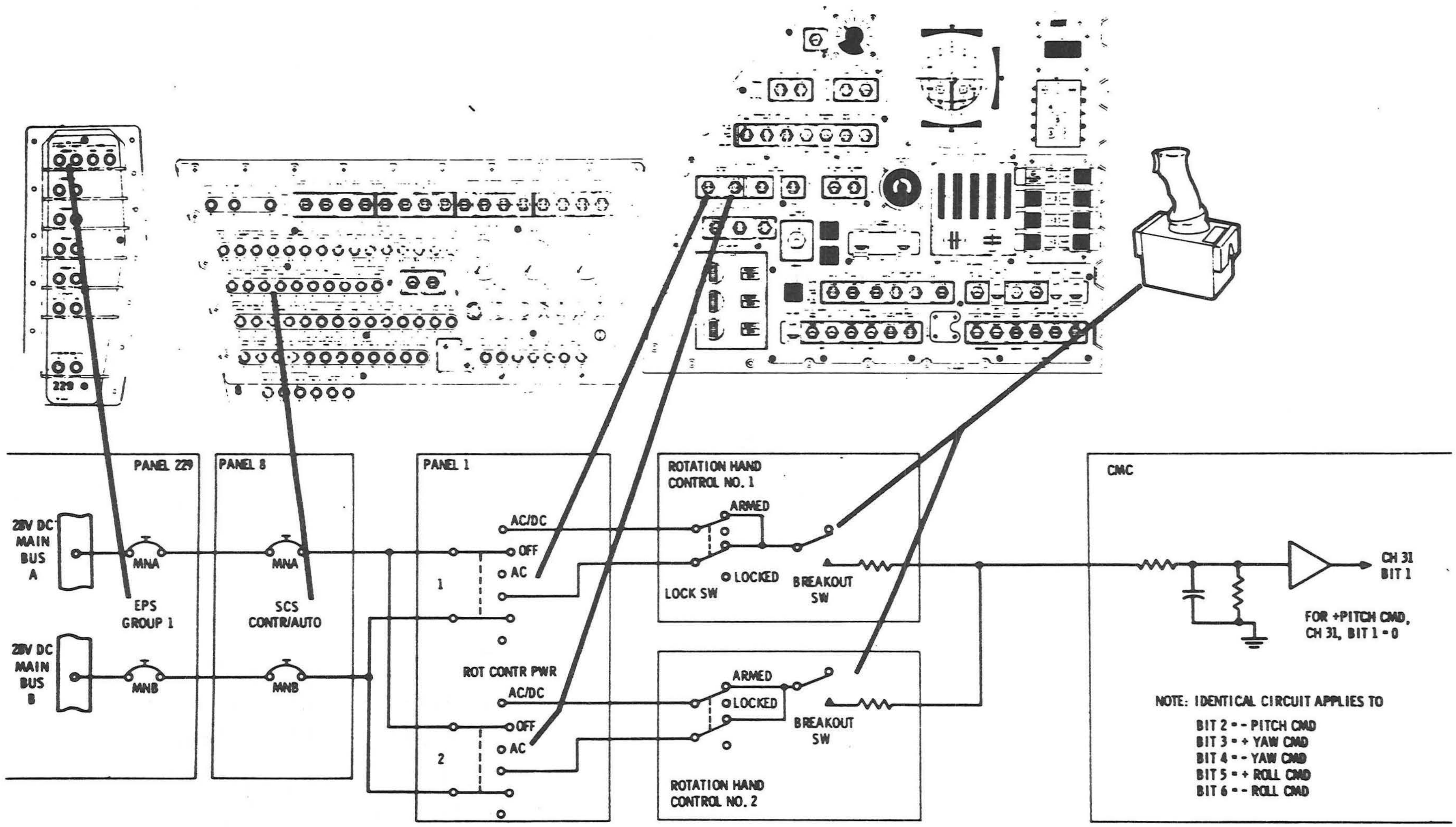


Fig. 3-24. Channel 31 Bits 1 thru 6, RCS Rotation Commands

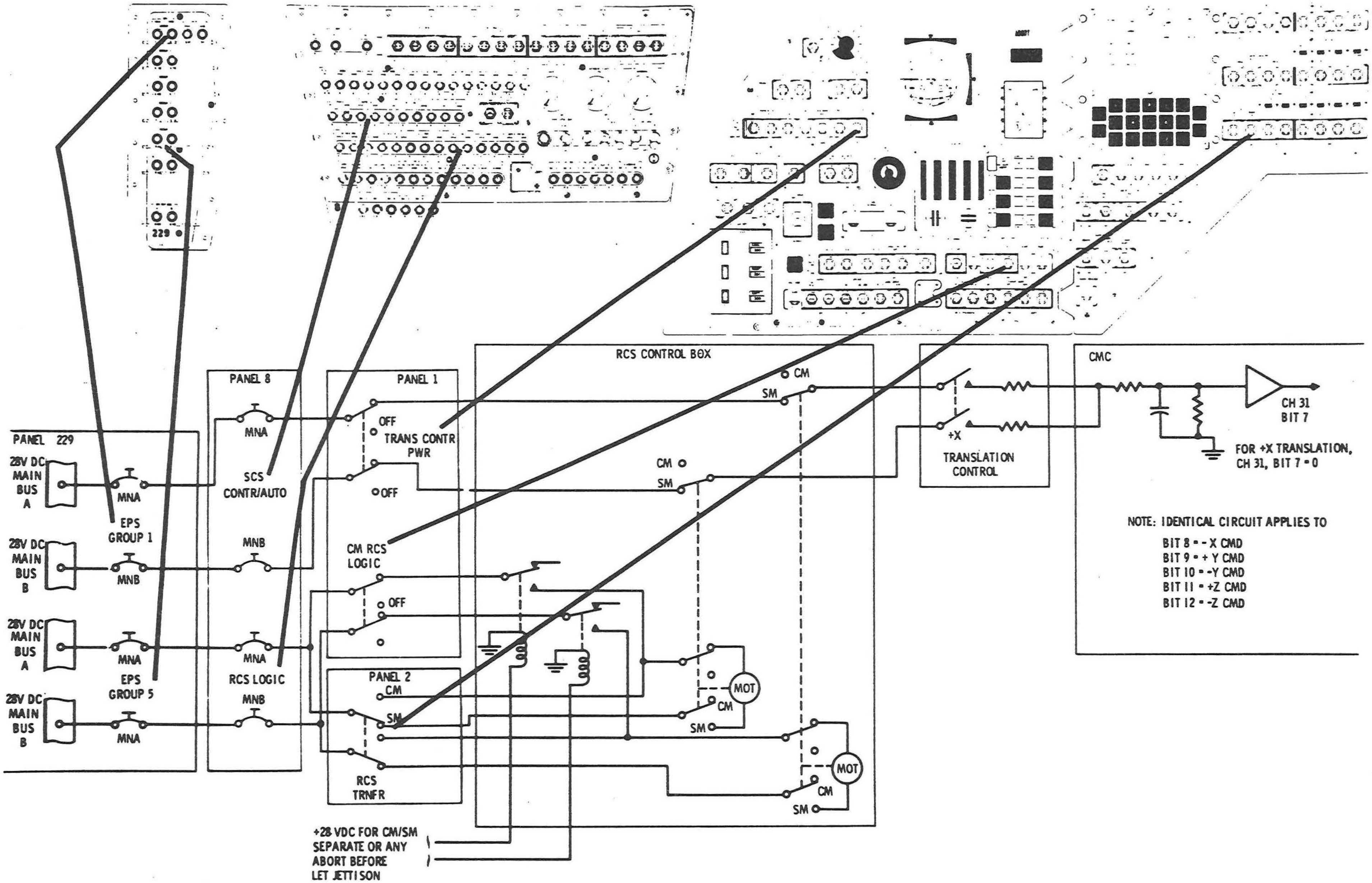


Fig. 3-25. Channel 31 Bits 7 thru 12, RCS Translation Commands

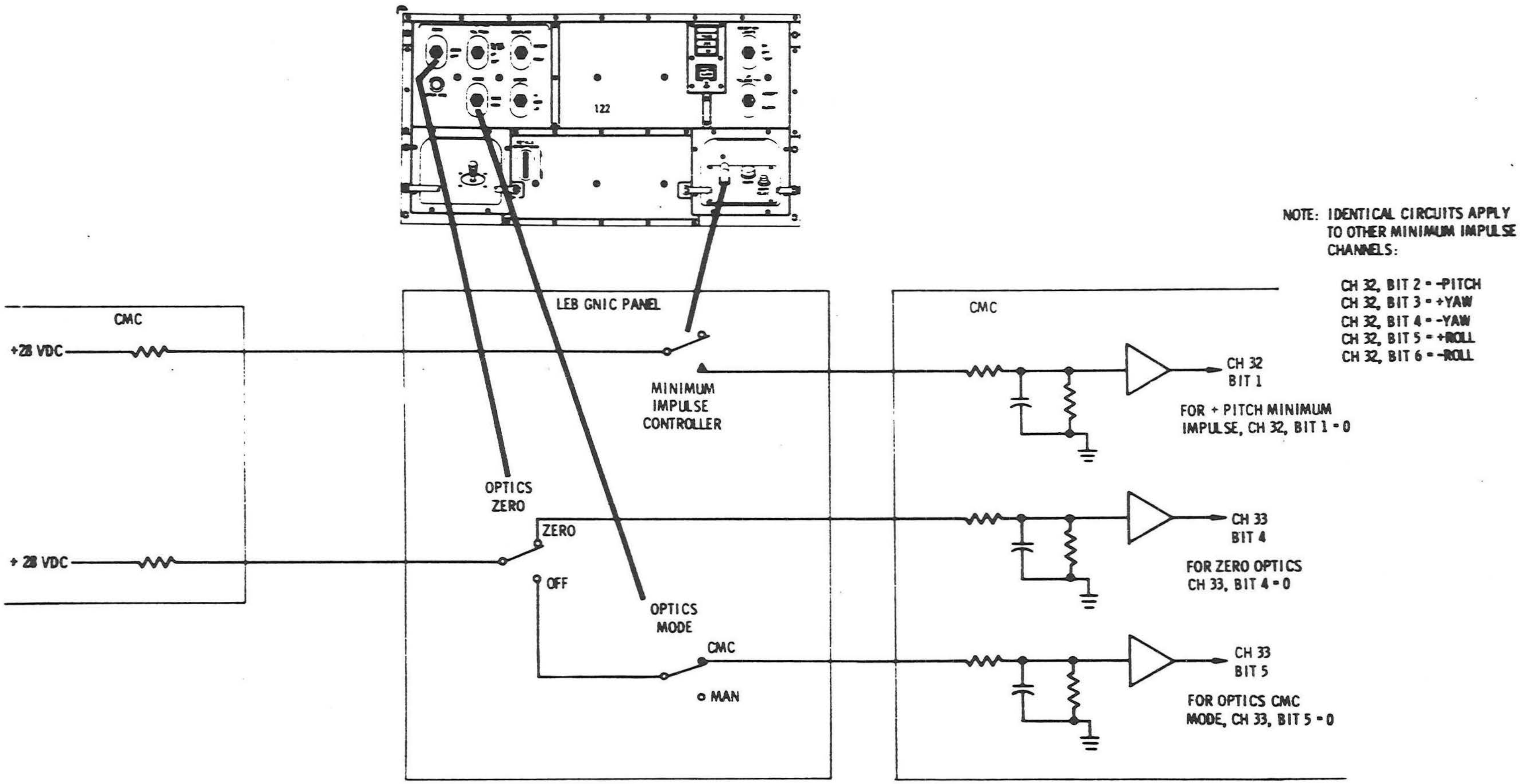


Fig. 3-26. Channel 32 Bits 1 thru 6, Minimum Impulse Commands and Channel 33 Bits 4 and 5, Optics Modes

Bit 11 informs the CMC that the LM is attached. Bit positions 12 and 13 are spares. Bit position 14 (Fig. 3-27) is an indication to the CMC that the PRO button on the DSKY has been pressed. Bit 15 is a spare.

3.5.12 Channel 33

Bit locations 1 and 3 of this channel are spares. Bit position 2 is used to indicate VHF data quality. Bit positions 4 and 5 (Fig. 3-26) provide the CMC with the status of the OSS. Bit 4 informs the CMC that the optics is in the zero mode. Bit 5 informs the CMC that the optics is in the CMC mode. Bit positions 6 through 9 are spares. Bit 10 (Fig. 3-28) provides for blocking of uplink data into the CMC. The remaining bit locations of channel 33 are associated with circuits internal to the CMC.

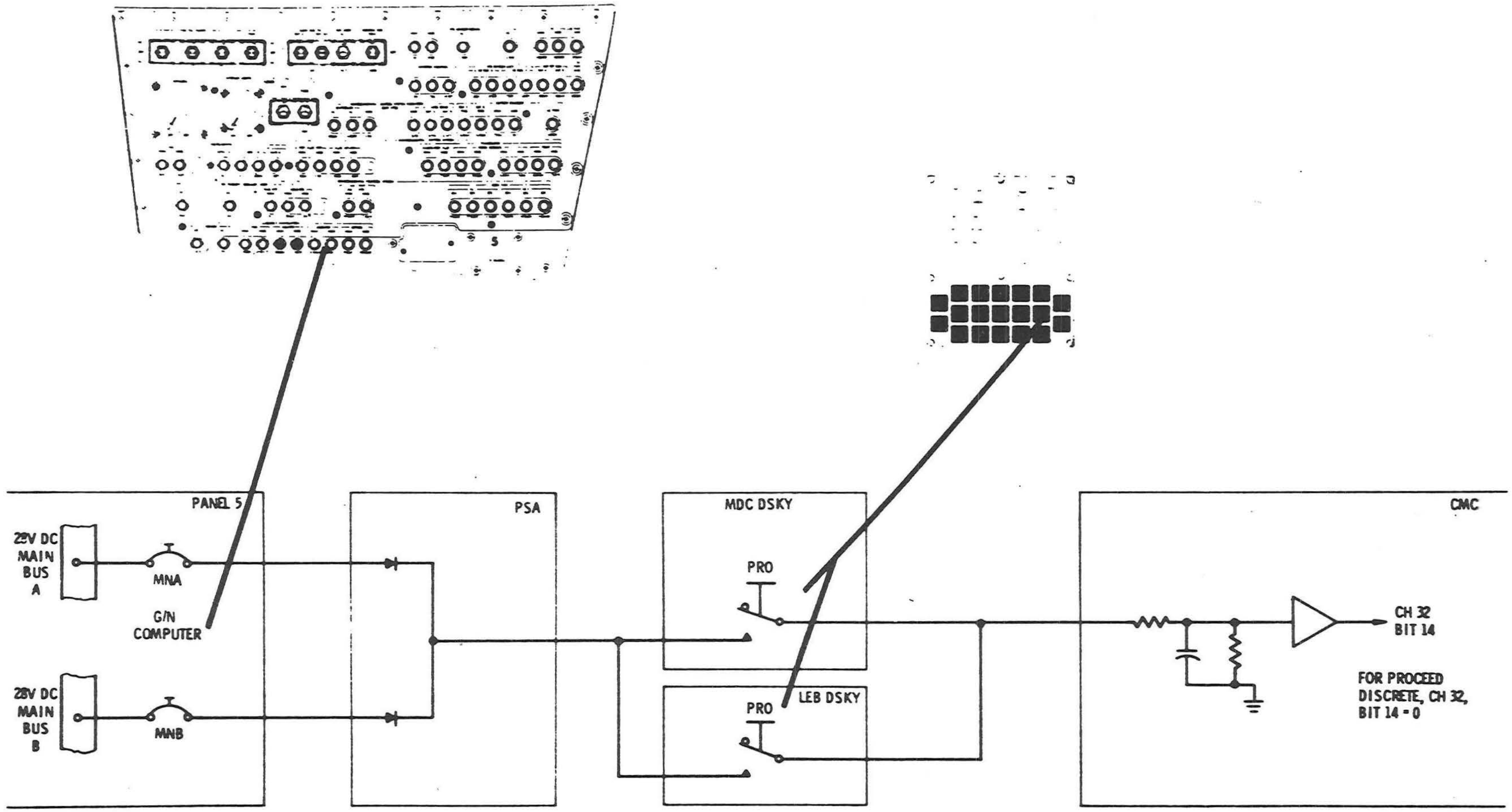


Fig. 3-27. Channel 32 Bit 14, Proceed

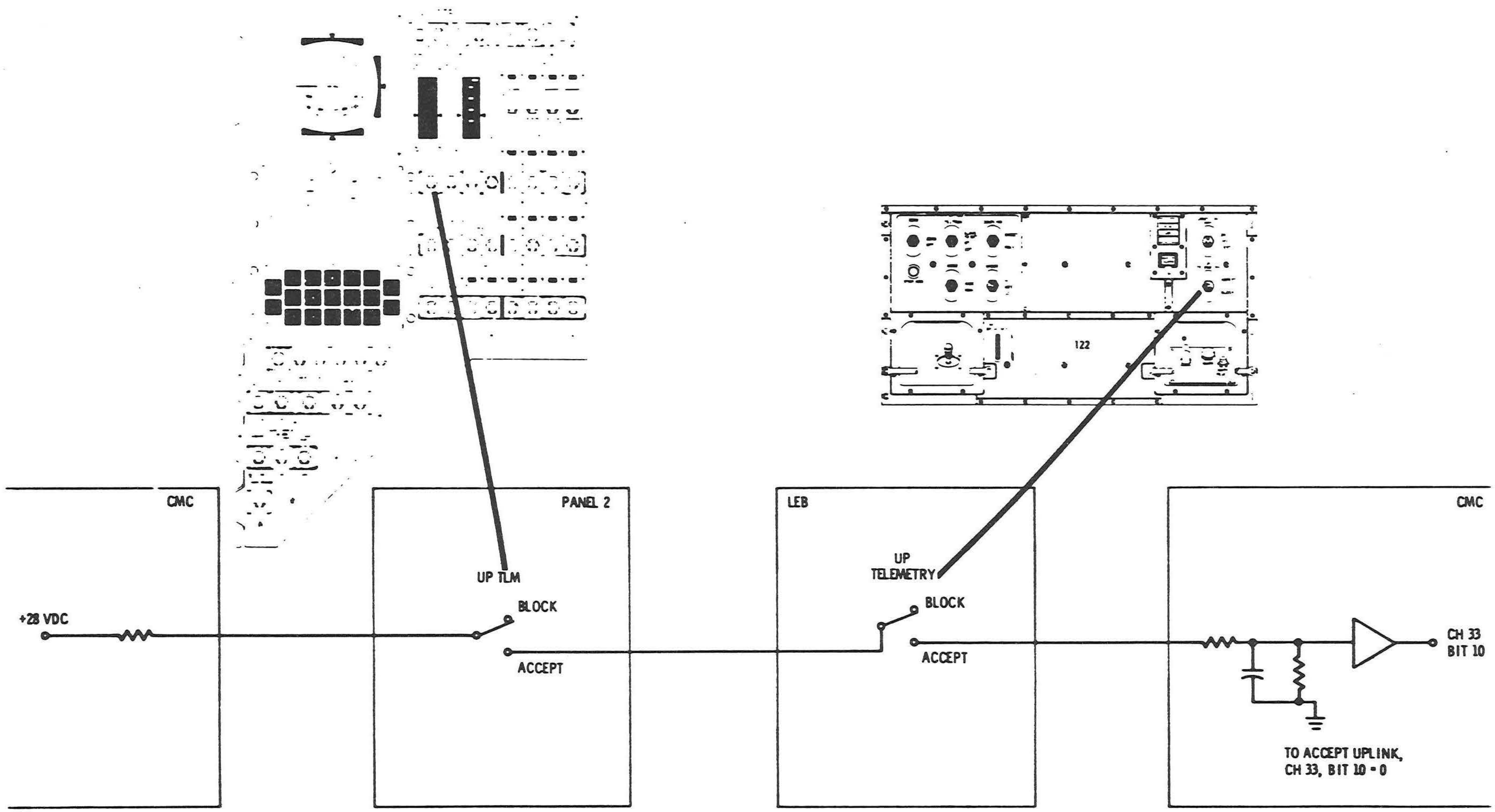


Fig. 3-28. Channel 33 Bit 10, Block Uplink

SECTION IV

PERFORMANCE AND DESIGN DATA

4.1 IMU

4.1.1 Operational Data

Gyroscopes: Three 25-IRIG

Normal Bias Drift Rate: 2 meru max (0.03 sec/sec)

Accelerometers: Three 16-PIP

Rotation: 720 degrees/sec about the outer gimbal axis
60 degrees/sec about any arbitrary axis in
passing up to 10 degrees of gimbal lock

CDU Error: Maximum range +49.6 arc sec to -63.4 arc sec
Mean = -6.9 arc sec, Standard deviation = ±24.5 arc sec

4.1.2 Limitations and Restrictions

Gimbal lock is obtained when the middle gimbal has moved to a position such as to make the outer and inner gimbal axes nearly colinear and thereby producing stabilization loops that are unstable. When this condition is attained, the IMU stable member must be realigned. To avoid gimbal lock, the inner gimbal axis is normally positioned to the plane of any planned trajectory or attitude turning maneuver prior to thrusting. To assist in gimbal lock avoidance, the GIMBAL LOCK indicator is actuated whenever the middle gimbal angle exceeds 70°. In addition, the ISS is downmoded to coarse align and the NO ATT and ISS indicators are actuated whenever the middle gimbal angle exceeds 85°.

Another IMU limitation is platform drift. Due to random errors and inaccurately corrected systematic bias, over a period of time the stabilized platform will have drifted out of alignment enough to cause serious degradation in inertial measurement accuracy. Therefore, the IMU alignment must be periodically checked and realigned to insure measurement accuracy during pending maneuvers. There is also a possibility of switching transients in the CDU's. These transient errors can be minimized by permitting the ISS and OSS to warm up (at least 5 minutes) prior to making navigation measurements.

Temperature restrictions also exist for the IMU. The system components have been designed to operate at specific temperatures which are maintained in standby or operating states as long as prime power is applied. Temperature changes due to power loss or for any other reason may change gyro and accelerometer characteristics. Changes in gyro characteristics due to small variations in temperature are temporary and revert when the temperature is returned to normal. Larger changes in temperature, however, may cause permanent changes in gyro characteristics. During those mission phases in which only the IMU standby state exists, possible power interruptions may occur for periods up to three minutes without system degradation. At such times that power is lost or the TEMP indicator is activated, the MSFN should be contacted to verify system performance.

4.2 CMC

4.2.1 Operational Data

Computer Type: Automatic, electronic, digital, general purpose and control

Memory: Random access

Erasable: Coincident current core; capacity = 2048 words

Fixed: Core-rope; capacity = 36, 864 words

Word length: 16 bits (or 15 bits plus parity)

Number System: Binary ones complement

Circuitry Type: Flat pack NOR micrologic

Logic: Positive

Machine Instructions: 56 Total

Regular: 42

Involuntary: 9

Peripheral: 5

Memory Cycle Time: 12μ seconds

Add Time: 24μ seconds

Double Precision Add: 36μ seconds

Multiply Time: 48μ seconds

Double Precision Multiply: 480μ seconds

Divide Time: 84μ seconds

Number of Counters: 29

Basic Clock Oscillator: 2.048 mc

4.3 DSKY

4.3.1 Operational Data

The DSKY utilizes white illuminated markings with incandescent light sources. The numeric readouts are green electroluminescent sections. The status indicators (including UPLINK ACTY, NO ATT, STBY, KEY REL, and OPR ERR) are used to inform the crew numbers of equipment or system status, and of the operation of essential equipment or are used to attract attention and impart information of a routine nature. The caution indicators (including TEMP, GIMBAL LOCK, PROG, RESTART, and TRACKER) are used to inform crew members of an impending dangerous condition requiring attention but not necessarily immediate corrective action.

Lighted Color:

Caution annunciators – Aviation yellow

Status annunciators – Aviation white

Numerical lights – Aviation green

Brightness:

Pushbuttons – 0.5 (±0.2) ft Lamberts

Annunciators – 15 (±3.0) ft Lamberts

Pushbutton Force Requirement to Actuate:

21 to 26 ounces

4.4 OSS

4.4.1 Operational Data

Scanning Telescope (SCT):

Single LOS

Unity power

60 degree field of view

Rotational freedom about two axes -

±60 degrees from zero about trunnion axis and unlimited 360° about shaft axis, except when slaved to SXT

Sextant (SXT):

Dual LOS, one fixed (LLOS), one moveable (SLOS)

28 power magnification

1.8 degree field of view

Rotational freedom of SLOS about two axes -

±60 degrees from zero about trunnion axis and ±270 degrees from zero about shaft axis

Accuracy between LLOS and SLOS is 10 arcsec.

The granularity of OCDU pulses is 10 arcseconds for the trunnion and 40 arcseconds for the shaft.

Modes of operation:

The OSS can be driven by the optics hand controller or automatically by the CMC auto-optics positioning program, or it can be controlled manually by the universal tool

In all powered modes of operation, the SCT shaft is slaved to the SXT. The SCT trunnion can be slaved to the SXT, set at 0°, or offset at 25°.

The hand controller can drive the optics at three different speeds and in a direct mode (up-down for trunnion, left-right for shaft) or a resolved mode (image follows hand controller motion).

4.4.2 Limitations and Restrictions

Because of obstructions caused by the spacecraft heat shield, the useful range of the optics trunnion angle is ±45 degrees. Therefore, the maximum field of view obtainable without maneuvering the spacecraft is a cone of 90 degrees.

During landmark tracking, landmarks should be chosen, if possible, so that they lie between 6 and 30 degrees from the ground track. At greater angles, landmarks are not in view for a sufficient length of time to be tracked accurately and are harder to identify. At angles less than 6 degrees, the spacecraft must be rolled to avoid the high slewing rate required to follow a target which passes close to a zero trunnion angle.

Whenever possible the OSS should be turned on 15 minutes before making optics sightings. Changes in temperature of the SXT cause the LOS to shift. The warmup period greatly reduces the effects of this shift. This warm up period also reduces the probability of OCDU switching angle transients.

For greater accuracy the SXT should be calibrated (after warmup) before making midcourse navigation marks and should be recalibrated every 15 minutes as long as marks are being made.

SECTION V

PROCEDURAL DATA

5.1 DSKY OPERATION

5.1.1 Mission Language

The mission language consists of nouns and verbs that enable the crew to address the CMC and the CMC to communicate to the crew through the DSKY. Each noun or verb is represented by a two-character decimal number. The verb code indicates the operation to be performed and the noun code indicates the operand to which the operation is applied. Verb-noun displays from the CMC are provided by the DSKY indicators. Communication to the CMC is provided by verb-noun entries on the DSKY keyboard (Fig. 5-1).

5.1.1.1 Keyboard Operation

The procedure for keyboard operation is to press a sequence of seven keys as follows:

VERB V_1 V_2 NOUN N_1 N_2 ENTR

Pressing the verb key blanks the verb display (VD1 and VD2) on the DSKY and clears the verb code register in the CMC. The next two numerical keys pressed comprise the verb code, V_1 and V_2, in decimal. These numerical characters appear in the VERB display on the DSKY as they are keyed in. In a similar manner the noun code is keyed in by pressing the noun key and two numerical keys. Pressing the ENTR (enter) key initiates the program indicated by the verb-noun combination on the display panel. No action is taken by the CMC on the verb-noun combination until the ENTR key is pressed.

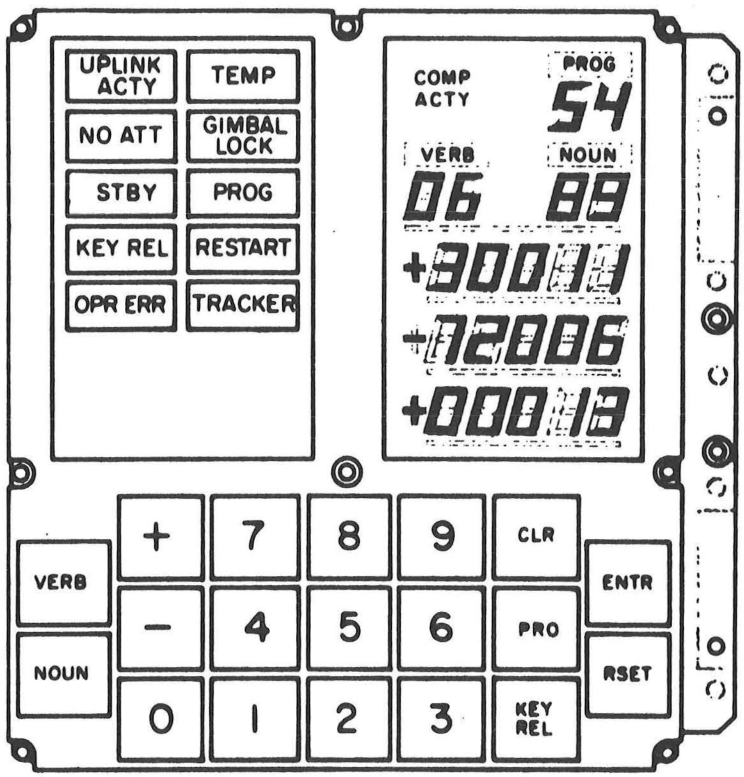


Fig. 5-1. DSKY Keyboard

Therefore, it is not necessary for the verb to be keyed in before the noun. They may be done in reverse order, or an old verb or old noun may be used without rekeying it.

If an error is noticed in either the verb or noun code before pressing the ENTR key, it can be corrected by pressing the VERB or NOUN key and keying in the correct code. The ENTR key, therefore, should not be pressed until the displayed verb and noun have been verified as being correct.

If the selected verb-noun combination requires data to be loaded by the operator, the VERB and NOUN lights start flashing (about once per second) after the ENTR key is pressed. Data is loaded in five-character words, and as it is keyed in, it is displayed character-by-character in one of the five-position data display registers: R1, R2, or R3. Numerical data is assumed to be octal unless the five-character data word is preceded by a plus or minus sign, in which case it is considered to be decimal. Decimal data must be loaded in full five-numerical character words (no zeros may be left out); octal data may be loaded with high-order zeros left out. If a decimal is used for any component of a multi-component load verb, it must be used for all components of that verb. In other words, no mixing of octal and decimal data is permitted for different components of the same load verb. If these conditions are violated, the OPR ERR light is turned on when the ENTR key is pressed. The ENTR key must be pressed after each data word to indicate to the program that a complete numerical word has been keyed in. The VERB-NOUN lights stop flashing after the ENTR button is pressed for the last time in a loading sequence.

The CLR (clear) button is used to remove errors in loading data as it is displayed in R1, R2, or R3. It does not affect the PROG (program), NOUN, or VERB lights. (The NOUN lights are blanked by the NOUN key, the VERB lights by the VERB key.) For single-component load verbs or "machine address to be specified" nouns, pressing the CLR button clears the register being loaded, provided the CLR button is pressed before the ENTR button. Once the ENTR key is pressed, the CLR key does nothing. The only way to correct an error after the data has been entered for a single-component load verb is to begin the load verb again. For two- or three-component load verbs, there is a CLR backing-up feature. The first depression of the CLR key clears the register being loaded. (The CLR key may be pressed after any character, but before the ENTR button is pressed.) Consecutive CLR button actuations clear the data display register above the current one until R1 is cleared. Any attempt to clear beyond R1 is simply ignored. The CLR backing-up function operates only on data pertinent to the load verb that initiated the loading sequence. For example, if the initiating load verb were a load second component only, no backing-up is possible.

Further signals from the numerical keys, the CLR key, and the sign keys are rejected after completion (final entry) of a data display or data load verb. At such time, only VERB, NOUN, ENTR, RSET (error reset), or KEY REL (key release) signals are accepted. Thus, the data keys are accepted only after the control keys have instructed the program to accept them. Similarly, the + and - keys are accepted only before the first numerical character of R1, R2, or R3 has been keyed in, and at no other time. The 8 or 9 key is accepted only while loading a data word into R1, R2, or R3, which is preceded by a + or - sign.

The keyboard and display system program may be used as a subroutine by internal computer programs. However, any operator keyboard action (except RSET) makes the keyboard and display system program busy to internal routines. The astronaut has control of the keyboard and display system until he wishes to release it. Thus, he is assured that the data he wishes to observe will not be replaced by internally initiated data displays. In general, it is recommended that the astronaut release the keyboard and display system for internal use when he has temporarily finished with it. This is done by pressing the KEY REL pushbutton. If there is no internal display waiting when the KEY REL is pressed the DSKY will blank.

The RSET key is pressed whenever a DSKY failure indicator comes on. It may be used to test for the presence of a continuous alarm rather than a transient alarm. In addition to a keycode, the RSET key initiates a light reset signal which resets the alarm flip-flops in the alarm control section of the output section. The keycode, through CMC operation, disables the alarm signals from output registers.

5.1.1.2 Verb-Noun Formats

A noun code may refer to a device, a group of computer registers, or a group of counter registers, or it may serve to convey information without referring to any particular computer register. The noun is made up of 1, 2, or 3 components; each component being entered separately as requested by the verb code. As each component is keyed, it is displayed on the display panel with component 1 displayed in R1, component 2 in R2, and component 3 in R3.

There are two classes of nouns: normal and mixed. A normal noun is one whose component members refer to computer registers that have consecutive addresses and use the same scale factor when converted to decimal. A mixed noun is one whose component members refer to nonconsecutive addresses and/or whose component members require different scale factors when converted to decimal. The keyboard and display routines perform decimal/binary and binary/decimal scale factoring of nouns.

A verb code indicates what action is to be taken. It also determines which component member of the noun group is to be acted upon. For example, there are five different load verbs. Verb 21 is required for loading the first component of the selected noun; verb 22 loads the second component; verb 23 loads the third component; verb 24 loads the first and second component; and verb 25 loads all three components. A similar component format is used in the display and monitor verbs. There are two general classes of verbs: standard and extended. The standard verbs (code 01 through 39) deal mainly with the loading, displaying, and monitoring of data. The extended verbs (codes 40 through 99) are principally concerned with the calling up of internal programs whose function is system testing and operation.

Whenever data is to be loaded by an astronaut the VERB and NOUN lights flash with the proper codes to indicate which data is to be loaded. The presently stored data is displayed in the appropriate register(s). If the present data is acceptable, the PRO button is keyed and no loading is necessary. If the astronaut wishes to change the data, he keys the appropriate load verb (21 through 25) with the noun unchanged. The VERB and NOUN lights keep flashing, the appropriate data display register (R1, R2, or R3) is blanked, and the internal computer storage register is cleared in anticipation of data loading. As each numerical character is punched in, it is displayed in the proper display register. Each data display register can handle only five numerical characters at a time (not including sign). If an attempt is made to key in more than five numerical characters at a time, the sixth and subsequent characters are rejected, they do not appear at the display register.

The + and - key signals are only accepted prior to inserting the first numerical character of R1, R2, or R3; if keyed in at any other time, the signs are rejected. If the 8 or 9 is keyed in at any time other than while loading a data word that has been preceded by a + or - sign, it is rejected and the OPR ERR (operator error) indicator lights.

In addition to requests for data load, there are several other verb-noun combinations that produce a flashing display. These include the following:

1. Please perform verb (V50) – This verb is used by the CMC to request astronaut action. It is used with two different nouns: Noun 18 requests automatic maneuver enable. Acceptance is by setting SC CONT to CMC and CMC to AUTO and keying PRO. Noun 25 requests performance of the checklist whose code appears in register 1. To accept, the requested checklist is performed and PRO keyed.

2. Please mark verb (V51) – This verb is used by the CMC to request optics marks. There is no noun displayed with it. To accept the request, one or more optics marks are made, followed by keying PRO.

3. Please calibrate verb (V59) – This verb is used by the CMC to request calibration of the SXT. There is no noun displayed with it. This request is accepted by superimposing the LLOS and SLOS on a single target, and marking.

4. Change program – To change a program, the sequence VERB 37 ENTR is keyed in. This causes the noun display register to be blanked and the verb

code to be flashed. A CMC request to change programs does the same. The two-character program code should then be loaded. For verification purposes, it is displayed as it is loaded in the noun display register. Keying ENTR stops the flashing, requests the new program to be entered, displays the new program code in the PROG display register if it is a legal program, and blanks the noun register. The OPR ERR indicator will light if an illegal program number is keyed.

5. Machine address to be specified nouns (01, 02, 03) – These are nouns which allow any machine address to be used. When using a noun of this type, when the verb-noun combination is executed, the flashing starts immediately. The verb code is left unchanged. The astronaut should load the complete machine address required (five-character octal). This address is displayed in R3 as it is keyed in. If an error is made in loading the address, the CLR key may be used to remove it. Pressing the ENTR key then causes execution of the verb. The data to be loaded is then keyed in followed by ENTR. If a number of addresses in numerical sequence are to be loaded a NOUN 15 ENTR can be keyed after the first data load. After subsequent data loads, a second ENTR automatically increments the address, thus eliminating the need to enter the address prior to each load.

6. Channel to be specified noun (N10) – This noun is similar to nouns 01, 02, and 03, except that a two digit input or output channel is loaded instead of a machine address.

The flashing is turned off by any one of four events:

1. Keying ENTR after performance of requested action or data load.
2. Entry of the V34E "terminate".
3. Keying of the PRO button to "proceed".
4. Entry of V32E "recycle".

It is important to end every load verb in one of the four preceding manners, especially if the load was initiated by program action within the computer. If an internally initiated load is not concluded correctly, the initiating program may never be recalled. Keying the PRO button to "proceed" is used to indicate that the operator is unable to, or does not wish to, supply the data requested but wants the initiating program to continue with the old data. The "terminate" verb is used to indicate that the operator chooses not to load the requested data and also wants to terminate the requesting routine. The "recycle" verb is used to return to a previous point in the program.

5.2 CMC SEQUENCING AND CONTROL

5.2.1 Sequence Initiation

The tasks performed by the CMC are made up of programs and routines. These are designed such that the same task may be used at different times under various conditions during the mission. Programs are initiated manually by DSKY entry or, in some cases, automatically by completion of the previous program. Programs may also be initiated by telemetry uplink, provided the UP TLM switch is not set to BLOCK. The numerical designation of the program being run by the CMC is displayed in the PROG register on the DSKY.

Most routines are called up automatically by programs or other routines. The CMC usually returns to the calling program upon completion of a routine. Some routines can be called by DSKY entry of an extended verb. Other extended verbs are used to call up tasks that are not classified as routines.

Because the CMC is a time shared computer, a priority must be established for the performance of the various CMC tasks. The priority control interrupts the program in process to command the CMC to a higher priority task. The priority control consists of three separate functional areas: start, counter, and program instruction control.

The start instruction control restarts the CMC following certain alarms and failures. The alarms are discussed in paragraph 2.3.5.3.

Counter interrupts are generated whenever pulses are received to update data stored in erasable memory. Counter interrupts have priority over program interrupts and, since the CMC can only update one counter at a time, a priority is assigned among the various counters. The updating of a counter requires one memory cycle time (12 microseconds). The counters store such data as: time (highest priority), CDU, PIPA, and BMAG pulses, and CDU and gyro drive pulses.

Program interrupts are caused by discrete events such as: time counters running out on time controlled tasks, DSKY entries, uplink and downlink requests, optics marks, and hand control inputs. The program interrupts cause the suspension of the processing of a program in process to execute the task called for by the interrupt. A program interrupt is limited to a single 1 microsecond pulse for input request.

5.2.2 Program Classification

The CMC programs are designated by a two-digit decimal number. These are classified according to mission function by the first digit as follows:

0X - Prelaunch and Service Programs

1X - Boost Programs (Except P17)

2X - Coast and Navigation Programs

3X - Prethrust Programs

4X - Thrust Programs

5X - IMU Alignment Programs

6X - Entry Programs

7X - Backup Programs

The prelaunch and service programs include: CMC idling (P00), prelaunch initialization (P01), gyro compassing (P02), optical verification of azimuth (P03), and GNCS power down (P06). Of these, P01, P02, and P03 are strictly prelaunch programs. P06 is used throughout the mission.

The only boost program is the earth orbit insertion monitor program P11.

The coast and navigation programs include: Transfer phase initiation (TPI) search (P17), rendezvous navigation (P20), ground track determination (P21), orbital navigation (P22), cislunar navigation (P23), and CMC update (P27). P17 is used to compute rendezvous parameters from a TPI time entered by the astronaut and to define the search sector for rendezvous intercept. P20 is used to update the CSM or LM state vector by optical tracking of the LM. P20 can be run simultaneously with other programs; but during thrusting and IMU alignment, the state vectors are not updated. P21 calculates the CSM or LM ground track without ground communication. P22 tracks a landmark optically. P23 obtains a navigational fix using a star and landmark or horizon. P27 provides a means for ground update of the CMC, by uplink telemetry or voice. P27 can be entered only from P00, P02.

The prethrusting programs provide targeting for the thrust maneuvers. The external delta V program (P30) and the lambert aim point guidance program (P31) provide the initial conditions for an SPS or RCS translation maneuver other than for rendezvous. Co-elliptic Sequence Initiation (P32/P72) and Constant Delta Altitude (P33/P73) Programs calculate delta v burn parameters. Programs P34 and P35, transfer phase initiation and transfer phase midcourse respectively, and P38 and P39, stable orbit rendezvous and stable orbit midcourse respectively, are used for rendezvous between an active CSM and an inactive LM. Similar backup programs, P74, P75, P78 and P79 are used when the LM is the active vehicle and the CMC is used to compute the thrusting parameters. In a like manner, P77 is a backup for P17. P37 is the targeting program for return to earth. Prior to the prethrusting programs, the digital autopilot must be loaded by routine R03. P76 is used to notify the CMC that the LM has changed its orbital parameters by performing a thrust maneuver, and supplies the CMC with the LM delta V for LM state vector update in the CMC.

The CMC controls thrusting through the SPS program P40 or the RCS program P41. A thrusting maneuver not controlled by GNCS can be monitored with the thrust monitor program P47.

The IMU alignment programs consist of the IMU orientation determination program P51 and IMU realign program P52 and backup programs for each, P53 and P54, respectively. The IMU orientation determination program is used when the IMU orientation is unknown, such as, after IMU turn on. The realign program is used to align the IMU to a designated orientation for thrusting. The IMU should be realigned fifteen minutes before thrusting.

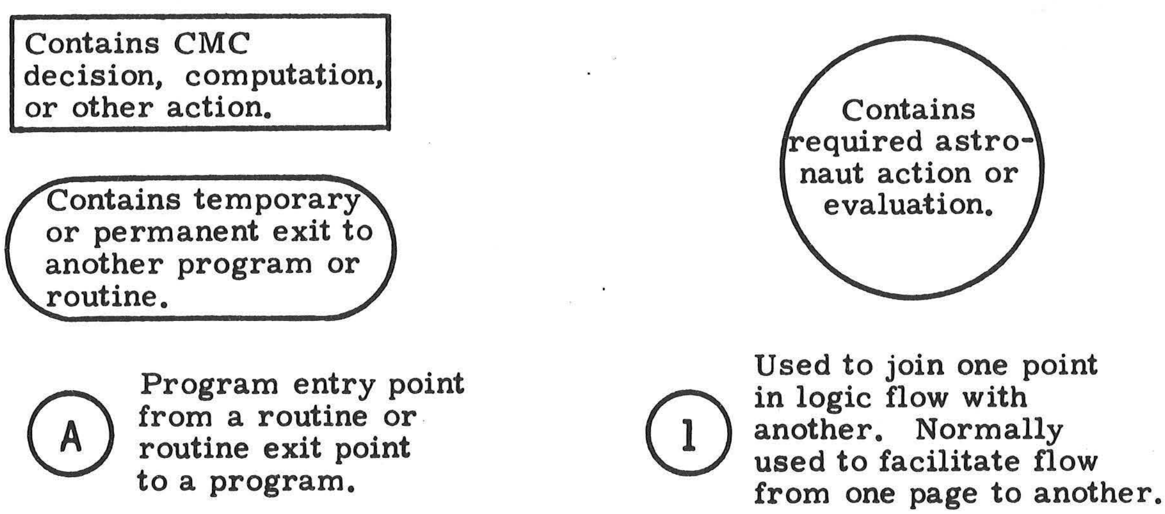
The entry programs: Entry preparation program (P61), CM/SM separation and pre-entry maneuver (P62), entry initialization (P63), post 0.05 g (P64), up control (P65), ballistic (P66), and entry final phase (P67) are automatically run in sequence after entering P61. Programs P65 and P66 may or may not be done depending upon entry conditions. The entry programs control the entry from preseparation maneuver to main chute deployment.

5.2.3 Program Descriptions and Flow

The programs and routines discussed in this section are those that have astronaut interface. The flow charts that accompany the program descriptions summarize the overall sequential computer flow. Not all internal computer operations are shown in these diagrams. Most major discretes and flags that affect the sequential flow are shown. For purposes of this discussion, a discrete is a two-state signal (either yes or no) that tells the CMC of an external equipment operational state or is a command from the CMC to external equipment.

A flag is an exclusively internal signal (either set or reset) which provides memory and the capability of checking program functional states; whereby, the sequential flow of programs may be properly maintained.

Astronaut-CMC interface action through the DSKY is shown on the diagrams along interconnecting lines. The flow begins at the top of each diagram and flows toward the bottom. The flow diagram format is as follows:



Tables 5-1 and 5-2 list verbs and nouns respectively. Checklist codes and option codes are listed in Tables 5-3 and 5-4, respectively.

TABLE 5-1

VERB LIST

VERB CODE	FUNCTION	DESCRIPTION
	REGULAR VERBS (00 TO 39)	
00	NOT USED	
01	DISPLAY 1ST COMPONENT OF:	PERFORMS OCTAL DISPLAY OF DATA ON R1.
02	DISPLAY 2ND COMPONENT OF:	PERFORMS OCTAL DISPLAY OF DATA ON R1.
03	DISPLAY 3RD COMPONENT OF:	PERFORMS OCTAL DISPLAY OF DATA ON R1.
04	DISPLAY 1ST AND 2ND COMPONENTS OF:	PERFORMS OCTAL DISPLAY OF DATA ON R1 AND R2.
05	DISPLAY 1ST, 2ND, AND 3RD COMPONENTS OF:	PERFORMS OCTAL DISPLAY OF DATA ON R1, R2, AND R3.
06	DISPLAY ALL COMPONENTS OF:	PERFORMS DECIMAL DISPLAY OF DATA ON APPROPRIATE REGISTERS. THE SCALE FACTORS, TYPES OF SCALE FACTOR ROUTINES, AND COMPONENT INFORMATION ARE STORED WITHIN THE MACHINE FOR EACH NOUN WHICH CAN BE DISPLAYED IN DECIMAL.
07	DOUBLE PRECISION DECIMAL DISPLAY:	PERFORMS A DOUBLE PRECISION DECIMAL DISPLAY OF DATA ON R1 AND R2. IT DOES NO SCALE FACTORING. IT MERELY PERFORMS A 10-CHARACTER, FRACTIONAL DECIMAL CONVERSION OF TWO CONSECUTIVE, ERASABLE REGISTERS, USING R1 AND R2. THE SIGN IS PLACED

TABLE 5-1 Page 2 of 11

VERB CODE	FUNCTION	DESCRIPTION
	REGULAR VERBS (00 TO 39)	
		IN THE R1 SIGN POSITION WITH THE R2 SIGN POSITION REMAINING BLANK. IT CANNOT BE USED WITH MIXED NOUNS. ITS INTENDED USE IS PRIMARILY WITH "MACHINE ADDRESS TO BE SPECIFIED" NOUNS, FOR CMC TESTING.
08	SPARE	
09	SPARE	
10	SPARE	
11	MONITOR 1ST COMPONENT OF:	PERFORMS OCTAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1.
12	MONITOR 2ND COMPONENT OF:	PERFORMS OCTAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1.
13	MONITOR 3RD COMPONENT OF:	PERFORMS OCTAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1.
14	MONITOR 1ST AND 2ND COMPONENTS OF:	PERFORMS OCTAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1 AND R2.
15	MONITOR 1ST, 2ND, AND 3RD COMPONENTS OF:	PERFORMS OCTAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1, R2, AND R3.
16	MONITOR ALL COMPONENTS OF:	PERFORMS DECIMAL DISPLAY OF UPDATED DATA EVERY SECOND ON APPROPRIATE REGISTERS. (SEE VERB 06)
17	MONITOR DOUBLE PRECISION DECIMAL:	PERFORMS DECIMAL DISPLAY OF UPDATED DATA EVERY SECOND ON R1 AND R2. (SEE VERB 07)
18	SPARE	
19	SPARE	
20	SPARE	
21	LOAD 1ST COMPONENT INTO:	PERFORMS DATA LOADING. OCTAL QUANTITIES ARE UNSIGNED. DECI-

TABLE 5-1 Page 3 of 11

VERB CODE	FUNCTION	DESCRIPTION
	REGULAR VERBS (00 TO 39)	
		MAL QUANTITIES ARE PRECEDED BY + OR - SIGN. DATA IS DISPLAYED ON R1.
22	LOAD 2ND COMPONENT INTO:	PERFORMS DATA LOADING. OCTAL QUANTITIES ARE UNSIGNED. DECIMAL QUANTITIES ARE PRECEDED BY + OR - SIGN. DATA IS DISPLAYED ON R2.
23	LOAD 3RD COMPONENT INTO:	PERFORMS DATA LOADING. OCTAL QUANTITIES ARE UNSIGNED. DECIMAL QUANTITIES ARE PRECEDED BY + OR - SIGN. DATA IS DISPLAYED ON R3.
24	LOAD 1ST AND 2ND COMPONENTS INTO:	PERFORMS DATA LOADING. OCTAL QUANTITIES ARE UNSIGNED. DECIMAL QUANTITIES ARE PRECEDED BY + OR - SIGN. DATA IS DISPLAYED ON R1 AND R2.
25	LOAD 1ST, 2ND, AND 3RD COMPONENTS INTO:	PERFORMS DATA LOADING. OCTAL QUANTITIES ARE UNSIGNED. DECIMAL QUANTITIES ARE PRECEDED BY + OR - SIGN. DATA IS DISPLAYED ON R1, R2, AND R3.
26	SPARE	
27	FIXED MEMORY DISPLAY:	PERMITS DISPLAY OF THE CONTENTS OF FIXED MEMORY IN ANY BANK. INTENDED FOR GROUND CHECKING OF PROGRAM ROPES AND THE BANK POSITION OF PROGRAM ROPES.
28	SPARE	
29	SPARE	
30	REQUEST EXECUTIVE:	THE EXECUTIVE PROGRAM SUPERVISES THE EXECUTION OF ALL REQUESTED JOBS ACCORDING TO AN ASSIGNED PRIORITY SCHEME. INTENDED FOR GROUND USE.

TABLE 5-1 Page 4 of 11

VERB CODE	FUNCTION	DESCRIPTION
	REGULAR VERBS (00 TO 39)	
31	REQUEST WAITLIST:	THE WAITLIST PROGRAM SCHEDULES THE EXECUTION OF TASKS WHICH MUST BE EXECUTED AT A SPECIFIC TIME. INTENDED FOR GROUND USE.
32	RECYCLE:	CAUSES PROGRAM TO RECYCLE WITHIN CURRENT COMPUTATIONAL LOOP.
33	PROCEED:	INFORMS ROUTINE REQUESTING DATA TO BE LOADED THAT THE OPERATOR CHOOSES NOT TO LOAD FRESH DATA, BUT WISHES THE ROUTINE TO CONTINUE WITH OLD DATA. FINAL DECISION FOR WHAT ACTION SHOULD BE TAKEN IS LEFT TO REQUESTING ROUTINE. THIS FUNCTION IS ALSO ACCOMPLISHED BY KEYING THE PRO PUSHBUTTON.
34	TERMINATE:	INFORMS ROUTINE REQUESTING DATA TO BE LOADED THAT THE OPERATOR CHOOSES NOT TO LOAD FRESH DATA AND WISHES THE ROUTINE TO TERMINATE. FINAL DECISION FOR WHAT ACTION SHOULD BE TAKEN IS LEFT TO REQUESTING ROUTINE. IF MONITOR IS ON, IT IS TURNED OFF.
35	TEST LIGHTS: (Perform only during P00)	TURNS ON THE LIGHTS ON THE DSKY. ALSO ALL 8'S AND +'S ARE SHOWN ON THE NUMBERICAL REGISTERS. AFTER 5 SECONDS, ALL THE LIGHTS GO OFF AND THE ORIGINAL PROGRAM NUMBER IS REDISPLAYED. THE NUMBERICAL REGISTERS RETAIN 8'S AND +'S FOR DISPLAY
36	FRESH START:	INITIALIZES THE PROGRAM CONTROL SOFTWARE AND THE KEY-

TABLE 5-1 Page 5 of 11

VERB CODE	FUNCTION	DESCRIPTION
	REGULAR VERBS (00 TO 39)	
		BOARD AND DISPLAY SYSTEM PROGRAM. (SEE PARA. 5.2.3.38.1)
37	CHANGE PROGRAM TO:	CHANGES PROGRAM ACCORDING TO THE PROGRAM CODE ENTRY, IF LEGAL.
38	SPARE	
39	SPARE	
	EXTENDED VERBS (40 TO 99)	
40	ZERO ICDU'S:	SETS ICDU REGISTERS TO ZERO. CAN BE USED ONLY WITH NOUN 20 (ICDU ANGLES). (SEE PARA. 5.2.3 .38.2)
41	COARSE ALIGN:	PERFORMS ALIGNMENT OF IMU GIMBALS TO ICDU ANGLES OR OPTICS TO OCDU ANGLES. CAN BE USED ONLY WITH NOUN 20 (ICDU ANGLES) OR NOUN 91 (OCDU ANGLES). (SEE PARA. 5.2.3.38.3 AND 5.2.3. 38.4)
42	PULSE TORQUE GYRO:	INITIATES GYRO TORQUING FOR IMU FINE ALIGNMENT. (SEE PARA. 5.2.3.38.5)
43	LOAD FDAI ATT ERROR NEEDLES	INITIATES SUBROUTINE WHICH LOADS SPECIFIED ANGLES INTO FDAI ERROR NEEDLES. (SEE PARA. 5.2.3.38.6)
44	SET SURFACE FLAG:	SETS A FLAG WHICH INDICATES THAT THE LM IS ON THE LUNAR SURFACE. (SEE PARA. 5.2.3.38.7)
45	RESET SURFACE FLAG:	RESETS FLAG SET BY VERB 44. (SEE PARA. 5.2.3.38.7)
46	ACTIVATE DAP:	ACTIVATES APPROPRIATE DAP ACCORDING TO CONFIGURATION OF NOUN 46 IN DAP LOAD ROUTINE (R03). (SEE PARA. 5.2.3.38.8)

TABLE 5-1 Page 6 of 11

VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40 TO 99)	
47	SET LM STATE VECTOR INTO CSM STATE VECTOR:	PERMITS SETTING CSM STATE VECTOR EQUAL TO LM STATE VECTOR. (SEE PARA. 5.2.3.38.9)
48	LOAD DAP (R03)	STARTS DIGITAL AUTOPILOT LOAD ROUTINE (R03). DISPLAYS NOUN 46, FOLLOWED BY NOUNS 47 AND 48 WHEN OPERATOR KEYS IN PRO. (SEE PARA. 5.2.3.32)
49	START CREW DEFINED MANEUVER (R62):	INITIATES CREW DEFINED MANEUVER ROUTINE (R62). (SEE PARA. 5.2.3.36)
50	PLEASE PERFORM:	USED ONLY BY INTERNAL ROUTINES TO REQUEST OPERATOR TO PERFORM A CERTAIN TASK. USUALLY USED WITH NOUN 25, "CHECKLIST." THE CODED NUMBER FOR THE CHECKLIST ITEM TO BE PERFORMED IS DISPLAYED IN REGISTER R1. (SEE LIST OF CHECKLIST CODES.) SHOULD NOT BE KEYED IN BY OPERATOR.
51	PLEASE MARK:	USED ONLY BY INTERNAL ROUTINES TO REQUEST THE OPERATOR TO MAKE AN OPTICS MARK ON A TARGET. SHOULD NOT BE KEYED IN BY OPERATOR.
52	MARK ON OFFSET LANDING SITE:	USED TO SET THE INDEX OF THE OFFSET DESIGNATOR EQUAL TO THE VALUE OF THE MARK COUNTER; THIS VERB IS ONLY MEANINGFUL IN P22.
53	PLEASE MARK ALTERNATE LOS:	USED ONLY BY INTERNAL ROUTINES TO REQUEST OPERATOR TO MAKE A SIGHTING MARK USING THE CREW OPTICAL ALIGNMENT SIGHT (COAS). SHOULD NOT BE KEYED IN BY OPERATOR.

TABLE 5-1

VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40 TO 99)	
54	START BACKUP RENDEZVOUS TRACKING SIGHTING MARK ROUTINE:	INITIATES BACKUP RENDEZVOUS TRACKING SIGHTING MARK ROUTINE (R23). (SEE PARA. 5.2.3.8.6)
55	INCREMENT CMC TIME (DECIMAL):	PERMITS CHANGING CMC CLOCK TIME WITHOUT A P27 UPDATE. (SEE PARA. 5.2.3.38.10)
56	TERMINATE TRACKING:	TERMINATES RENDEZVOUS NAVIGATION PROGRAM (P20). (SEE PARA. 5.2.3.38.11)
57	START RENDEZVOUS TRACKING SIGHTING MARK ROUTINE:	INITIATES RENDEZVOUS TRACKING SIGHTING MARK ROUTINE (R21). (SEE PARA. 5.2.3.8.5)
58	RESET STICK FLAG:	USED AFTER A MANUAL MANEUVER (R61) TO RESET STICK FLAG, WHICH ENABLES GNCS AUTOMATIC MANEUVERS. (SEE PARA. 5.2.3.38.12)
59	PLEASE CALIBRATE MARK:	USED BY PROGRAM P23 TO REQUEST OPERATOR TO PERFORM CALIBRATION OF THE OPTICS. SHOULD NOT BE KEYED IN BY OPERATOR.
60	SET ATTITUDE ERROR REFERENCE EQUAL TO PRESENT ATTITUDE:	INITIATES SUBROUTINE WHICH SETS ATTITUDE ERROR REFERENCE (NOUN 17) EQUAL TO PRESENT ATTITUDE (NOUN 20). (SEE PARA. 5.2.3.38.13)
61	DISPLAY DAP ATTITUDE ERROR:	INITIATES SUBROUTINE WHICH DISPLAYS ON THE FDAI ERROR NEEDLES THE DIFFERENCE BETWEEN CURRENT CDU ANGLES AND DAP COMMANDED ANGLES. (SEE PARA. 5.2.3.38.14)
62	DISPLAY TOTAL ATTITUDE ERROR (NOUN22-NOUN20):	INITIATES SUBROUTINE WHICH DISPLAYS TOTAL ATTITUDE ERROR, WITH RESPECT TO NOUN 22 (THETAD) ON THE FDAI ERROR NEEDLES (SEE PARA. 5.2.3.38.15)

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VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40 TO 99)	
63	DISPLAY TOTAL ASTRONAUT ATT. ERROR(NOUN17-NOUN 20):	INITIATES SUBROUTINE WHICH DISPLAYS TOTAL ASTRONAUT ATTITUDE ERROR. WITH RESPECT TO NOUN 17 (CPHIX). (SEE PARA. 5.2.3.38.16)
64	START S-BAND ANTENNA ROUTINE(R05):	INITIATES S-BAND ANTENNA ROUTINE (R05). (SEE PARA. 5.2.3.33)
65	VERIFY PRELAUNCH ALIGN OPTICS	INITIATES OPTICAL VERIFICATION OF GYRO COMPASSING PROGRAM (P03). (SEE PARA. 5.2.3.4)
66	SET CSM STATE VECTOR INTO LM STATE VECTOR:	TRANSFERS STATE VECTOR OF CSM TO BE USED AS STATE VECTOR OF LM. (SEE PARA. 5.2.3.38.17)
67	START W-MATRIX RMS ERROR DISPLAY:	INITIATES W-MATRIX RMS ERROR DISPLAY. (SEE PARA. 5.2.3.38.18)
68	CSM STROKE TEST ON (LM ON ONLY):	INITIATES STROKE TEST ON CSM SPS ENGINE BELL. (SEE PARA. 5.2.3.38.19)
69	RESTART:	FORCES CMC INTO A TC TRAP WHICH CAUSES A CMC RESTART. (SEE PARA. 5.2.3.38.20)
70	UPDATE LIFTOFF TIME (P27):	PROVIDES AN INCREMENT FOR THE CMC CLOCK AND TEPHEM. IN P27. (SEE PARA. 5.2.3.12)
71	UNIVERSAL UPDATE, BLOCK ADDRESS(P27):	PROVIDES LOAD CAPABILITY FOR A BLOCK OF SEQUENTIAL ERASABLE MEMORY LOCATIONS, IN P27. (SEE PARA. 5.2.3.12)
72	UNIVERSAL UPDATE, SINGLE ADDRESS (P27):	PROVIDES LOAD CAPABILITY FOR ONE THROUGH NINE INDIVIDUALLY SPECIFIED ERASABLE MEMORY LOCATIONS, IN P27. (SEE PARA. 5.2.3.12)
73	UPDATE CMC TIME (OCTAL) (P27):	PROVIDES AN INCREMENT DURING P27 UPDATE FOR THE CMC CLOCK

VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40 TO 99)	
		ONLY. (SEE PARA. 5.2.3.12)
74	INITIALIZE ERASABLE DUMP VIA DOWNLINK:	INITIATES SUBROUTINE WHICH DOWNLINKS ALL DATA IN ERASABLE MEMORY. (SEE PARA. 5.2.3.38.21)
75	BACKUP LIFTOFF:	INITIATES EARTH ORBIT INSERTION MONITOR PROGRAM (P11). IN CASE LIFTOFF DISCRETE IS NOT RECEIVED TO COMMAND P11. (SEE PARA. 5.2.3.3 and 5.2.3.38.21A)
76	SET PREFERRED ATTITUDE FLAG (PREFERRED TRACK AXIS):	SETS A FLAG WHICH DEFINES THE ATTITUDE TO WHICH THE SPACECRAFT IS TO BE ALIGNED BY TRACKING ATTITUDE ROUTINE. (SEE PARA. 5.2.3.38.22)
77	RESET PREFERRED ATTITUDE FLAG (X-AXIS):	RESETS FLAG SET BY VERB 76. (SEE PARA. 5.2.3.38.22)
78	UPDATE PRELAUNCH AZIMUTH:	USED BY OPERATOR DURING PROGRAM P02 TO INITIATE SUBROUTINE WHICH PERMITS CHANGING OF PRELAUNCH AZIMUTH.
79	START BARBEQUE MODE ROUTINE (R64):	SEE PARA. 5.2.3.37A.
80	UPDATE LM STATE VECTOR:	SETS LM STATE VECTOR FLAG SO THE LM STATE VECTOR IS UPDATED BY THE TRACKING PROCESS IN THE RENDEZVOUS NAVIGATION PROGRAM (P20). (SEE PARA. 5.2.3.38.23)
81	UPDATE CSM STATE VECTOR:	SETS CSM STATE VECTOR FLAG SO THE CSM STATE VECTOR IS UPDATED BY THE TRACKING PROCESS IN THE RENDEZVOUS NAVIGATION PROGRAM (P20). (SEE PARA. 5.2.3.38.23)
82	START ORBIT PARAMETER DISPLAY (R30):	INITIATES ORBIT PARAMETER DISPLAY ROUTINE (R30). (SEE PARA. 5.2.3.20.3)

TABLE 5-1 Page 10 of 11

VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40 -99)	
83	START RENDEZVOUS PARAMETER DISPLAY (R31):	INITIATES RENDEZVOUS PARAMETER DISPLAY ROUTINE NUMBER 1 (R31). (SEE PARA. 5.2.3.8.7)
84	SPARE	
85	START RENDEZVOUS PARAMETER DISPLAY NO. 2 (R34):	INITIATES RENDEZVOUS PARAMETER DISPLAY ROUTINE NUMBER 2 (R34). (SEE PARA. 5.2.3.8.7)
86	REJECT BACKUP RENDEZVOUS SIGHTING MARK:	USED TO REJECT AN UNSATISFACTORY SIGHTING MARK DURING BACKUP RENDEZVOUS TRACKING SIGHTING MARK ROUTINE (R23).(PARA. 5.2.3.38.23A)
87	SET VHF RANGE FLAG:	SETS A FLAG WHICH ALLOWS AUTOMATIC VHF RANGE DATA TO BE USED BY THE RENDEZVOUS DATA PROCESSING ROUTINE (R22). (SEE PARA. 5.2.3.38.24)
88	RESET VHF RANGE FLAG:	RESETS FLAG SET BY VERB 87. (SEE PARA. 5.2.3.38.24)
89	START RENDEZVOUS FINAL ATTITUDE ROUTINE:	INITIATES RENDEZVOUS FINAL ATTITUDE ROUTINE (R63). (SEE PARA. 5.2.3.37)
90	START RENDEZVOUS OUT OF PLANE DISPLAY ROUTINE:	INITIATES RENDEZVOUS OUT OF PLANE DISPLAY ROUTINE (R36). (SEE PARA. 5.2.3.35)
91	COMPUTE BANKSUM:	INITIATES SUBROUTINES WHICH DISPLAY THE SUM OF EACH MEMORY BANK AND THE BANK NUMBER. (SEE PARA. 5.2.3.38.25)
92	START IMU PERFORMANCE TEST (P07):	INITIATES IMU PERFORMANCE TEST, (P07), FOR GROUND TESTING.
93	ENABLE W MATRIX INITIALIZATION:	USED IN RENDEZVOUS NAVIGATION PROGRAM (P20) TO RESET THE W MATRIX FLAG WHICH ENABLES INITIALIZATION OF THE W MATRIX. (SEE PARA. 5.2.3.38.26)
94	ENABLE CISLUNAR TRACKING RECYCLE:	RECYCLES CISLUNAR NAVIGATION PROGRAM (P23) BACK TO A POINT

TABLE 5-1

VERB CODE	FUNCTION	DESCRIPTION
	EXTENDED VERBS (40-99)	
		WHICH ALLOWS PERFORMANCE OF AN ATTITUDE MANEUVER (R60). (SEE PARA. 5.2.3.38.27)
95	SPARE	
96	TERMINATE INTEGRATION AND GO TO P00 (SELECT P00 BY V37 AFTER USE OF V96):	USED TO SUSPEND STATE VECTOR INTEGRATION IN POO. (SEE PARA. 5.2.3.38.28)
97	SPS THRUST FAIL(R40):	USED BY ENGINE FAIL ROUTINE (R40) TO REQUEST OPERATOR PERFORMANCE OF ENGINE FAIL PROCEDURE.
98	SPARE	
99	ENABLE ENGINE IGNITION:	USED IN SPS PROGRAM (P40) TO REQUEST OPERATOR TO ENABLE SPS ENGINE IGNITION.

BLANK

TABLE 5-2

NOUN LIST

NOUN CODE	DESCRIPTION	SCALE AND FORMAT	UNITS
00	NOT USED		
01	SPECIFY ADDRESS (FRACTIONAL)	.XXXXX	FRACTION
	(MAXIMUM - 0.99996)	.XXXXX	FRACTION
		.XXXXX	FRACTION
02	SPECIFY ADDRESS (WHOLE NUMBER)	XXXXX.	INTEGER
	(MAXIMUM - 16383.)	XXXXX.	INTEGER
		XXXXX.	INTEGER
03	SPECIFY ADDRESS (DEGREES)	XXX.XX	DEGREES
	(MAXIMUM - 359.99)	XXX.XX	DEGREES
		XXX.XX	DEGREES
04	SPARE		
05	ANGULAR ERROR OR DIFFERENCE	XXX.XX	DEGREES
06	OPTION CODE (USED WITH VERB 04)	OCTAL	
	(SEE OPTION CODE LIST. TABLE 5-4)	OCTAL	
07	FLAGWORD OPERATOR:		
	ECADR (ADDRESS) OF WORD	OCTAL	
	BITS TO BE CHANGED	OCTAL	
	SET (ONE), RESET (ZERO)	OCTAL	
08	ALARM DATA	OCTAL	
		OCTAL	
		OCTAL	
09	ALARM CODE (DISPLAYED WITH VERB)	OCTAL	
	05) (SEE ALARM CODE LIST. TABLE 2-2)	OCTAL	
		OCTAL	
10	CHANNEL TO BE SPECIFIED	OCTAL	
11	TIG of CSI	00XXX.	HOURS
		000XX.	MINUTES
		0XX.XX	SECONDS

NOUN CODE	DESCRIPTION		SCALE AND FORMAT	UNITS
12	OPTION CODE (SEE NOUN 06)		OCTAL	
13	TIG of CDH		00XXX.	HOURS
			000XX.	MINUTES
			0XX.XX	SECONDS
14	SPARE			
15	INCREMENT MACH ADDRESS (R1)		OCTAL	
16	TIME OF EVENT (USED BY		00XXX.	HOURS
	EXTENDED VERBS ONLY)		000XX.	MINUTES
	(SEE NOUN 24 FOR LIMITATIONS)		0XX.XX	SECONDS
17	ASTRONAUT TOTAL ATTITUDE:	ROLL	XXX.XX	DEGREES
		PITCH	XXX.XX	DEGREES
		YAW	XXX.XX	DEGREES
			(MAX. 359.99)	
18	AUTOMATIC MANEUVER BALL ANGLES:			
		ROLL	XXX.XX	DEGREES
		PITCH	XXX.XX	DEGREES
		YAW	XXX.XX	DEGREES
			(MAX. 359.99)	
19	SPARE			
20	PRESENT ICDU ANGLES:	ROLL	XXX.XX	DEGREES
		PITCH	XXX.XX	DEGREES
		YAW	XXX.XX	DEGREES
			(MAX. 359.99)	
21	PIPA PULSES: X		XXXXX.	PULSES
	Y		XXXXX.	PULSES
	Z		XXXXX.	PULSES
			(MAX. 16383.)	
22	NEW ICDU ANGLES:	ROLL	XXX.XX	DEGREES
		PITCH	XXX.XX	DEGREES
		YAW	XXX.XX	DEGREES
			(MAX. 359.99)	
23	SPARE			
24	DELTA CMC CLOCK TIME		00XXX.	HOURS
			000XX.	MINUTES
			0XX.XX	SECONDS
25	CHECKLIST (PLEASE PERFORM) (SEE CHECKLIST CODE LIST, TABLE 5-3)		XXXXX.	NUMERIC

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
26	PRIORITY/DELAY	OCTAL	
	ADRES	OCTAL	
	BBCON	OCTAL	
27	SELF TEST ON/OFF SWITCH	XXXXX.	NUMERIC
28	SPARE		
29	X_{SM} LAUNCH AZIMUTH	XXX.XX	DEGREES
30	TARGET CODE (GYRO COMPASSING	XXXXX.	NUMERIC
	VERIFICATION)	XXXXX.	NUMERIC
		XXXXX.	NUMERIC
31	SPARE		
		0XX.XX	SECONDS
32	TIME FROM PERIGEE (SEE NOUN 24 FOR LIMITATIONS)	00XXX.	HOURS
		000XX.	MINUTES
		0XX.XX	SECONDS
33	TIME OF IGNITION (IN GET) (SEE	00XXX.	HOURS
	NOUN 24 FOR LIMITATIONS)	000XX.	MINUTES
		0XX.XX	SECONDS
34	TIME OF EVENT (IN GET) (SEE NOUN	00XXX.	HOURS
	24 FOR LIMITATIONS)	000XX.	MINUTES
		0XX.XX	SECONDS
35	TIME FROM EVENT (SEE NOUN 24 FOR LIMITATIONS)	00XXX.	HOURS
		000XX.	MINUTES
		0XX.XX	SECONDS
36	TIME OF CMC CLOCK (SEE NOUN 24	00XXX.	HOURS
	FOR LIMITATIONS)	000XX.	MINUTES
		0XX.XX	SECONDS
37	GETI-TPI (SEE NOUN 24 FOR FOR LIMITATIONS)	00XXX.	HOURS
			MINUTES
			SECONDS
38	TIME OF STATE VECTOR	00XXX.	HOURS
	(SEE NOUN 24 FOR LIMITATIONS)	000XX.	MINUTES
		0XX.XX	SECONDS
39	DELTA TIME OF TRANSFER (SEE	00XXX.	HOURS
	NOUN 24 FOR LIMITATIONS)	000XX.	MINUTES
		0XX.XX	SECONDS

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
40	TF GETI/TFC (MAX.59min.,59sec., GREATER DISPLAYED AS 59 59.)	XXBXX	MIN, SEC
	VELOCITY TO BE GAINED (VG)	XXXX.X	FEET/SEC
	DELTA V ACCUMULATED	XXXX.X	FEET/SEC
41	TARGET AZIMUTH (MAX. 359.59)	XXX.XX	DEGREES
	TARGET ELEVATION (MAX. 89.99)	XX.XXX	DEGREES
	TARGET IDENTIFIER	0000X	NUMERIC
42	APOGEE ALTITUDE (HA)	XXXX.X	NAUTICAL MILES
	PERIGEE ALTITUDE (HP)	XXXX.X	NAUTICAL MILES
	DELTA V (REQUIRED)	XXXX.X	FEET/SEC
43	LATITUDE(+ IS NORTH)	XXX.XX	DEGREES
	LONGITUDE(+ IS EAST)	XXX.XX	DEGREES
	ALTITUDE	XXXX.X	NAUTICAL MILES
44	APOGEE ALTITUDE(HA)	XXXX.X	NAUTICAL MILES
	PERIGEE ALTITUDE(HP)(N50)	XXXX.X	NAUTICAL MILES
	TIME OF FREE FALL TO 300,000 FT ALT ABOVE LAUNCH PAD RADIUS.IF (HP) IS GREATER, OR (HA)IS LESS, THAN 300,000 FEET(35,000 FT,LUNAR ORBIT),TFF WILL READ -59 59.	XXBXX	MIN,SEC
45	NUMBER OF MARKS	XXBXX	VHF,OPTICS
	TF GETI OF NEXT BURN	XXBXX	MIN, SEC
	MIDDLE GIMBAL ANGLE (MAX. 359.99)	XXX.XX	DEGREES

46 DAP CONFIGURATION

R1 DATA CODE:

BIT A (LEFTMOST) - VEHICLE CONFIGURATION
0=NO DAP, 1=CSM, 2=CSM/LM, 3=CSM/SIVB/LM
6=CSM/LM (ASCENT ONLY)

BIT B - QUAD AC FOR +X TRANSLATION: 0=NO, 1=YES

BIT C - QUAD BD FOR +X TRANSLATION: 0=NO, 1= YES

BIT D - DEADBAND: 0=+/- 0.5 DEG, 1=+/- 5.0 DEG

BIT E - MANEUVER RATE: 0=0.05 DEG/SEC, 1=0.2 DEG/SEC
2=0.5 DEG/SEC, 3=2.0 DEG/SEC

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
	R2 DATA CODE:		
	BIT A - QUADS AC OR BD FOR ROLL: 0 = BD ROLL, 1 = AC ROLL		
	BIT B - QUAD A FAIL CODE: 0 = QUAD FAILED, 1 = QUAD GOOD		
	BIT C - QUAD B FAIL CODE: 0 = QUAD FAILED, 1 = QUAD GOOD		
	BIT D - QUAD C FAIL CODE: 0 = QUAD FAILED, 1 = QUAD GOOD		
	BIT E - QUAD D FAIL CODE: 0 = QUAD FAILED, 1 = QUAD GOOD		
47	CSM WEIGHT	XXXXX.	POUNDS
	LM WEIGHT	XXXXX.	POUNDS
48	PITCH TRIM	XXX.XX	DEGREES
	YAW TRIM	XXX.XX	DEGREES
49	DELTA R - MAGNITUDE OF DIFFERENCE BETWEEN POSITION VECTOR, R, BEFORE AND AFTER INCORPORATION OF SIGHTING DATA.	XXXX.X	NAUTICAL MILES
	DELTA V - MAGNITUDE OF DIFFERENCE BETWEEN VELOCITY VECTOR, V, BEFORE AND AFTER INCORPORATION OF SIGHTING DATA.	XXXX.X	FEET/SEC
	SOURCE CODE (VHF OR OPTICS)	0000X.	NUMERIC
50	DELTA R (MISS DISTANCE) (+ IS OVERSHOOT)	XXXX.X	NAUTICAL MILES
	PERIGEE (HP)	XXXX.X	NAUTICAL MILES
	TFF (SEE NOUN44)	XXBXX	MIN. SEC
51	S-BAND ANTENNA ANGLES: RHO	XXX.XX	DEGREES
	GAMMA	XXX.XX	DEGREES
52	CENTRAL ANGLE OF ACTIVE VEHICLE	XXX.XX	DEGREES
53	RANGE - DISTANCE TO LM	XXX.XX	NAUTICAL MILES
	RANGE RATE - RATE OF CHANGE OF DISTANCE TO LM (- INDICATES CLOSING)	XXXX.X	FEET/SEC
	PHI - ANGLE BETWEEN STAR LOS AND LOCAL HORIZONTAL PLANE	XXX.XX	DEGREES
54	RANGE - DISTANCE TO LM	XXX.XX	NAUTICAL MILES
	RANGE RATE - RATE OF CHANGE OF DISTANCE TO LM (- INDICATES CLOSING)	XXXX.X	FEET/SEC
	THETA - ANGLE BETWEEN CSM +X AXIS AND LOCAL HORIZONTAL PLANE	XXX.XX	DEGREES

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
55	PER CODE	XXXXX.	NUMERIC
	E- ELEVATION ANGLE BETWEEN LM/CSM LINE-OF-SIGHT AND LOCAL HORIZONTAL PLANE AT TIG(TPI)(SEE NOUN 37)	XXX.XX	DEGREES
	CENTRAL ANGLE OF PASSIVE VEHICLE	XXX.XX	DEGREES
56	RE-ENTRY ANGLE	XXX.XX	DEGREES
	DELTA V	XXXXX.	FEET/SEC
57	DELTA R (SOR)- OFFSET OF STABLE ORBIT POINT, SPECIFIED AS THE DISTANCE ALONG PASSIVE VEHICLE ORBIT (+ INDICATES BEHIND PASSIVE VEHICLE)	XXXX.X	NAUTICAL MILES
58	PERIGEE(TPI OR SOR)-ALTITUDE OF PERIGEE AFTER TRANSFER PHASE OR STABLE ORBIT RENDEZVOUS INITIATION MANEUVER	XXXX.X	NAUTICAL MILES
	DELTA V(TPI OR SOR)- REQUIRED DELTA V TO ACCOMPLISH TRANSFER PHASE OR STABLE ORBIT RENDEZVOUS INIT-IATION MANEUVER	XXXX.X	FEET/SEC
	DELTA V(TPF OR SOR FINAL)- REQD DELTA V TO ACCOMPLISH TRANSFER PHASE OR STABLE ORBIT RENDEZVOUS FINAL MANEUVER	XXXX.X	FEET/SEC
59	DELTA V (LOS)- COMPONENTS OF DELTA V AT GETI,IN LINE-OF-SIGHT COORDINATES LOS 1	XXXX.X	FEET/SEC
	LOS 2	XXXX.X	FEET/SEC
	LOS 3	XXXX.X	FEET/SEC
60	G MAX- PREDICTED G FOR FREE FALL AND ENTRY AT NOMINAL BANK ANGLE(L/D = 0.18)	XXX.XX	G
	V PRED- PREDICTED INERTIAL VELOCITY AT 400,000 FEET ALT	XXXXX.	FEET/SEC
	GAMMA EI- FLIGHT PATH ANGLE, ANGLE BETWEEN INERTIAL VELOCITY VECTOR AND LOCAL HORIZONTAL AT ENTRY INTERFACE ALTITUDE (400,000 FEET)	XXX.XX	DEGREES

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
61	IMPACT LAT. - LATITUDE OF DESIRED IMPACT POINT (+ IS NORTH)	XXX.XX	DEGREES
	IMPACT LONG. - LONGITUDE OF DESIRED IMPACT POINT (+ IS EAST)	XXX.XX	DEGREES
	ENTRY ROLL ATTITUDE (+ IS HEADS UP/ LIFT DOWN, - IS HEADS DOWN/LIFT UP)	00001.	
62	VI - INERTIAL VELOCITY MAGNITUDE	XXXXX.	FEET/SEC
	H DOT - RATE OF CHANGE OF ALTITUDE	XXXXX.	FEET/SEC
	H - ALTITUDE	XXXX.X	NAUTICAL MILES
63	RTGO - RANGE TO GO FROM 0.05G TO SPLASH	XXXX.X	NAUTICAL MILES
	VIO - PREDICTED INERTIAL VELOCITY	XXXXX.	FEET/SEC
	TFE - TIME FROM 0.05G	XXBXX	MIN SEC
64	G - DRAG ACCELERATION	XXX.XX	G
	VI - INERTIAL VELOCITY	XXXXX.	FEET/SEC
	RTOGO- RANGE TO TARGET (+ IS OVERSHOOT)	XXXX.X	NAUTICAL MILES
65	SAMPLED CMC TIME (FETCHED IN INTERRUPT)	00XXX.	HOURS
		000XX.	MINUTES
		0XX.XX	SECONDS
66	BETA - COMMANDED BANK ANGLE	XXX.XX	DEGREES
	CROSS RANGE ERROR (+ IS TARGET TO RIGHT)	XXXX.X	NAUTICAL MILES
	DOWN RANGE ERROR (+ IS OVERSHOOT)	XXXX.X	NAUTICAL MILES
67	RTOGO- RANGE TO TARGET (+ IS OVER-SHOOT)	XXXX.X	NAUTICAL MILES
	LAT, PRESENT POSITION (+ IS NORTH)	XXX.XX	DEGREES
	LONG, PRESENT POSITION (+IS EAST)	XXX.XX	DEGREES
68	BETA - COMMANDED BANK ANGLE	XXX.XX	DEGREES
	VI - INERTIAL VELOCITY	XXXXX.	FEET/SEC
	H DOT - RATE OF CHANGE OF ALTITUDE	XXXXX.	FEET/SEC
69	BETA - COMMANDED BANK ANGLE	XXX.XX	DEGREES
	DL - DRAG ACCELERATION AT SKIPOUT	XXX.XX	G
	VL - SKIPOUT VELOCITY	XXXXX.	FEET/SEC

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
70	CELESTIAL BODY CODE (BEFORE MARK)	OCTAL	
	LANDMARK DATA	OCTAL	
	HORIZON DATA	OCTAL	
	NOTE: NOUNS 70 and 71 CONSIST OF SAME TARGET CODES: R1= 000XX STAR IDENTIFICATION NUMBER R2= ABCDE WHERE, A=1 FOR KNOWN LANDMARK, A=2 FOR UNKNOWN LANDMARK(P22) B= INDEX OF OFFSET DESIGNATOR C=1 FOR EARTH LANDMARK, C=2 FOR MOON LANDMARK(P23) DE= LANDMARK IDENTIFICATION NO. (=00 IF NOT STORED) R2= 00000 FOR HORIZON MEASUREMENT R3= 00CD0 WHERE, C=1 FOR EARTH HORIZON, C=2 FOR MOON HORIZON D=1 FOR NEAR HORIZON, D=2 FOR FAR HORIZON R3= 00000 FOR LANDMARK MEASUREMENT		
71	CELESTIAL BODY CODE (AFTER MARK)	OCTAL	
	LANDMARK DATA	OCTAL	
	HORIZON DATA	OCTAL	
72	DELTA ANGLE(TPI)- CENTRAL ANGLE AROUND EARTH OR MOON BETWEEN ACTIVE AND PASSIVE VEHICLE(+ INDICATES ACTIVE VEHICLE AHEAD)	XXX.XX	DEGREES
	DELTA ALTITUDE(TPI)- ALTITUDE DIFFERENCE BETWEEN ACTIVE AND PASSIVE VEHICLE(+ INDICATES PASSIVE VEHICLE ABOVE ACTIVE)	XXXX.X	NAUTICAL MILES
	SEARCH OPTION- CODE FOR CMC SEARCH TO DEFINE TERMINAL PHASE (00001 INDICATES INTERCEPT AT CENTRAL ANGLE LESS THAN 180 DEG., 00002 INDICATES GREATER THAN 180 DEG.)	0000X.	NUMERIC
73	ALTITUDE (P21)	XXXXX.	<u>TEN</u> NAUTICAL MILES
	VELOCITY (P21)	XXXXX.	FEET/SEC
	GAMMA (P21)	XXX.XX	DEGREES
74	BETA- COMMANDED BANK ANGLE	XXX.XX	DEGREES
	VI- INERTIAL VELOCITY	XXXXX.	FEET/SEC
	G- DRAG ACCELERATION	XXX.XX	G

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
75	DELTA H (CDH)	XXXX.X	NAUTICAL MILES
	DELTA TIME (CDH-CSI or TPI-CDH)	XXBXX	MIN, SEC
	DELTA TIME (TPI-CDH or TPI-NOM TPI)	XXBXX	MIN, SEC
76	SPARE		
77	SPARE		
78	SPARE		
79	SC RATE	X.XXXX	DEG/SEC
	SC DEADBAND	XXX.XX	DEG
	AXIS CODE 0=X AXIS	XXXXX.	NUMERICAL
	NON ZERO = Y AXIS		
80	SPARE		
81	DELTA VX(LV)-COMPONENT OF CSM DELTA V AT IGN ALONG (RXV)XR	XXXX.X	FEET/SEC
	DELTA VY(LV)-COMPONENT OF CSM DELTA V AT IGN ALONG VXR	XXXX.X	FEET/SEC
	DELTA VZ(LV)-COMPONENT OF CSM DELTA V AT IGN ALONG -R	XXXX.X	FEET/SEC
	(R IS GEOCENTRIC OR SELENOCENTRIC RADIUS VECTOR AND V IS INERTIAL VELOCITY VECTOR AT IGNITION)		
82	DELTA VX, VY, VZ (AS IN N81)		
83	DELTA V(CONT)-COMPONENTS OF	X=XXXX.X	FEET/SEC
	INTEGRATED ACCELERATION	Y=XXXX.X	FEET/SEC
	ALONG THE CONTROL AXES	Z=XXXX.X	FEET/SEC
84	DELTA VX(OV)-COMPONENT OF LM DELTA V AT IGN ALONG(RXV)XR	XXXX.X	FEET/SEC
	DELTA VY(OV)-COMPONENT OF LM DELTA V AT IGN ALONG VXR	XXXX.X	FEET/SEC
	DELTA VZ(OV)-COMPONENT OF LM DELTA V AT IGN ALONG -R	XXXX.X	FEET/SEC
	(R IS GEOCENTRIC OR SELENOCENTRIC RADIUS VECTOR AND V IS INERTIAL VELOCITY VECTOR AT IGNITION)		
85	VG BODY-COMPONENT OF VELOCITY	X=XXXX.X	FEET/SEC
	TO BE GAINED ALONG THE	Y=XXXX.X	FEET/SEC
	CONTROL AXES	Z=XXXX.X	FEET/SEC

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
86	DELTA VX (LV)	XXXXX.	FEET/SEC
	DELTA VY (LV)	XXXXX.	FEET/SEC
	DELTA VZ (LV)	XXXXX.	FEET/SEC
87	MARK DATA: OPTICS SHAFT ANGLE	XXX.XX	DEGREES
	OPTICS TRUNNION ANGLE	XX.XXX	DEGREES
88	PLANET UNIT POSITION VECTOR X	.XXXXX	NUMERIC
	Y	.XXXXX	NUMERIC
	Z	.XXXXX	NUMERIC
89	LANDMARK LATITUDE (+ IS NORTH)	XX.XXX	DEGREES
	LANDMARK LONGITUDE/2 (+ IS EAST)	XX.XXX	DEGREES
	LANDMARK ALTITUDE	XXX.XX	NAUTICAL MILES
90	Y - OUT OF PLANE COMPONENT OF DISTANCE TO LM OR CSM ALONG (VXR) (R IS GEOCENTRIC OR SELENOCENTRIC RADIUS VECTOR AND V IS INERTIAL VELOCITY VECTOR).	XXX.XX	NAUTICAL MILES
	Y DOT - RATE OF CHANGE OF Y	XXXX.X	FEET/SEC
	PSI - ANGLE BETWEEN CSM ORBITAL PLANE AND LINE-OF-SIGHT TO LM	XXX.XX	DEGREES
91	PRESENT OCDU ANGLES: SHAFT	XXX.XX	DEGREES
	TRUNNION	XX.XXX	DEGREES
92	NEW OCDU ANGLES: SHAFT	XXX.XX	DEGREES
	TRUNNION	XX.XXX	DEGREES
93	DELTA GYRO ANGLES: X	XX.XXX	DEGREES
	Y	XX.XXX	DEGREES
	Z	XX.XXX	DEGREES
94	OCDU ANGLES (R56 & R23): SHAFT	XXX.XX	DEGREES
	TRUNION	XX.XXX	DEGREES
95	PREFERRED ATTITUDE ICDU ANGLES		
		XXX.XX	DEGREES
		XXX.XX	DEGREES
		XXX.XX	DEGREES
96	+X AXIS ATTITUDE ICDU ANGLES		
		XXX.XX	DEGREES
		XXX.XX	DEGREES
		XXX.XX	DEGREES

NOUN CODE	DESCRIPTION	SCALE AND FACTOR	UNITS
97	SYSTEM TEST INPUTS	XXXXX.	INTEGER
		XXXXX.	INTEGER
		XXXXX.	INTEGER
98	SYSTEM TEST RESULTS	XXXXX.	INTEGER
		.XXXXX	FRACTION
		XXXXX.	INTEGER
99	POS ERR	XXXXX.	FEET
	VEL ERR	XXXX.X	FEET/SECOND
	OPTION CODE	XXXXX.	INTEGER

TABLE 5-3

CHECKLIST CODES

CHECKLIST CODES	DESCRIPTION	WHERE USED	ACTION REQUESTED
00013	PERFORM COARSE ALIGN	P52 P54	KEY IN PRO.
00014	PERFORM FINE ALIGN	P52 P54	KEY IN PRO.
00015	PERFORM CELESTIAL BODY ACQUISITION	P51 THRU P54	IF NECESSARY, MANUEVER SC UNTIL TWO NAVIGATIONAL BODIES ARE WITHIN SXT RANGE OF ACQ. KEY PRO.
00016	TERMINATE MARK SEQUENCE	P03 R53 R56	KEY IN PRO.
00041	PERFORM CM/SM SEPARATION	P62	SET SWITCHES(SW) AND CIRCUIT BREAKERS (CB) AS FOLLOWS:

MAIN BUS TIE - BAT A/C & B/C SWS-on (UP)
A/C ROLL-MNA & MNB CBS - OPEN
B/D ROLL-MNA CB - CLOSED
B/D ROLL-MNB CB - OPEN
PITCH - MNA CB - CLOSE
PITCH - MNB CB - OPEN
YAW - MNA CB - CLOSE
YAW - MNB CB - OPEN
AUTO RCS SELECT SWS- (16) - MNA
SECS - ARM A & B CBS - CLOSE
SECS - LOGIC A & B CBS - CLOSE
SECS - LOGIC 1 & 2 SWS - ON
ELS - BAT A & BAT B CBS - CLOSE
SECS -PYRO ARM A & B SWS - ARM
PRPLNT DUMP SW - RCS CMD
RCS - TRNFR SW - CM

TEST ROLL JETS WITH RHC - NO FIRE
SET CM RCS PRESS SW - ON (UP)
SET RCS IND SELECTOR TO A THEN TO B AND VERIFY SAME READINGS OF:
HE - 4000 TO 4450 PSIA
MANF - 285 TO 302 PSIA
TEST ROLL JETS - FIRE
SET RCS - TRNFR SW TO SM
SET CMC MODE SW TO FREE
AT SEPARATION SET CM/SM SEP 1 & SEP 2 SWS TO ON (UP)

00041 (Cont)			AFTER ADEQUATE SEPARATION KEY IN PRO. SET SWITCHES AS FOLLOWS: CAUTION/WARNING MODE - CM CMC MODE - AUTO RCS - TRNSFR - CM CM PROPELLANT JETT - LOGIC - OFF AUTO RCS SELECT - ALL CM (12)- MNA AUTO RCS SELECT - +Y (BOTH) - OFF AUTO RCS SELECT - -Y (BOTH) - OFF
00062	SHUT DOWN CMC	P06	PRESS PRO BUTTON UNTIL STBY INDICATOR LIGHTS.
00202	PERFORM GNCS AUTOMATIC MANEUVER	P23	KEY IN PRO.
00204	PERFORM ENGINE GIMBAL DRIVE TEST	P40	KEY IN PRO. CHECK SPS GIMBAL POSITION INDICATORS SEQUENTIALLY DISPLAY THE FOLLOWING FOR TWO SECONDS EACH:

	PITCH (DEG.)	YAW (DEG.)
1.	+2	0
2.	-2	0
3.	0	0
4.	0	+2
5.	0	-2
6.	0	0

OPTION* CODE	PURPOSE	WHERE USED	OPTIONS IN R2
00001	SPECIFY IMU ORIENTATION	P52 and P54	00001 = PREFERRED; SELECTED BY PREVIOUS PROGRAM AS OPTIMUM ORIENTATION. 00002 = NOMINAL; BASED ON POSITION AND VELOCITY AT SELECTED TIME 00003 = REFSMMAT; ORIENTATION CURRENTLY STORED IN CMC. 00004 = LANDING SITE.
00002	SPECIFY VEHICLE	P21, R30 and R36	00001 = THIS VEHICLE 00002 = OTHER VEHICLE
00003	SPECIFY TRACKING ATTITUDE	R63	00001 = PREFERRED 00002 = OTHER
00005	SPECIFY STABLE ORBIT RENDEZVOUS PHASE	P38 P78	00001 = FIRST 00002 = SECOND
00007	SPECIFY PROPULSION SYSTEM	P37	00001 = SPS 00002 = RCS

* APPEARS IN R1

TABLE 5-4 OPTION CODES

5.2.3.1 CMC Idling Program (P00)

The CMC idling program (Fig. 5-2) maintains the CMC in a condition of readiness for entry into any other program which does not need to be preceded by another specific program. It provides a program that does not require crew coordination and maintains the GNCS in a state whereby random manual attitude maneuvers can be made with minimum concern for the GNCS. During the program, the CSM and LM state vectors are periodically extrapolated forward to the present time.

The program is entered manually by the astronaut (V37E00E) or automatically from extended verb 96. If entered from V96, W-matrix extrapolation may be incorrect. V96, terminates state vector integration. During P00 operation, the CMC erasable storage may be initialized by keying V36E. However, this action is only performed at initial GNCS startup or when the contents of erasable storage are in question.

If crew manual maneuvers are made during P00 operation, care must be taken to avoid gimbal lock. The IMU gimbal angles may be monitored by keying V16 N20E (ICDU monitoring) or by monitoring the FDAI ball.

5.2.3.2 Prelaunch Initialization Program (P01)

The prelaunch initialization program (Fig. 5-3) provides initial prelaunch orientation of the IMU stable member. It zeros the ICDU's and CDU registers. It coarse aligns the IMU platform for gyro compassing.

The program is entered by manual DSKY entry of V37E01E. At the end of the coarse alignment, when the system is inertial, the CMC automatically enters program (P02).

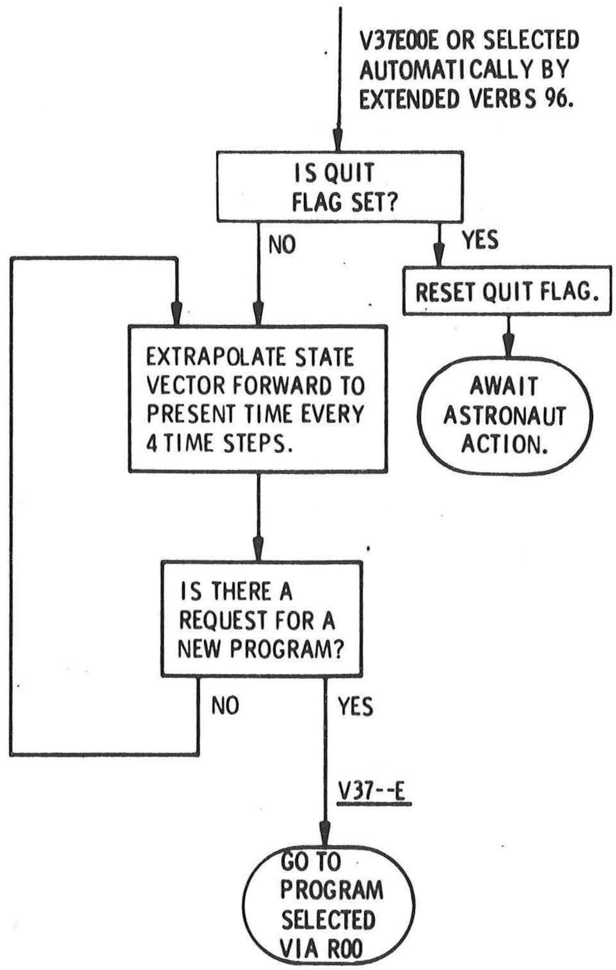


Fig. 5-2. CMC Idling Program (P00)

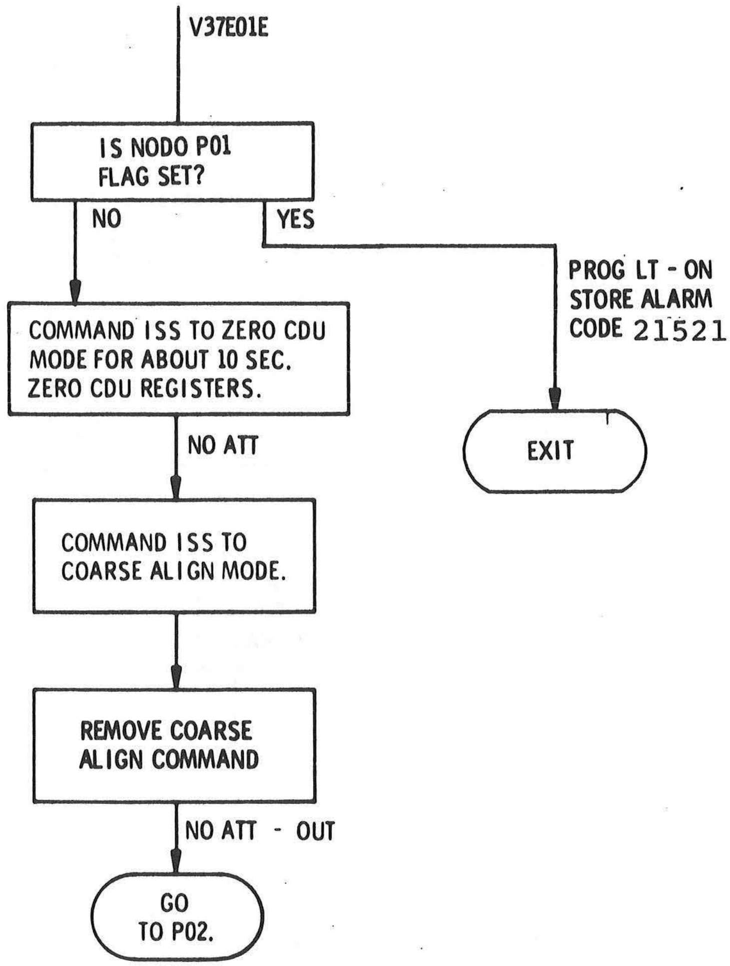


Fig. 5-3. Prelaunch Initialization Program (P01)

5.2.3.3 Gyro Compassing Program (P02)

The gyro compassing program (Fig. 5-4) aligns the IMU stable member to and maintains the stable member at the desired launch azimuth. Gyro compassing is a self-alignment process: each gyro senses a calculable portion of earth rate when the stable member is aligned to some particular orientation with respect to an earth referenced coordinate system. The CMC compensates for earth rate torquing of the gyros by sending a predetermined number of torquing pulses per unit time to each gyro. If the stable member is not aligned to the desired azimuth, the gyro torquing pulses will not compensate for earth rate, and the accelerometers originally in the horizontal plane will be located in a different plane and will sense gravity components of acceleration. These accelerometer error signals are used by the CMC to calculate the necessary torque pulses to drive the stable member to the desired azimuth. This program has the capability (V78) to change launch azimuth of the stable member while gyro compassing.

The program is entered automatically upon completion of program P01. It runs until receipt of the liftoff discrete. The crew backs up termination by keying V75 two minutes before liftoff and ENTR if program P11 has not been entered by the time notification of liftoff is received from the ground. Program P02 may be interrupted by the crew to perform program P03.

5.2.3.4 Optical Verification of Azimuth Program (P03)

The purpose of the optical verification of azimuth program (Fig. 5-5) is to provide the crew with the capability of optically checking the azimuth alignment of the IMU stable member during gyro compassing. This is accomplished by sighting on two designated targets with the SXT. The CMC uses the measured angles to calculate the stable member misalignment and displays the required change in gyro angles. If they are not excessive, the crew commands the CMC to torque the gyros to the required position. Otherwise the program is terminated and the ground notified.

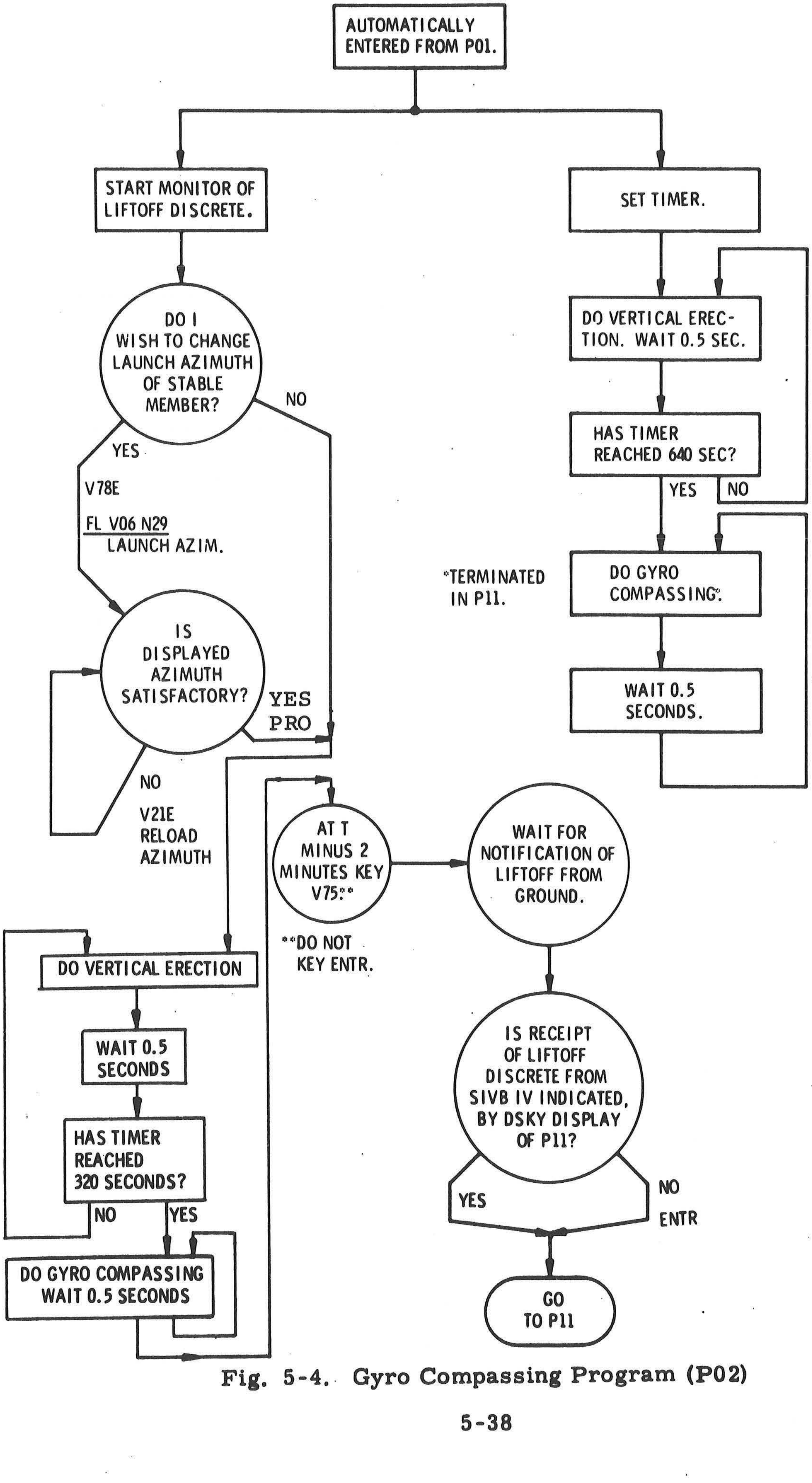


Fig. 5-4. Gyro Compassing Program (P02)

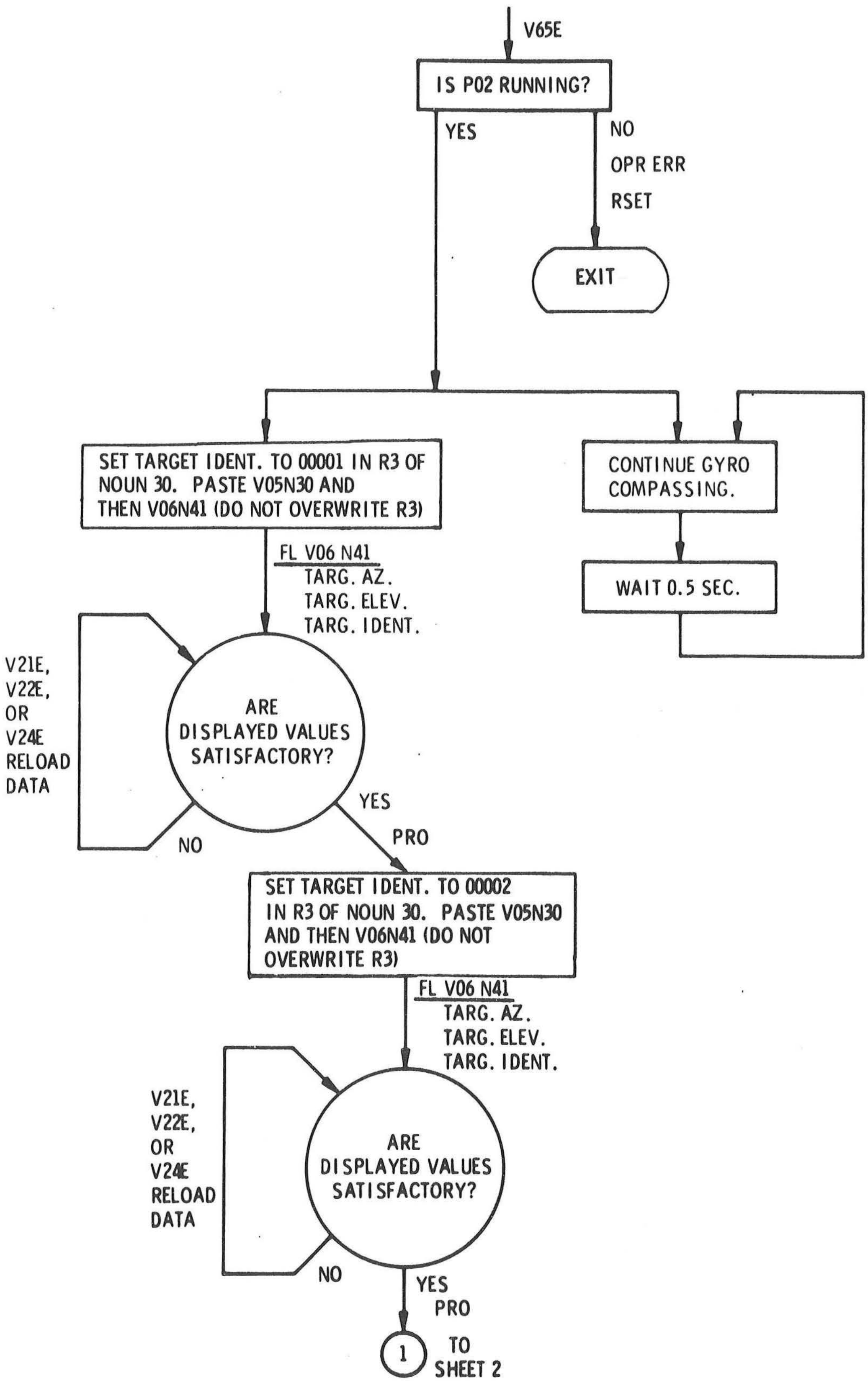


Fig. 5-5. Optical Verification of Azimuth Program (P03) (Sheet 1 of 3)

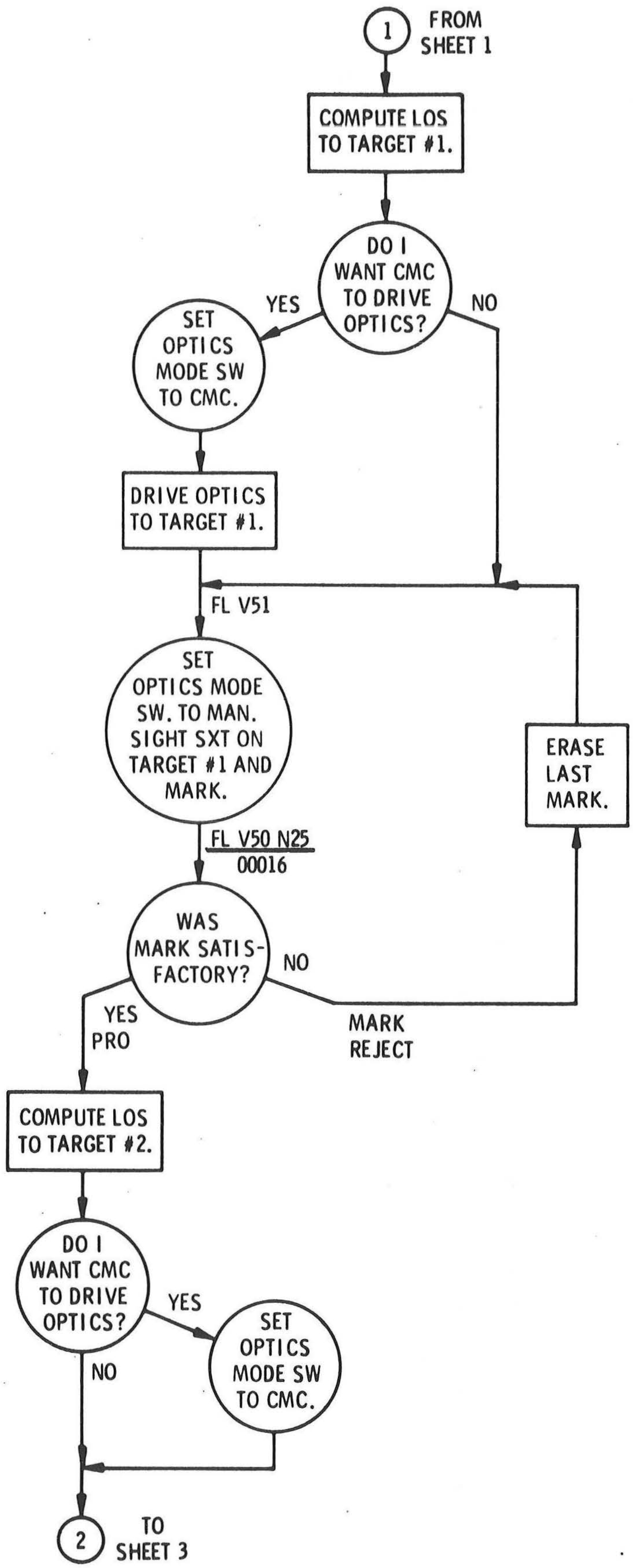


Fig. 5-5. Optical Verification of Azimuth Program (P03) (Sheet 2 of 3)

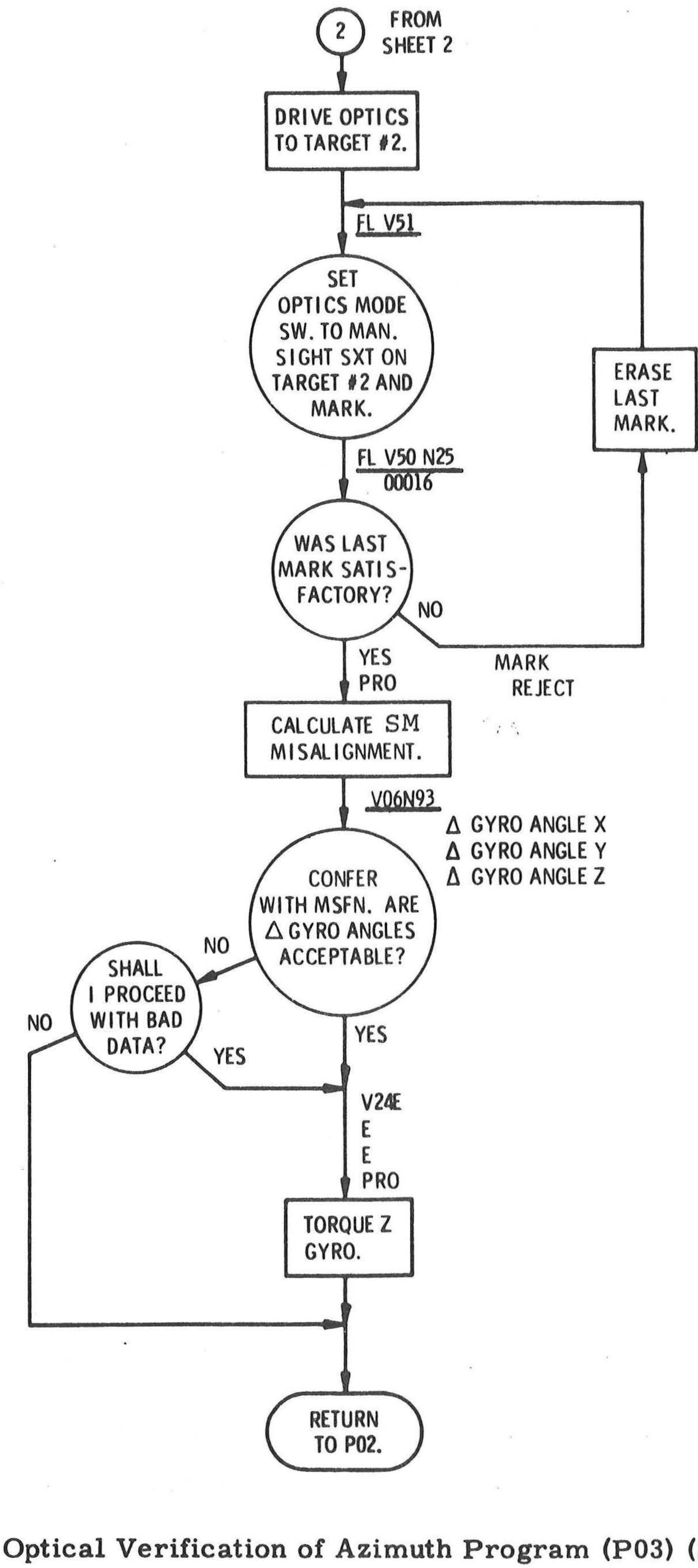


Fig. 5-5. Optical Verification of Azimuth Program (P03) (Sheet 3 of 3)

This program is entered only by DSKY entry of V65E and only during program P02. During program P03 the CMC maintains the gyro compassing started in P02 and returns to P02 upon completion of P03. If launch azimuth has been changed in P02 (via V78E) a minimum of 45 minutes should pass before calling P03.

5.2.3.5 CMC Power Down Program (P06)

The CMC power down program (Fig. 5-6) is used to transfer the CMC from the operate condition to standby. During standby the CMC maintains clock time and synchronization of other CSM systems. All caution/warning signals associated with the CMC except CMC warning, are inhibited. The CMC should not be powered down below standby as this would require a fresh start (V36E) to initialize erasable storage and the state vector and CMC clock time would have to be updated. The CMC can maintain an accurate GET for approx. 23 hours during standby. If it is not brought out of standby at least once within 23 hours, GET must be updated. This program is entered only by DSKY entry of V37E06E.

The normal condition of the PGNS when not being used is STANDBY. The ISS should not be shut down below standby; i.e., the IMU HEATER circuit breakers must be left on, except in extreme emergency. If the IMU heaters are off for extended periods, IMU calibration is no longer valid.

5.2.3.6 Earth Orbit Insertion Monitor Program (P11)

P11 (Fig. 5-7) indicates that the CMC has received the liftoff discrete. This program is normally selected by P02 automatically. From liftoff until the beginning of the pitchover/rollout maneuver, P11 generates and displays an attitude error equal to the difference between present attitude and launch attitude. During the pitchover/rollout the attitude error is based on a comparison of present attitude and a CMC computed attitude. Manual or CMC control of Saturn may be initiated during P11 (See fig. 5-78) .

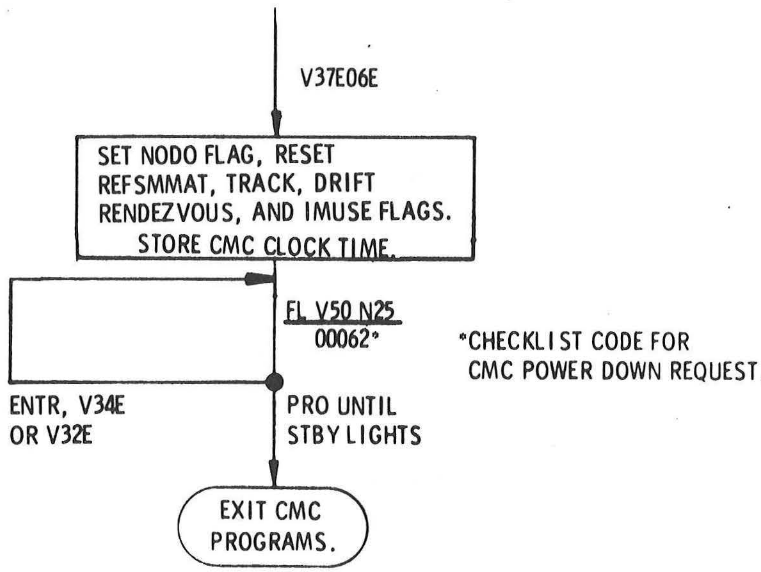


Fig. 5-6. CMC Power Down Program (P06)

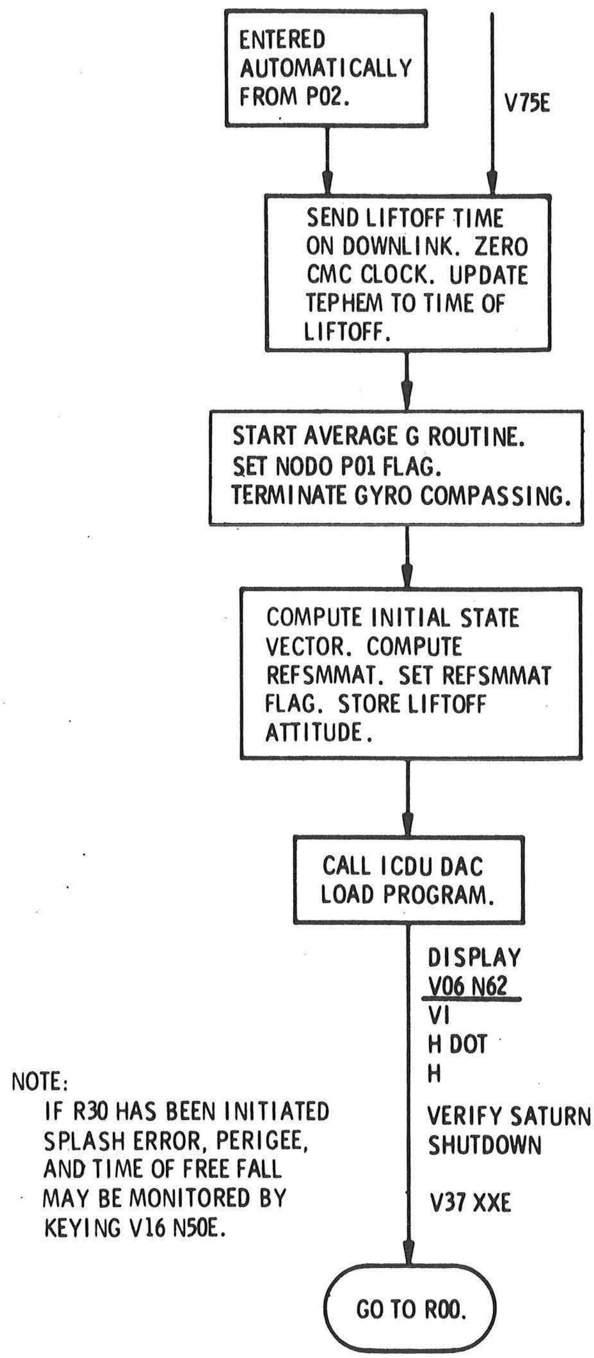


Fig. 5-7. Earth Orbit Monitor Program (P11)

This program is entered automatically from P02 on receipt of the liftoff discrete. The crew backs up the liftoff discrete with V75E as described in paragraph 5.2.3.3. The crew terminates this program by commanding another program (V37E XXE), upon verification of Saturn shutdown.

5.2.3.7 TPI Search Program (P17)

The TPI search program (Fig. 5-8) is used to permit the astronaut to designate a time of transfer phase initiation and a search option which defines the initial transfer trajectory search sector. There are two options: one for a central angle at GETI (TPI) of greater than 180 degrees, and one for less than 180 degrees. After the desired time and option are entered through the DSKY, the CMC calculates and displays the TPI parameters: perigee (or perilune) altitude, delta V (TPI), delta V (TPF), per code (whether perigee or perilune), and central angle. Entry into this program is by DSKY entry of V37E17E.

5.2.3.8 Rendezvous Navigation Program (P20)

The rendezvous navigation program (Fig. 5-9) is used to control the CSM attitude and optics to acquire the LM in the SXT and point the CSM radar transponder at the LM or to acquire the LM along the CSM +X axis. It provides the capability to update either the CSM or LM state vector on the basis of the optical tracking and/or VHF range data. Entry into the program is by DSKY entry of V37E 20E.

The program maintains estimates of CSM and LM state vectors during all free-fall phases of the rendezvous. The selection of which state vector to update is primarily based upon which vehicle has the most accurate initial state vector estimates and which is controlling the rendezvous. During normal rendezvous maneuvers the LM is the active vehicle and the LM state vector usually is updated. The state vector to be updated can be changed at any flashing verb-noun display during P20 by keying in V80E for LM or V81E for CSM (paragraph 5.2.3.38.23). After

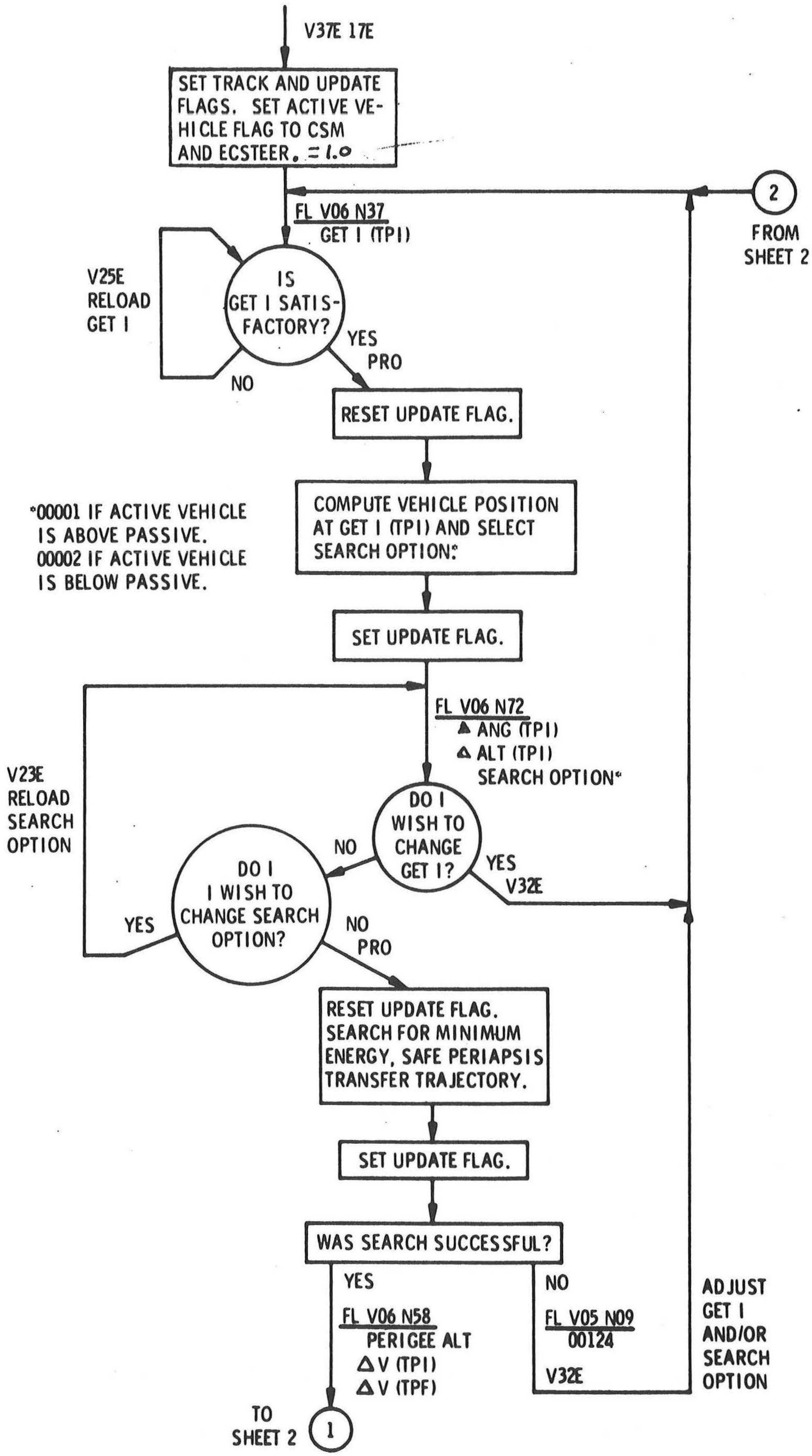


Fig. 5-8. TPI Search Program (P17) (Sheet 1 of 2)

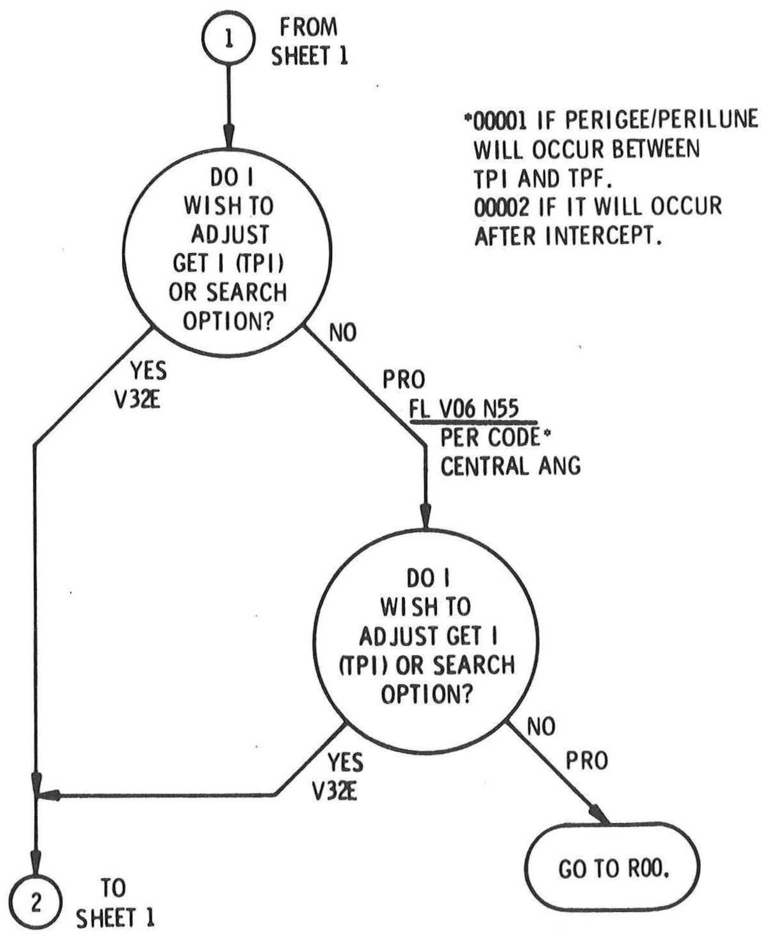


Fig. 5-8. TPI Search Program (P17) (Sheet 2 of 2)

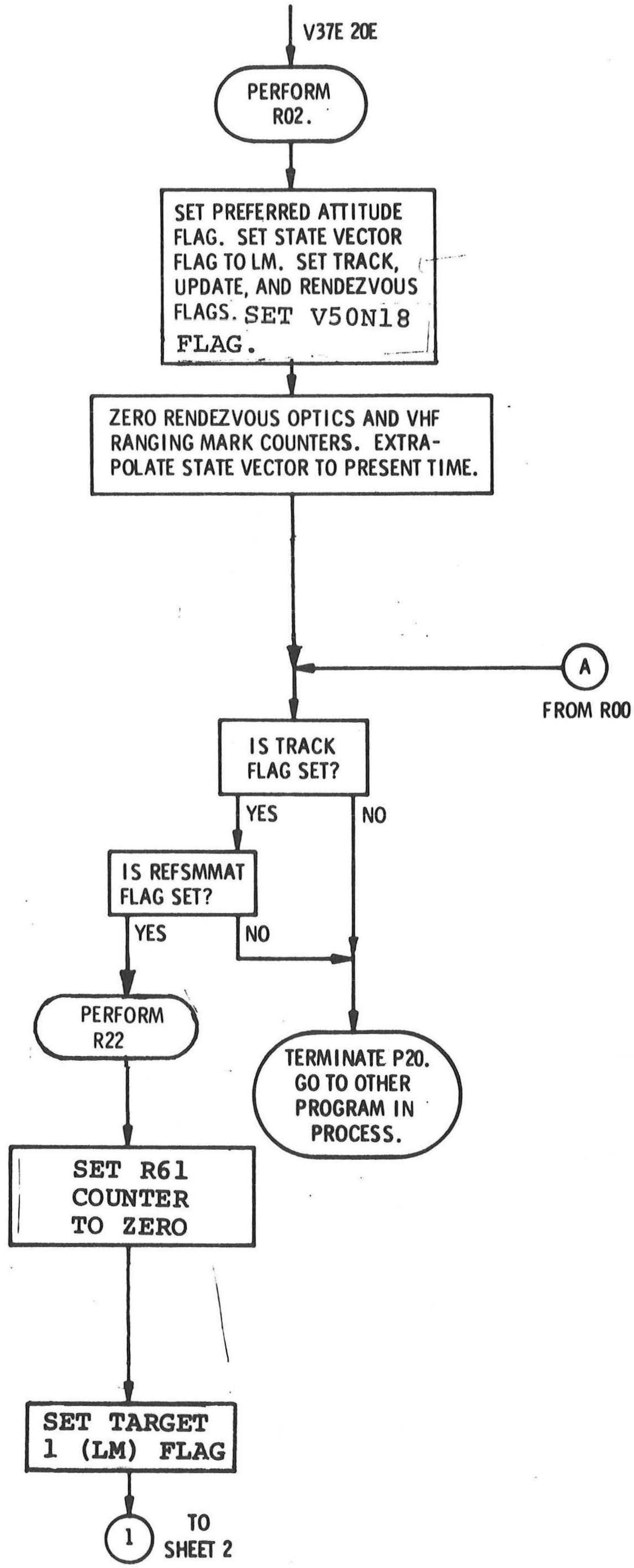


Fig. 5-9. Rendezvous Navigation Program (P20) (Sheet 1 of 2)

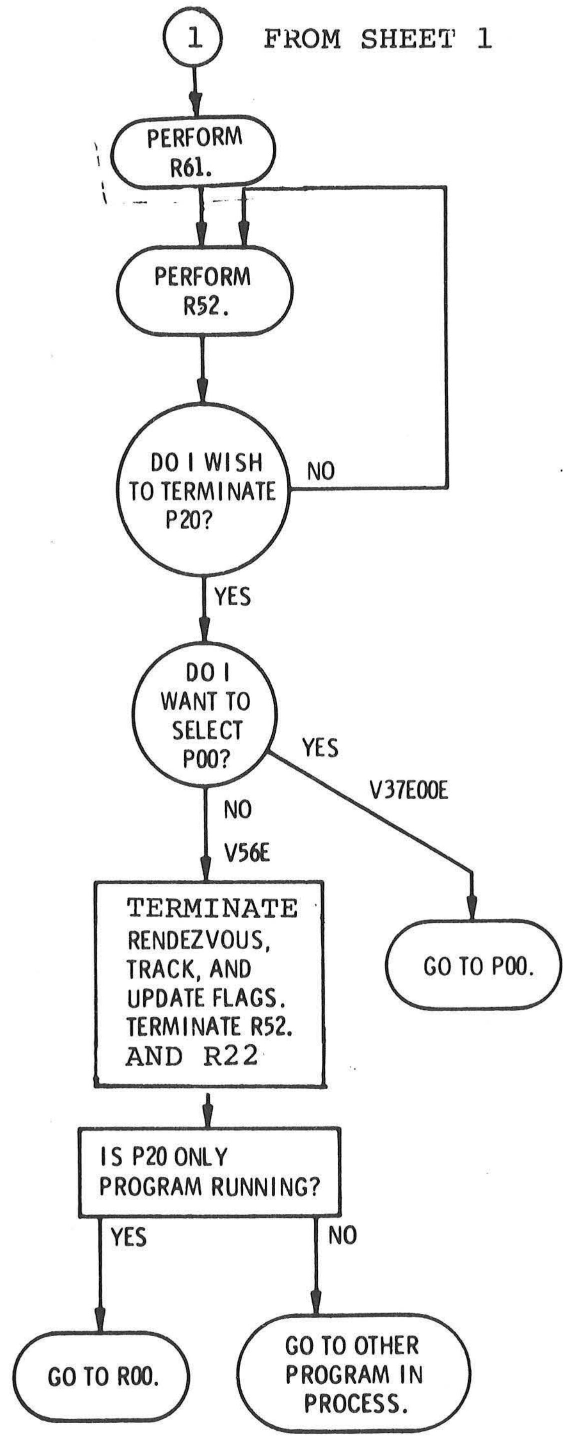


Fig. 5-9. Rendezvous Navigation Program (P20) (Sheet 2 of 2)

initialization, P20 calls the rendezvous data processing routine (R22) (paragraph 5.2.3.8.1) which continues running as long as P20 is running.

The tracking attitude routine (R61) (paragraph 5.2.3.8.2) is used to compute the CSM attitude required to point the optics and the CSM radar transponder at the LM. The attitude maneuver routine (R60) (paragraph 5.2.3.8.3) is performed to move the CSM to the tracking attitude computed in (R61). The LM is also maintaining a preferred tracking attitude to keep the optics beacon pointed at the CSM. After the tracking attitude maneuver, the automatic optics positioning routine R52 (paragraph 5.2.3.8.4) is performed to keep the optics pointing at the LM. This routine recalls R61 for recalculation of tracking attitude and maneuver (R60) if necessary.

Whenever the astronaut wishes to make sighting marks on the LM, he selects the rendezvous tracking sighting mark routine (R21) (paragraph 5.2.3.8.5) by keying V57E, or the backup rendezvous sighting mark routine (R23) (paragraph 5.2.3.8.6) by keying V54E. This can only be done when the CMC is holding for a flashing verb-noun display. During sighting mark routine, routines R61, R52, R22, and R21 are all running simultaneously. Program P20 can run simultaneously with other programs.

5.2.3.8.1 <u>Rendezvous Tracking Data Processing Routine (R22)</u>. This routine (Fig. 5-10) is started automatically by program P20 and continues to run until P20 is terminated or the track flag is reset. This routine processes rendezvous sighting mark and VHF ranging data and updates the state vector of the vehicle designated by the state vector flag. Incorporation of VHF ranging data is enabled by V87E and disabled by V88E (paragraph 5.2.3.38.24).

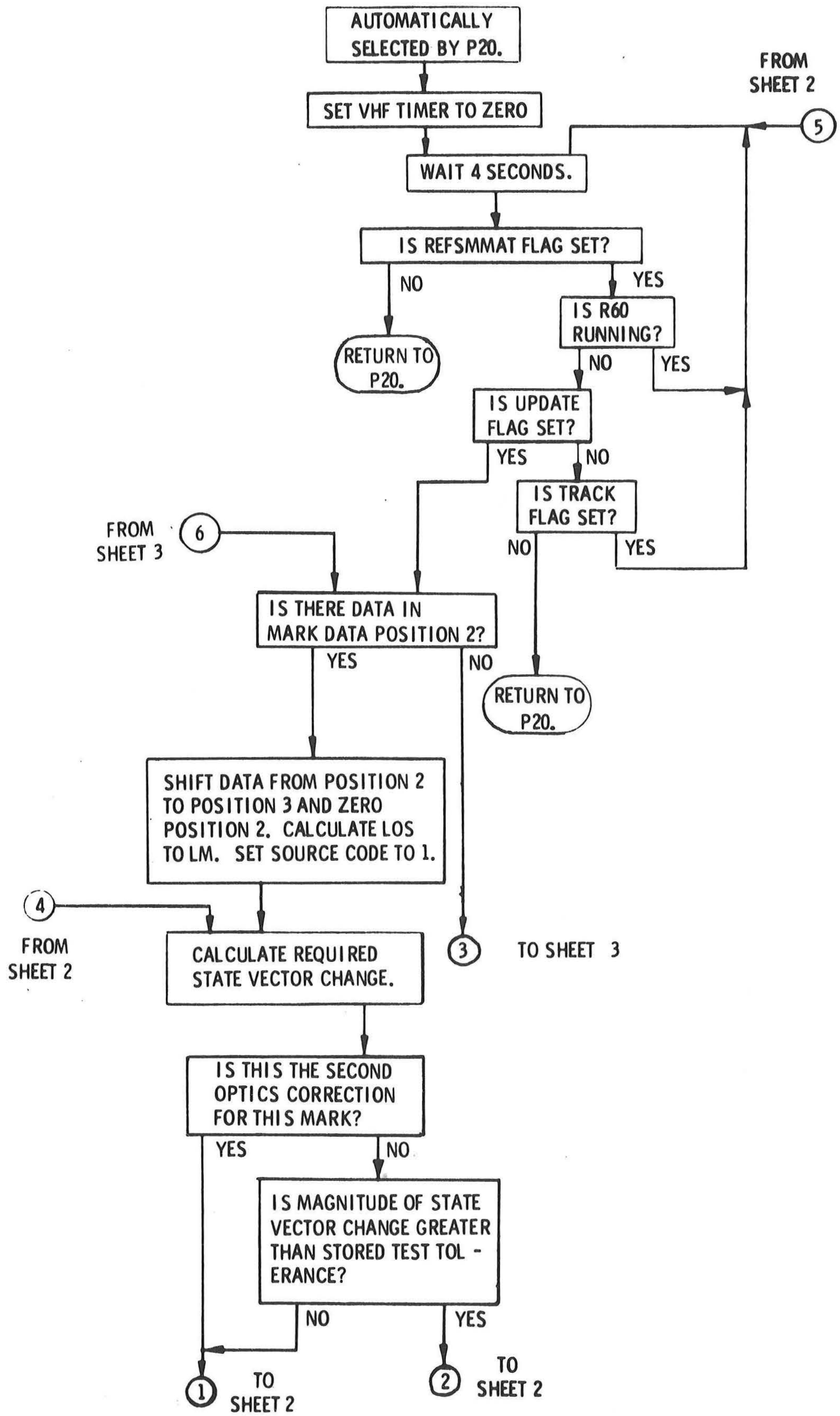


Fig. 5-10. Rendezvous Tracking Data Processing Routine (R22) (Sheet 1 of 3)

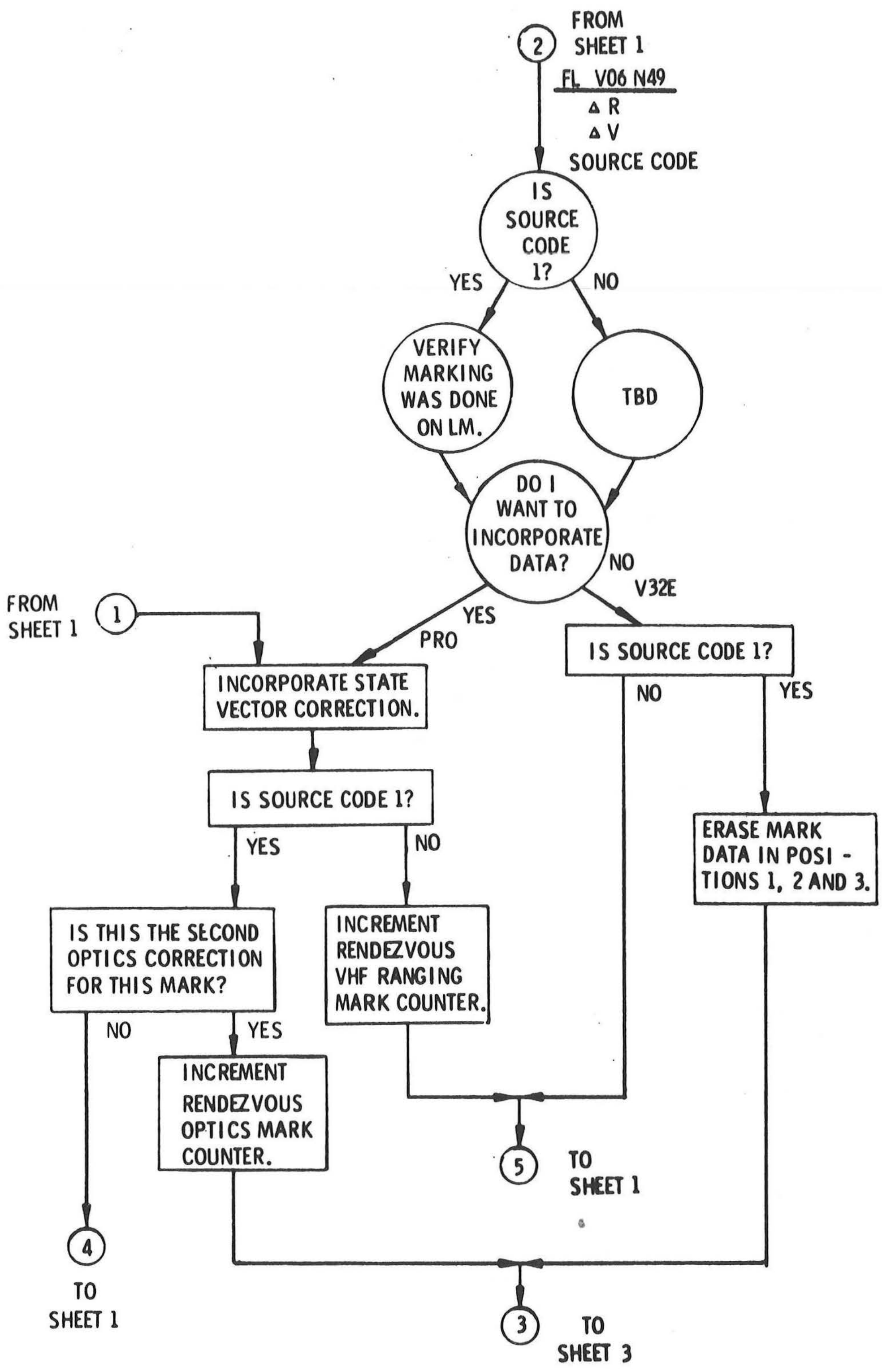


Fig. 5-10. Rendezvous Tracking Data Processing Routine (R22)
(Sheet 2 of 3)

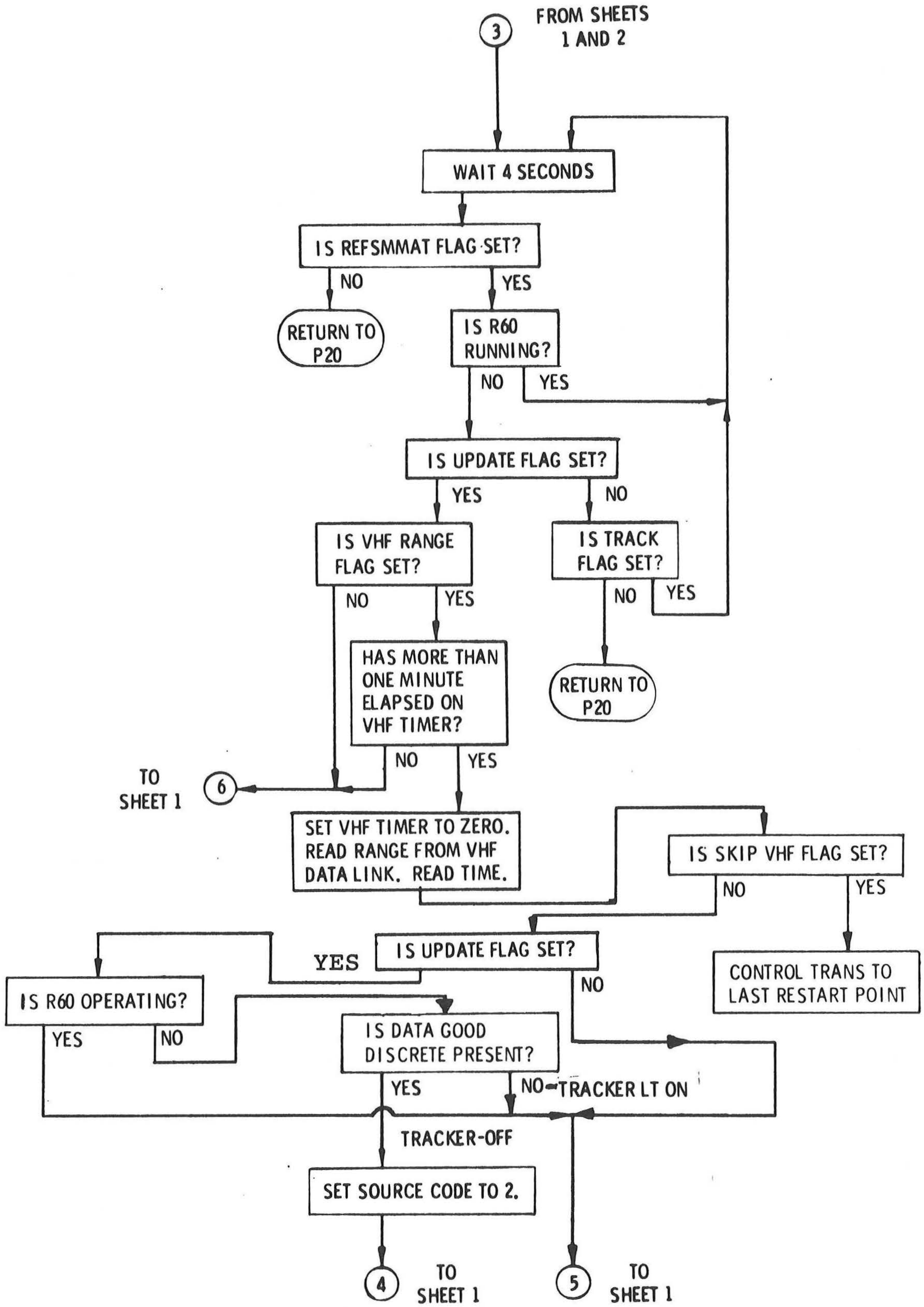


Fig. 5-10. Rendezvous Tracking Data Processing Routine (R22)
(Sheet 3 of 3)

5.2.3.8.2 Tracking Attitude Routine (R61). This routine (Fig. 5-11) keeps the CSM oriented properly with the LM during rendezvous tracking. It extrapolates the CSM and LM state vectors to the present time, calculates the LOS from the CSM to the LM, and computes the required gimbal angles if present IMU orientation is held. The attitude held is determined by the preferred attitude flag; if it is set, a preferred attitude, for optics or VHF tracking, is selected; if it is reset the +X axis is pointed at the LM for COAS tracking. The preferred attitude flag is set by V76E and reset by V77E (paragraph 5.2.3.38.22). It compares the required and present gimbal angles and computes the required change in gimbal angles. If any of the changes are greater than 10 degrees, the CMC commands a maneuver (R60) to the required gimbal angles. If none of the required changes in gimbal angles are over 10 degrees the CMC calculates the angular velocity of the LOS and resolves it into RCS DAP control axes. After maneuvering or inputing the RCS DAP the CMC returns to the calling program, P20 or R52. If called by R52, R61 is performed every fourth time through R52 until terminated by resetting of the track flag.

5.2.3.8.3 Attitude Maneuver Routine (R60). The purpose of this routine (Fig. 5-12) is to maneuver the spacecraft to an attitude specified by the calling program. The astronaut has the option of doing the maneuver manually or automatically. If automatic maneuver is selected, the CMC calculates the maneuver and commands the jet firing to accomplish the desired attitude. Initial and desired final gimbal angles are used to calculate the proper jet commands. If the manual option is selected, the astronaut must command the maneuver with the rotational hand control and monitor for gimbal lock on the FDAI.

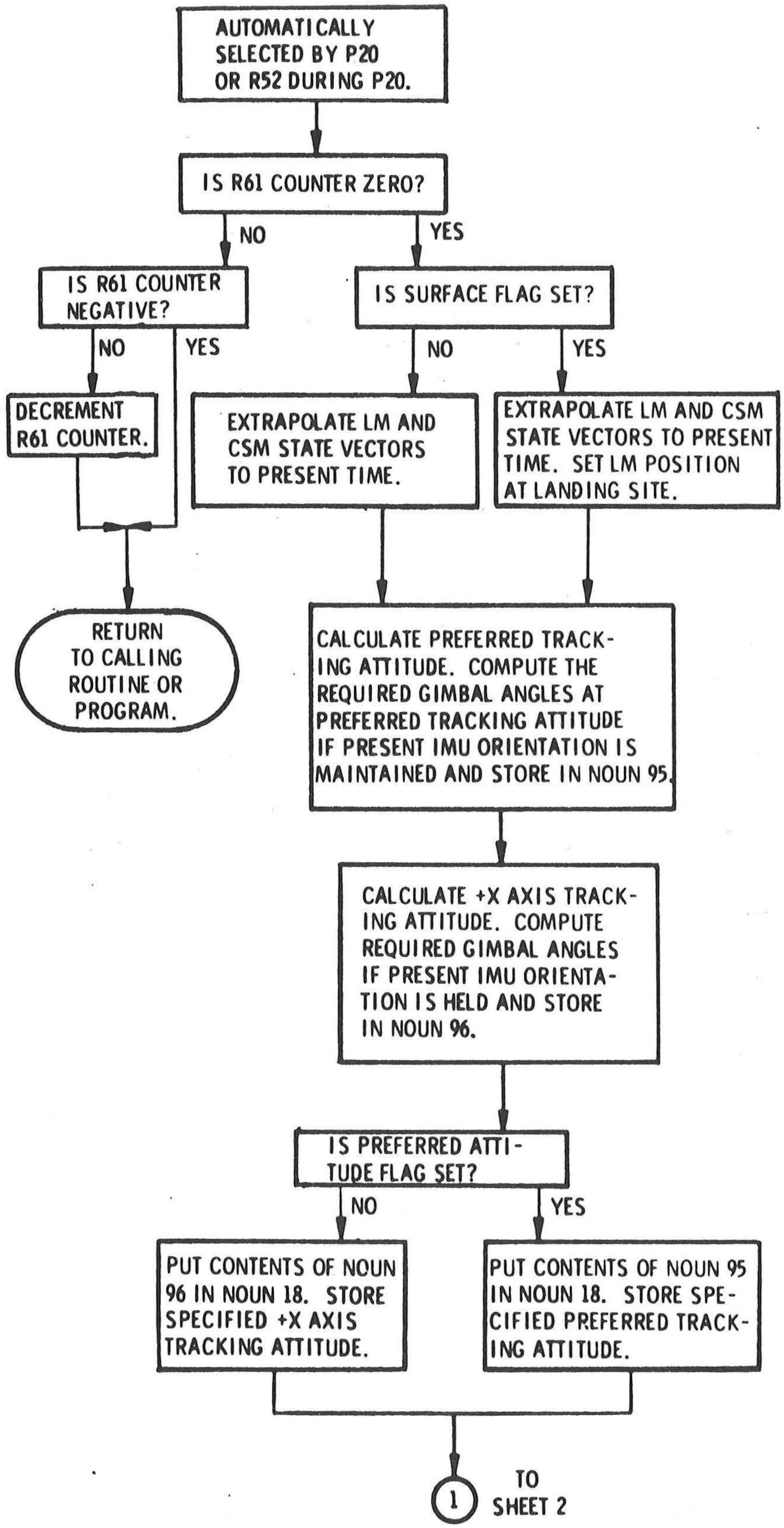


Fig. 5-11. Tracking Attitude Routine (R61) (Sheet 1 of 2)

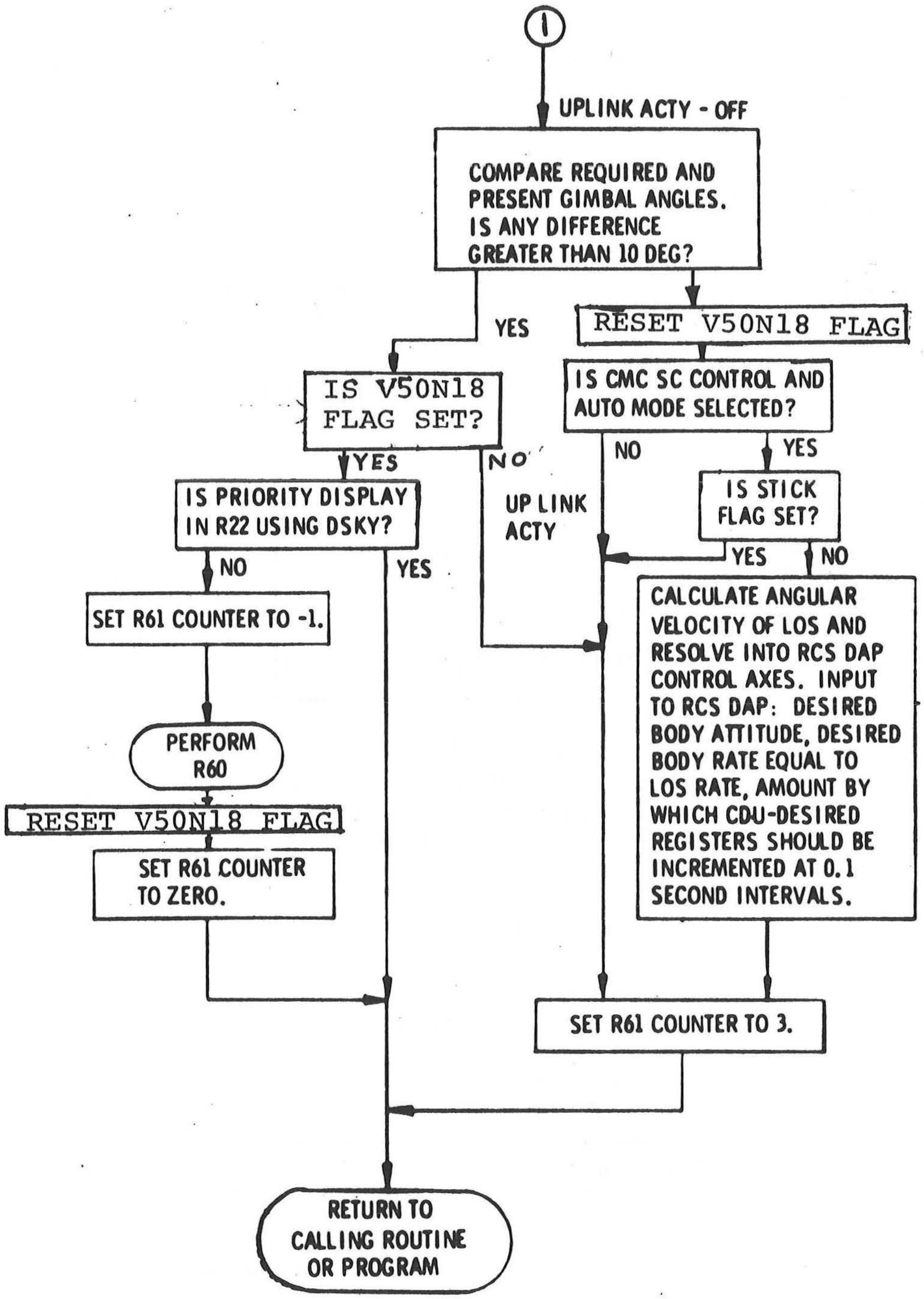


Fig. 5-11. Tracking Attitude Routine (R61) (Sheet 2 of 2)

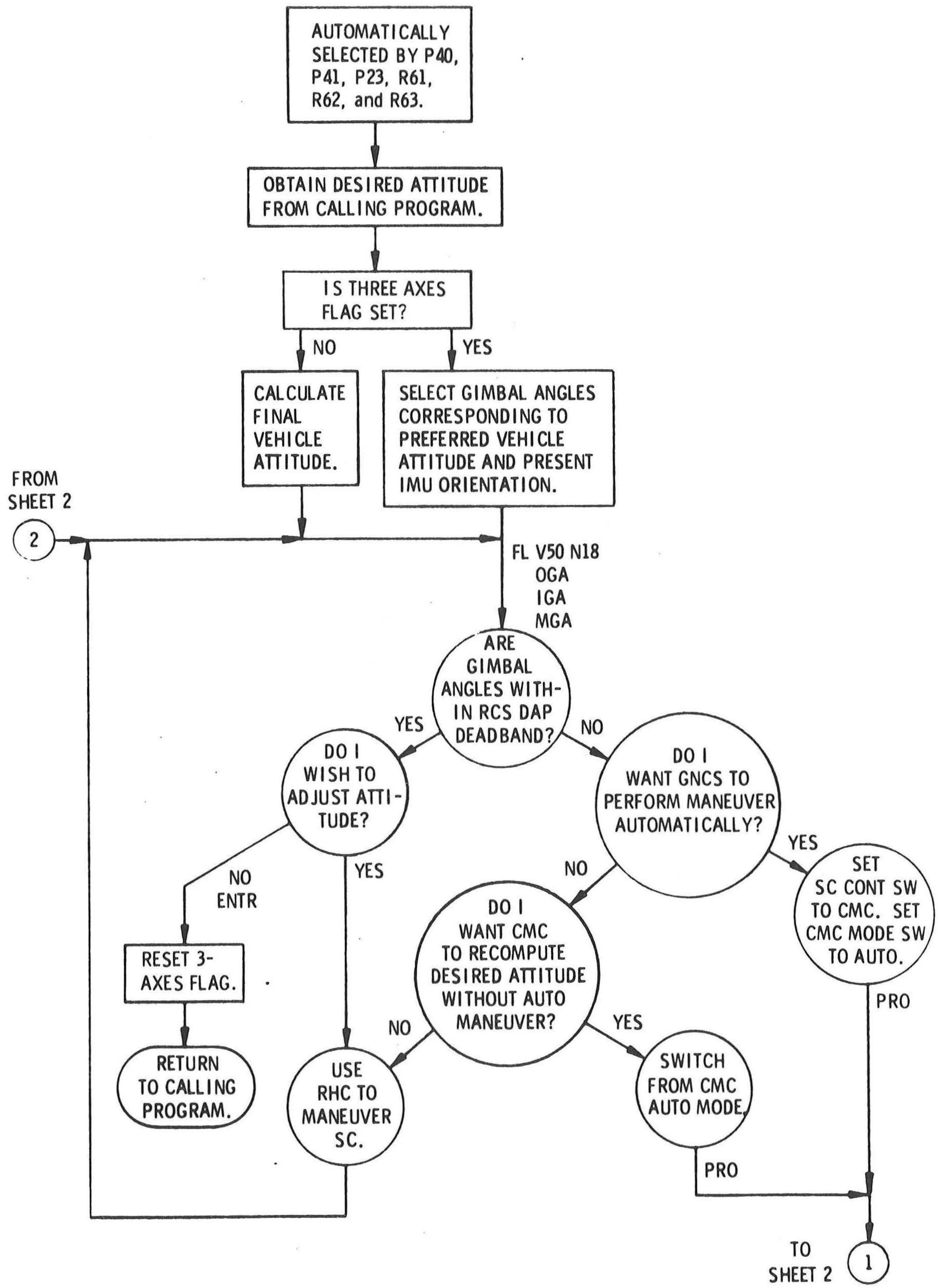


Fig. 5-12. Attitude Maneuver Routine (R60) (Sheet 1 of 2)

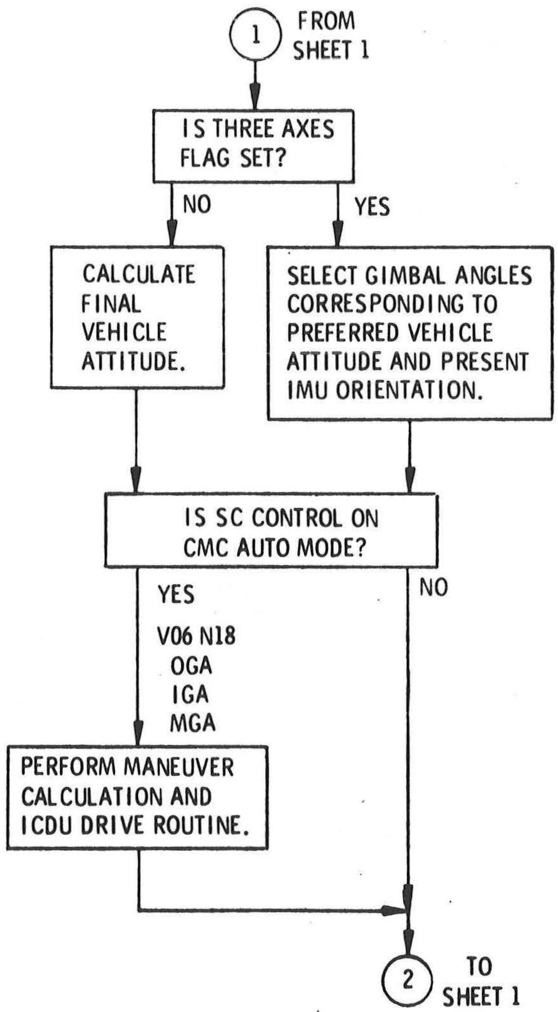


Fig. 5-12. Attitude Maneuver Routine (R60) (Sheet 2 of 2)

5.2.3.8.4 Automatic Optics Positioning Routine (R52) (During Rendezvous). This routine (Fig. 5-13) is used to keep the CSM optics pointed at the LM during rendezvous tracking. In this case the target 1 flag and track flag are set. If the preferred attitude flag is set, the routine calculates the LOS vector from the CSM to the LM. If the trunnion angle is not excessive (it should not be, since R61 is in process and the OSS is in the CMC mode), the CMC drives the shaft and trunnion to keep the optics pointed at the LM. R52 is continually repeated until the track flag is reset.

5.2.3.8.5 Rendezvous Tracking Sighting Mark Routine (R21). This routine (Fig. 5-14) is called by keying V57E during routine R22 and requests the astronaut to make sighting marks on the LM. The astronaut may make as many marks as he desires; but if more than one every minute is made, the marks are too close together to be useful. The astronaut commands termination of sighting marks by keying PRO.

5.2.3.8.6 Backup Rendezvous Sighting Mark Routine (R23). This routine (Fig. 5-15) is very similar to R21 except that it uses the crew optical alignment sight (COAS) for optical sightings. It is called by keying V54E.

5.2.3.8.7 Rendezvous Parameter Display Routines (R31 and R34). These routines (Figs. 5-16 and 5-17) are called by DSKY entry: V83E for R31 and V85E for R34. They both display range and range rate between the CSM and LM, calculated from the stored LM and CSM state vectors. R31 also displays the angle (Theta) between the CSM +X axis and the local horizontal plane at the present time. R34 displays the angle (Phi) between the SXT SLOS and the local horizontal plane at the present time.

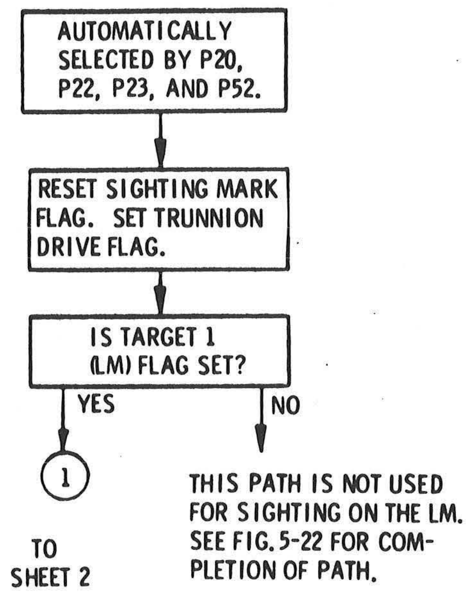


Fig. 5-13. Automatic Optics Positioning Routine (R52) (Rendezvous) (Sheet 1 of 2)

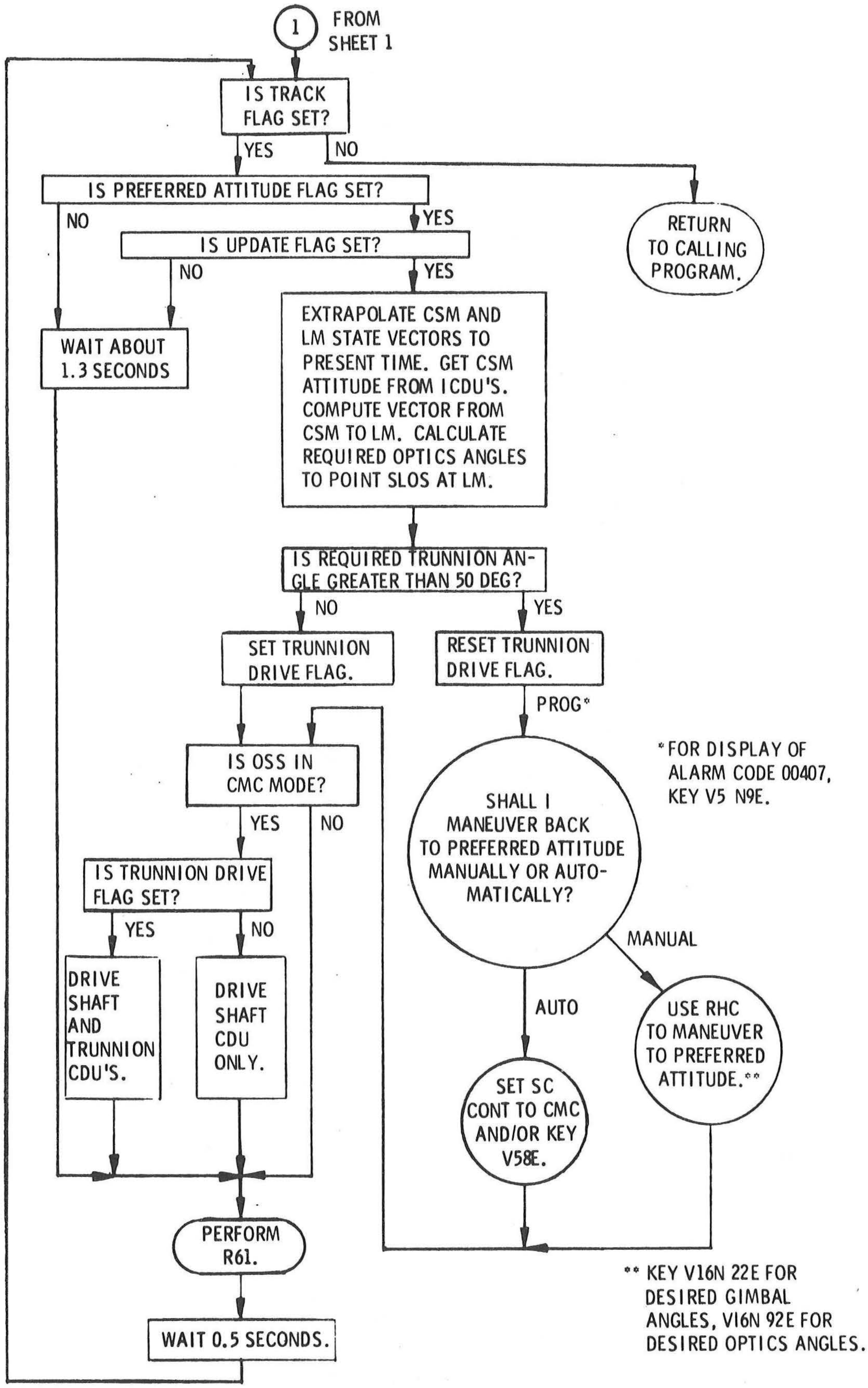


Fig. 5-13. Automatic Optics Positioning Routine (R52) (Rendezvous) (Sheet 2 of 2)

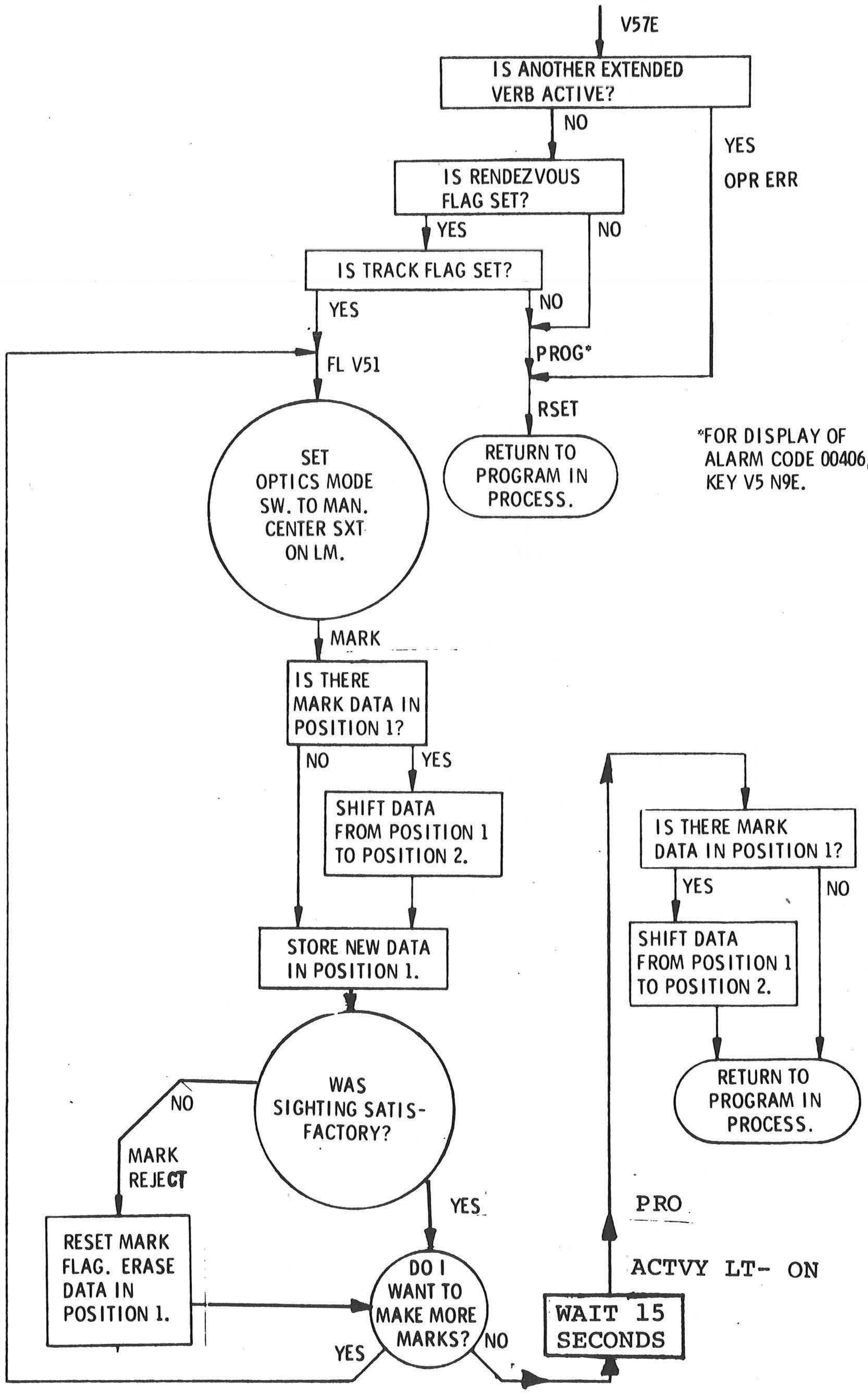


Fig. 5-14. Rendezvous Tracking Sighting Mark Routine (R21)

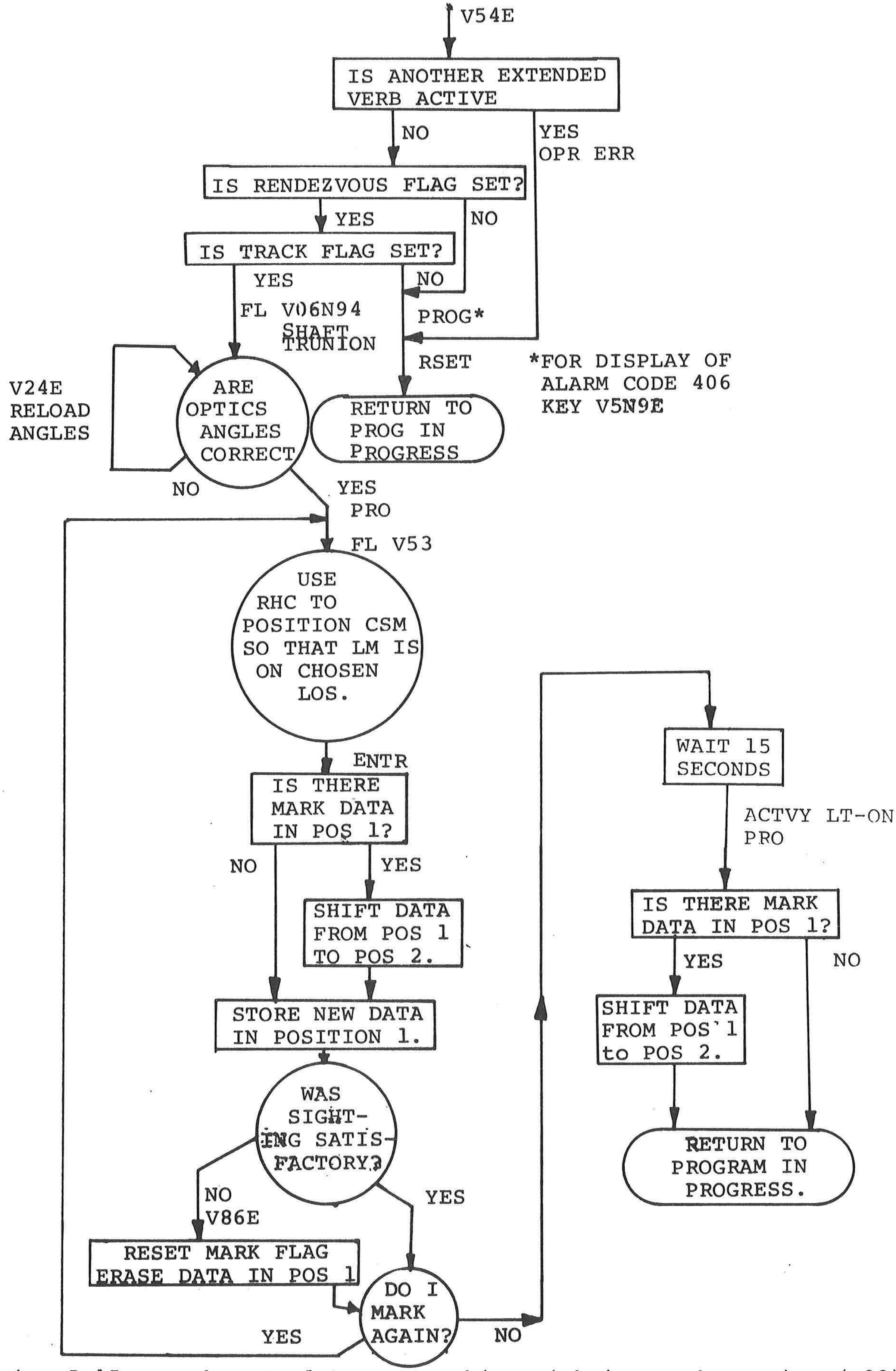


Fig. 5-15. Backup Rendezvous Tracking Sighting Mark Routine (R23)

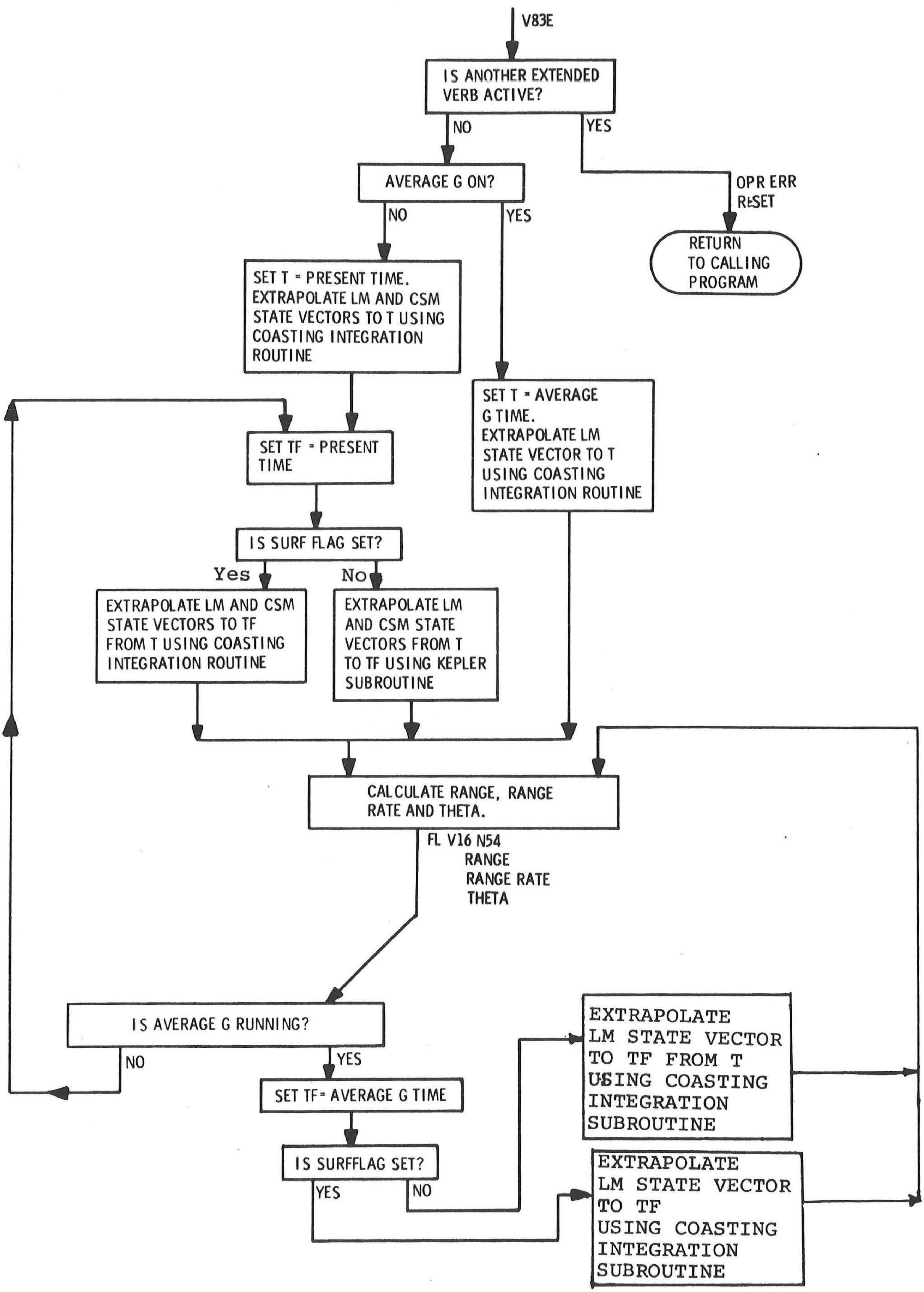


Fig. 5-16. Rendezvous Parameter Display Routine No. 1 (R31)

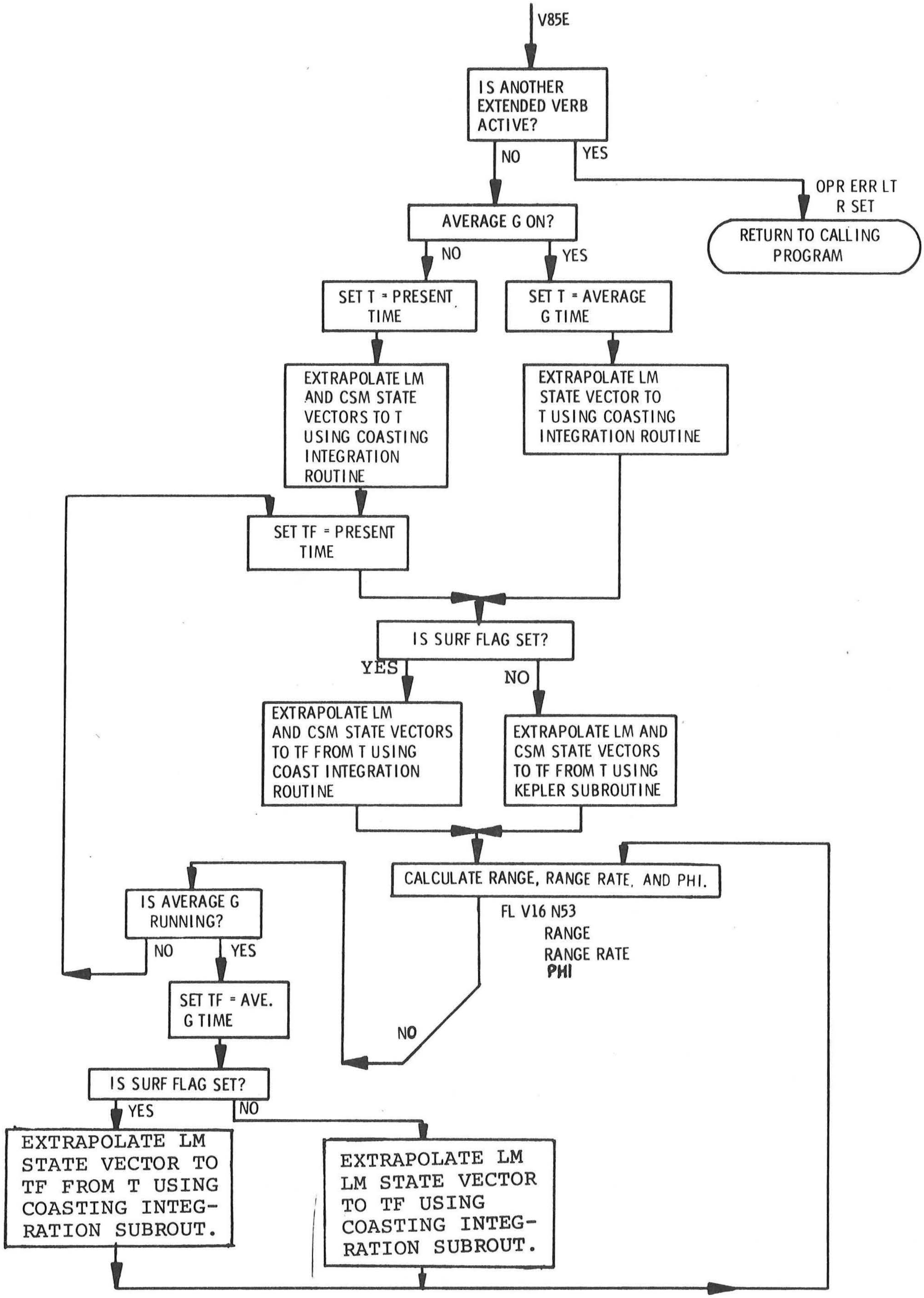


Fig. 5-17. RENDEZVOUS PARAMETER DISPLAY ROUTINE NO. 2 (R34)

5.2.3.9 Ground Track Determination Program (P21)

The ground track determination program (Fig. 5-18) provides the crew with a display of the CSM or LM latitude, longitude, and altitude at a time specified by the crew, without need for ground communication. During the program a display of the vehicle position at ten minute intervals from the initial position can be selected. This program is entered by DSKY entry of V37E 21E.

5.2.3.10 Orbital Navigation Program (P22)

The orbital navigation program (Fig. 5-19) is used for two purposes, (1) to update the CSM state vector during earth or lunar orbit by tracking landmarks, and (2) for landing site mapping. Prior to this program the IMU has been aligned to two stars. The ISS provides the CMC with gimbal angle changes from which the CMC calculates the spacecraft orientation.

1. There are two methods of landmark tracking: on known landmarks or on unknown landmarks. The data received from landmark tracking consist of the optical angles and time of mark. From the OSS and ISS inputs, the CMC calculates the landmark direction relative to the stable member. This calculation is equivalent to two simultaneous star-landmark measurements. For known landmarks, the landmark measurements, time of mark, and known latitude, longitude, and altitude of the landmark are used to calculate the difference in position and velocity from the estimated trajectory stored in the CMC. For unknown landmarks, two or more marks must be made on the same landmark. The change in time and position between the marks is then used to calculate the change from the estimated trajectory. Weighting functions are applied to the landmark measurements and present trajectory, and calculations are made to determine a new estimated trajectory which is stored in the CMC and used in the calculations of the next landmark measurement.

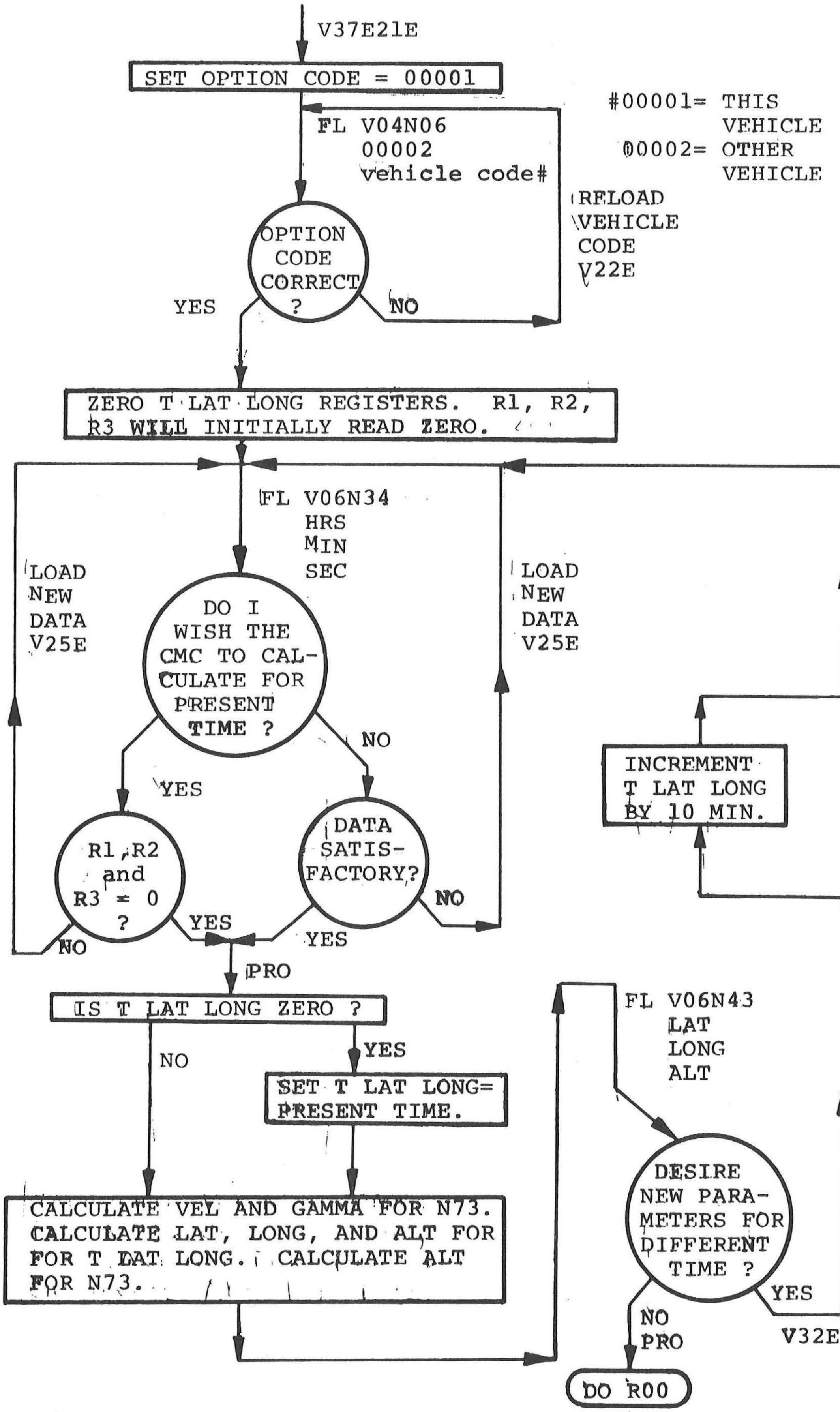


Fig. 5-18. Ground Track Determination Program (P21)

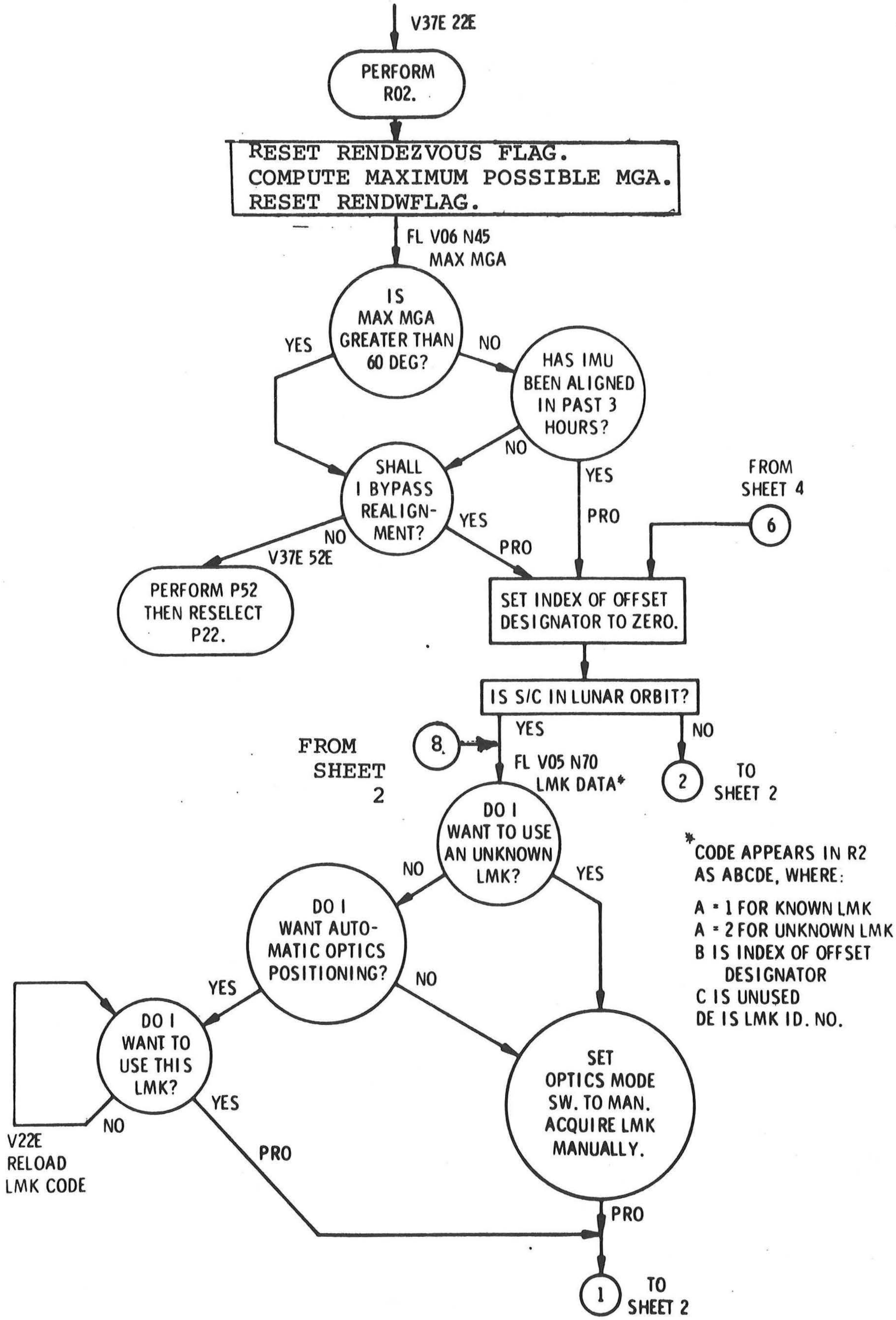


Fig. 5-19. Orbital Navigation Program (P22) (Sheet 1 of 4)

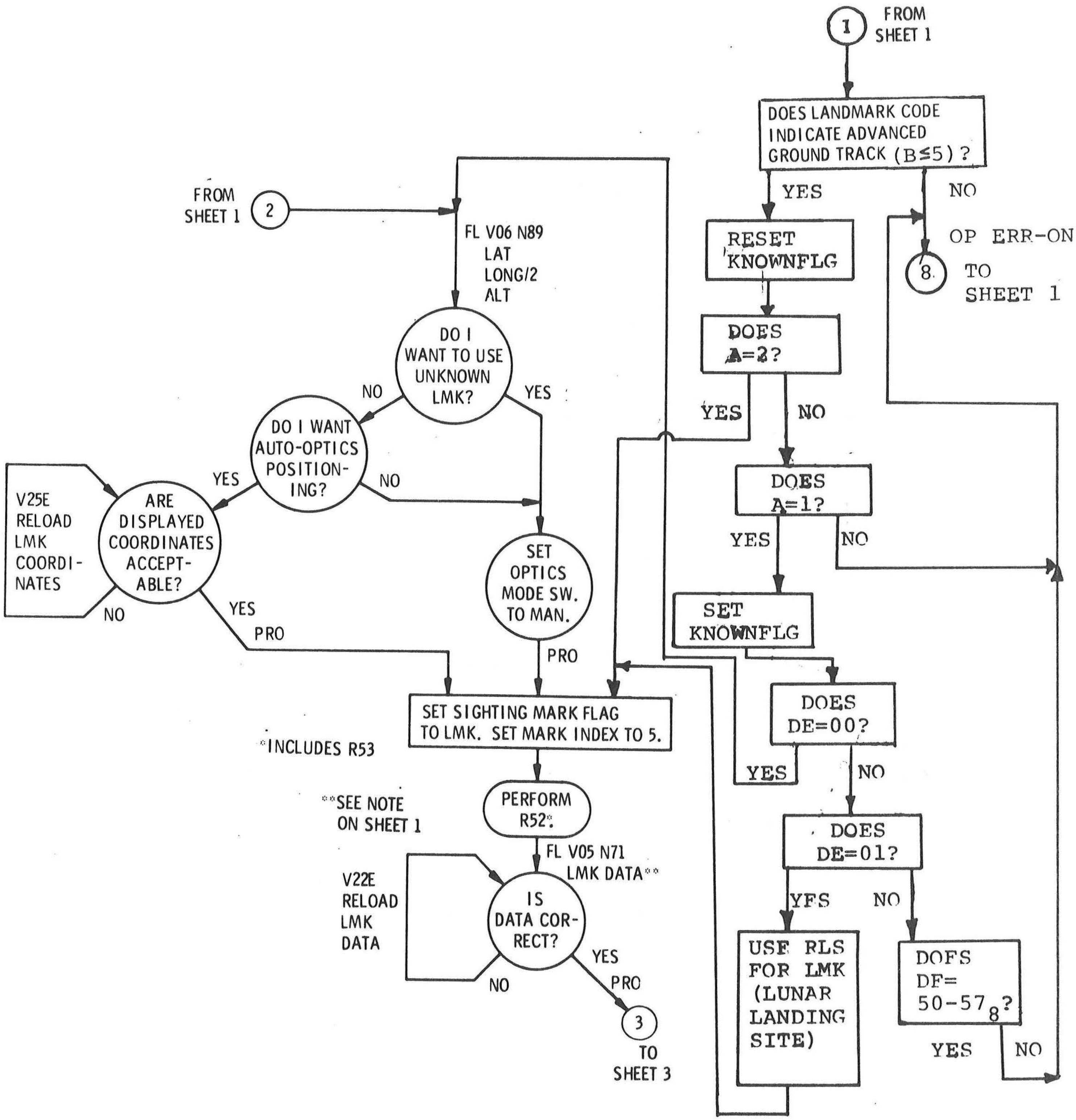


Fig. 5-19. Orbital Navigation Program (P22) (Sheet 2 of 4)

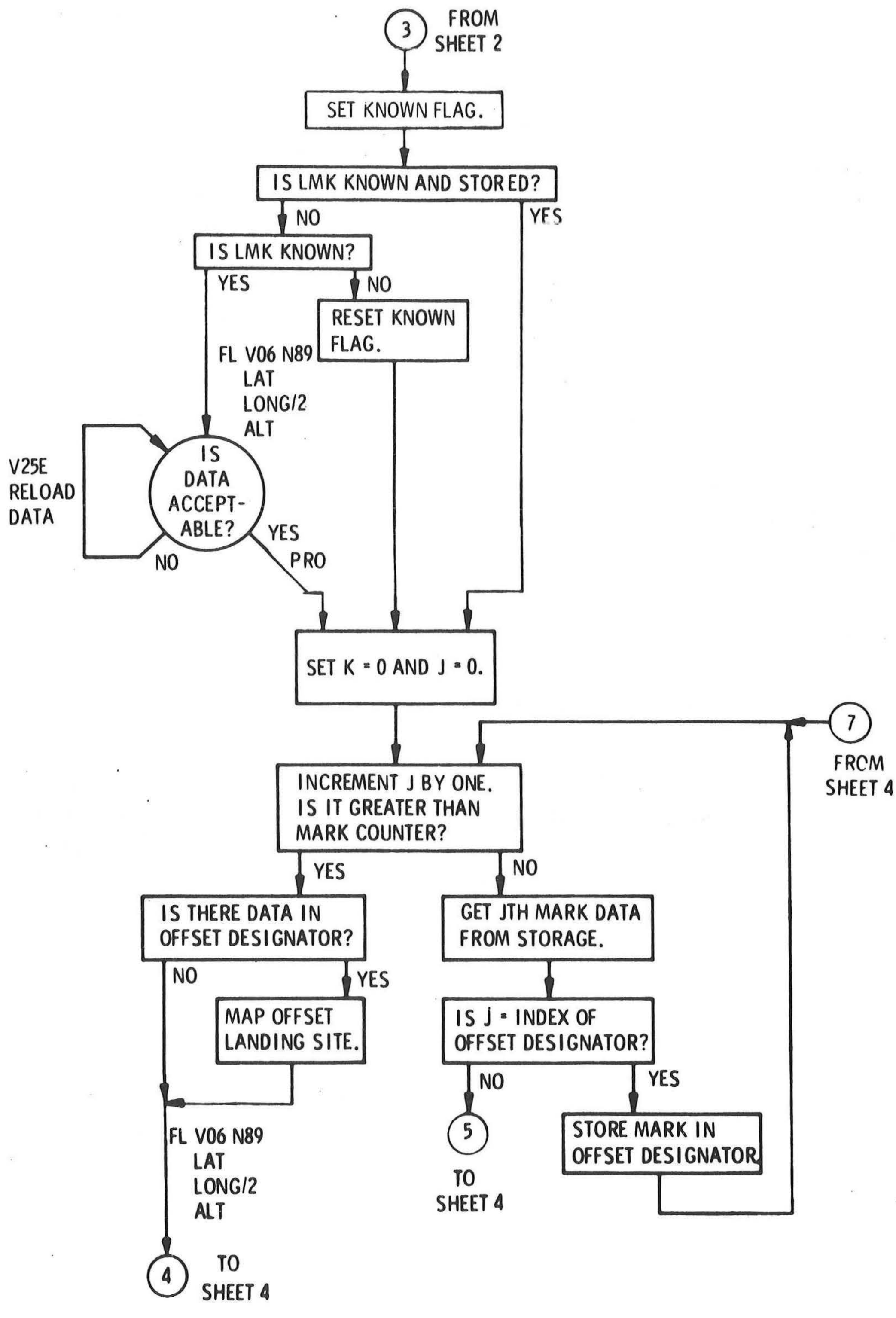


Fig. 5-19. Orbital Navigation Program (P22) (Sheet 3 of 4)

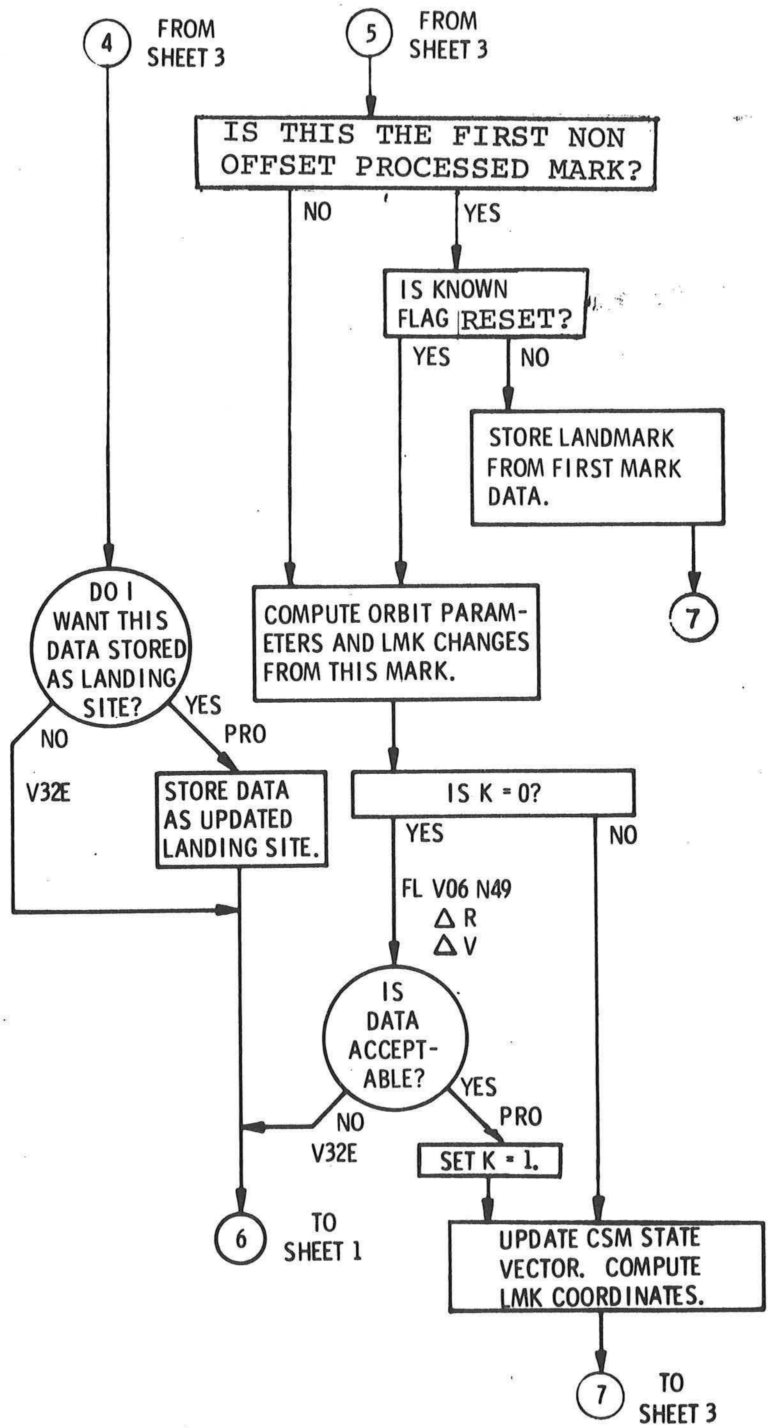


Fig. 5-19. Orbital Navigation Program (P22) (Sheet 4 of 4)

In performing known landmark tracking, the SCT is used because its large field of view is required for the high angular rate (2.78 deg/sec maximum) of the landmark with respect to the spacecraft. A landmark close to the orbital ground track (100 miles maximum, and preferably within 50 miles) is chosen. (See Fig. 5-20). The spacecraft is oriented with the roll axis (X) forward along the local horizontal. After a landmark is selected, the spacecraft is rolled, if necessary, to put the landmark from 10 to 30 degrees from the spacecraft X-Z plane. This is done because the trunnion cannot pass through zero. If the landmark were in, or very near, the X-Z plane, an extremely high SCT shaft drive rate would be needed for continuous tracking as the spacecraft passes over the landmark.

The spacecraft is maneuvered to the tracking attitude. The program is entered manually by V37E 22E. The navigator may choose to have the optics positioned automatically, in which case routine R52 (paragraph 5.2.3.10.2) is performed, or he may wish to acquire the landmark manually. In either case, the sighting mark routine R53 (paragraph 5.2.3.10.3) is performed.

2. Landing site mapping is done in two ways: landing site designation and landing site offset. In the former, an unknown landmark is marked. Its co-ordinates are then calculated and stored as the designated landing site. In the landing site offset method, a mark is made on the selected landing site while tracking and marking a primary landmark. The index of the offset designator is set to the mark number of the mark made on the landing site. Its coordinates are calculated and stored.

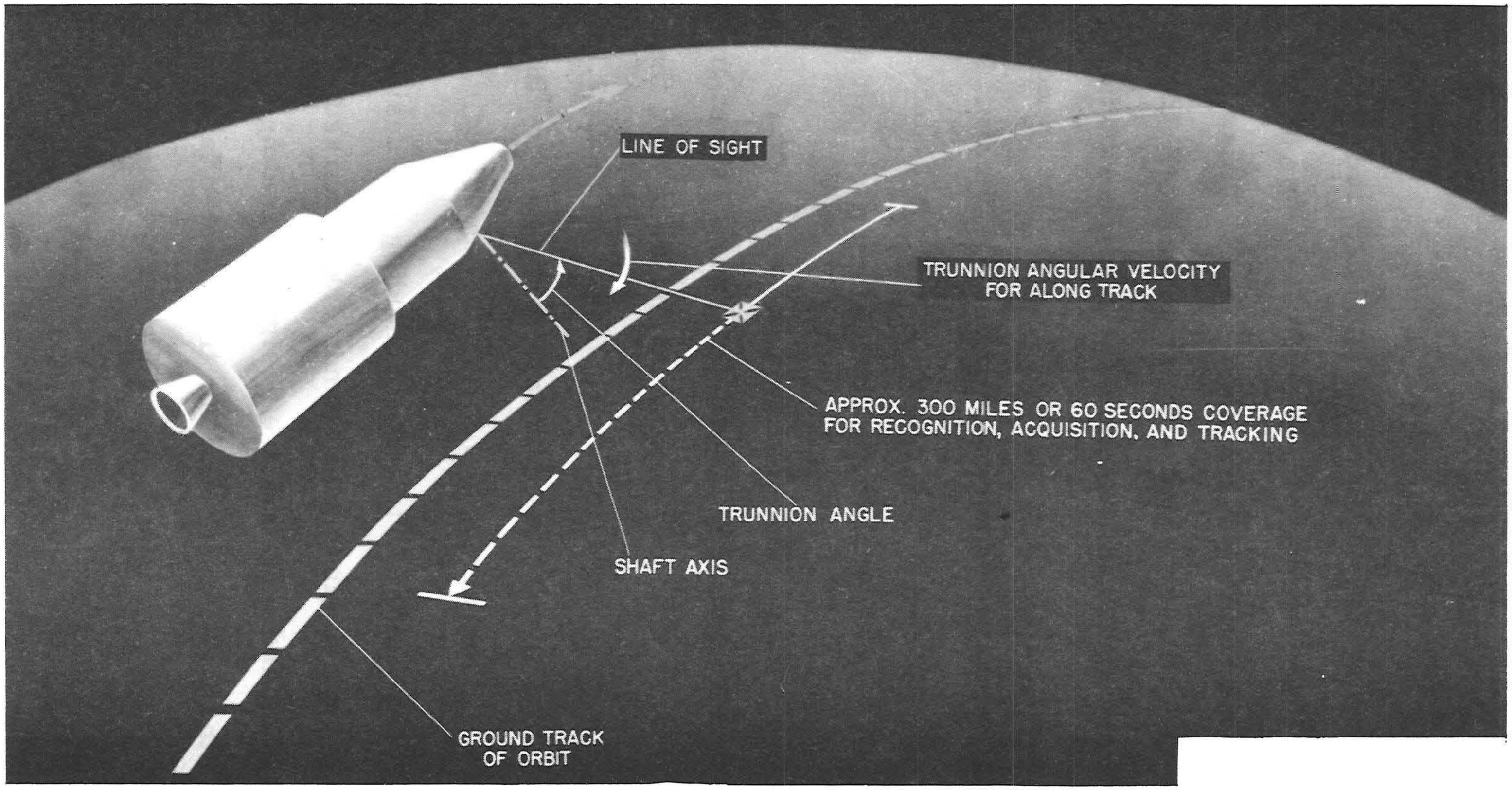


Fig. 5-20 Geometrical Aspects of a Landmark Navigational Measurement

5.2.3.10.1 Lunar Landmark Selection Routine (R35).

DELETED

5.2.3.10.2 Automatic Optics Positioning Routine (R52) (During Navigation). This routine (Fig. 5-22) is used to point the SXT star line of sight (SLOS) at a selected target (celestial body, landmark, or LM). The type of target is determined by the state of the target 1 and target 2 flags: target 1 set - LM, target 2 set - landmark, neither set - celestial body. If the routine was called by program P22, target 2 flag is set.

The CMC computes the line of sight vector to the target. If the required trunnion angle is excessive, it is displayed (if R53 has not yet been selected) and the navigator has the option of maneuvering the spacecraft so that the target can be automatically acquired, selecting a new target, or terminating the program and acquiring the target manually. In the first two cases the program recycles to an earlier point and recalculates the LOS vector to the target. When the required trunnion angle is acceptable the CMC drives the optics to alignment with the target. The navigator then sets the OPTICS MODE switch to MAN and the sighting mark routine (R53) is entered.

5.2.3.10.3 Sighting Mark Routine (R53). The sighting mark routine (Fig. 5-23) is used to perform the optical sighting marks on celestial bodies and landmarks. The program requires the navigator to move the optics manually until the target is centered in the optics (SXT for celestial bodies and unknown landmarks, SCT for known landmarks) and then to mark. If mark is unsatisfactory, DELETED

Fig. 5-21. Lunar Landmark Selection Routine (R35) (Sheet 1 of 2)

DELETED

Fig. 5-21. Lunar Landmark Selection Routine (R35) (Sheet 2 of 2)

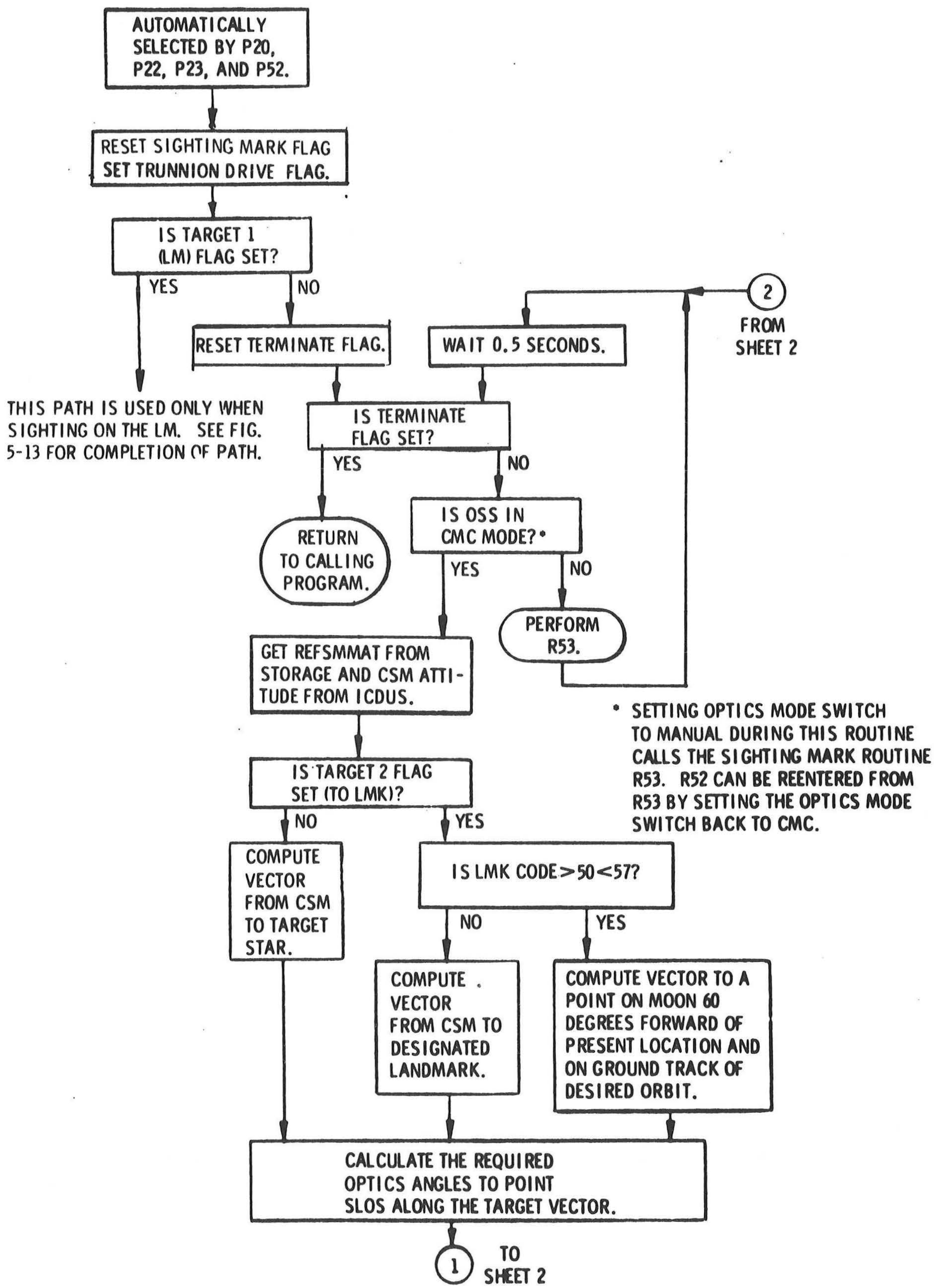


Fig. 5-22. Automatic Optics Positioning Routine (R52) (Navigation) (Sheet 1 of 2)

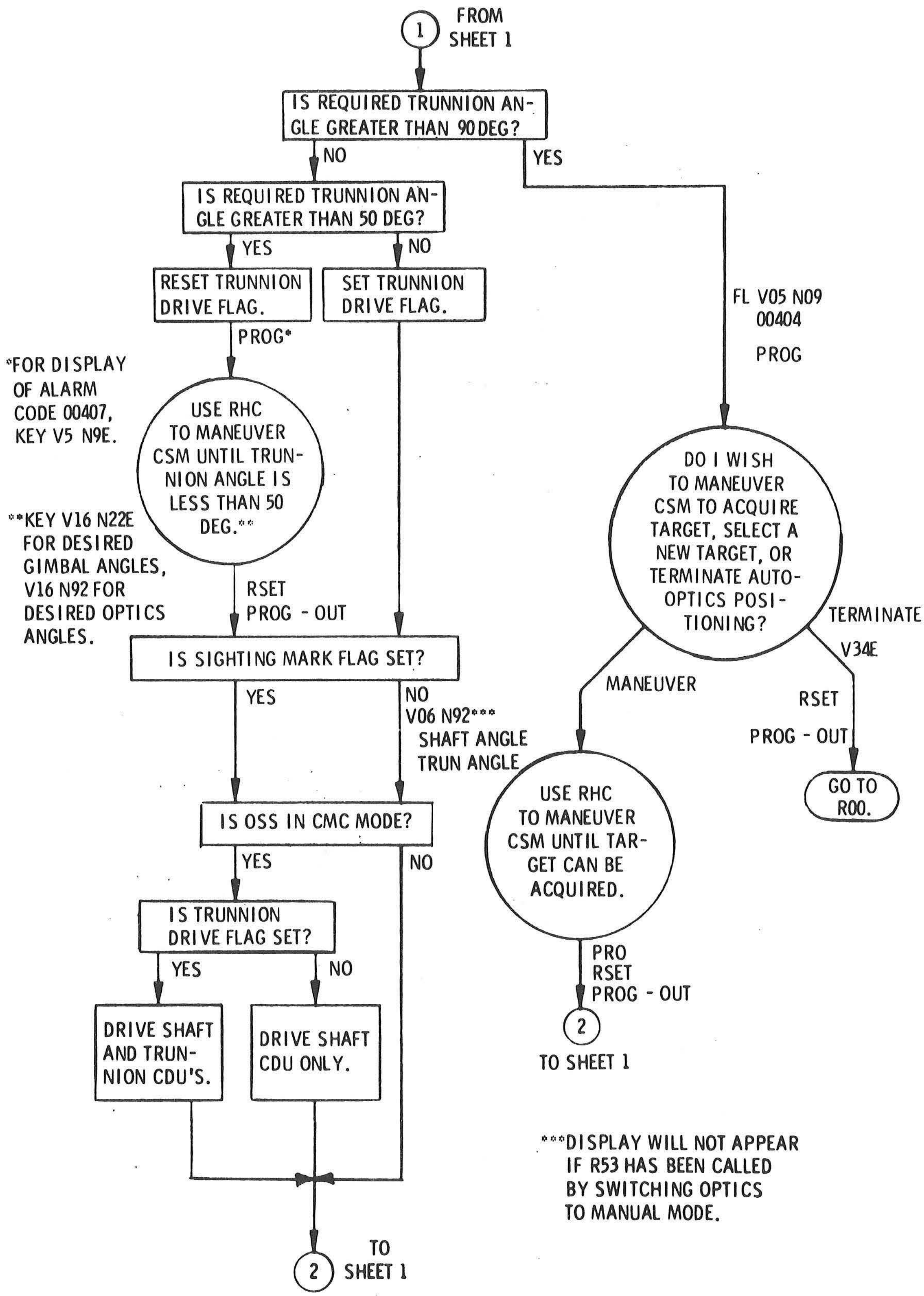


Fig. 5-22. Automatic Optics Positioning Routine (R52) (Navigation) (Sheet 2 of 2)

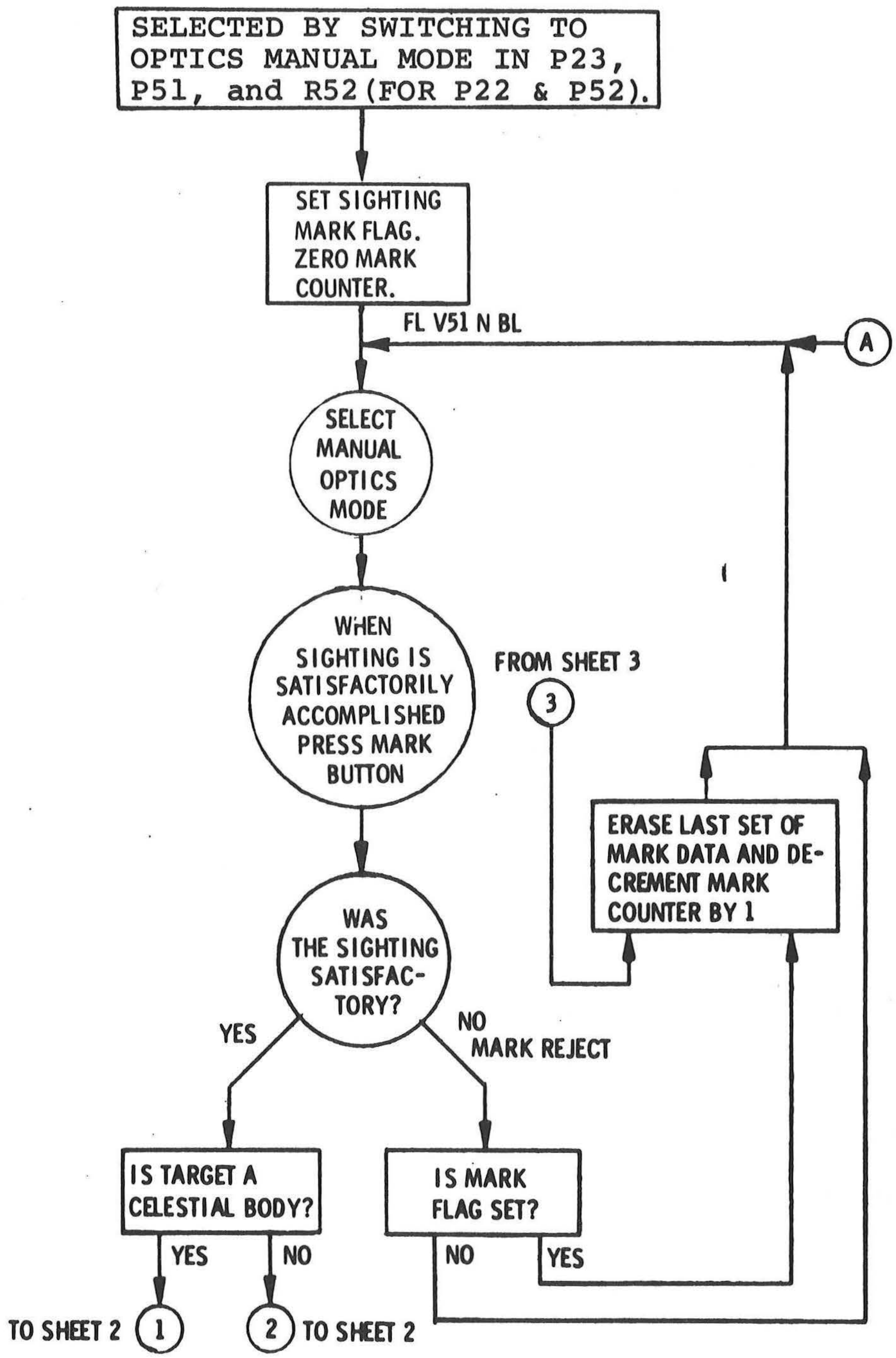


Fig. 5-23. Sighting Mark Routine (R53) (Sheet 1 of 3)

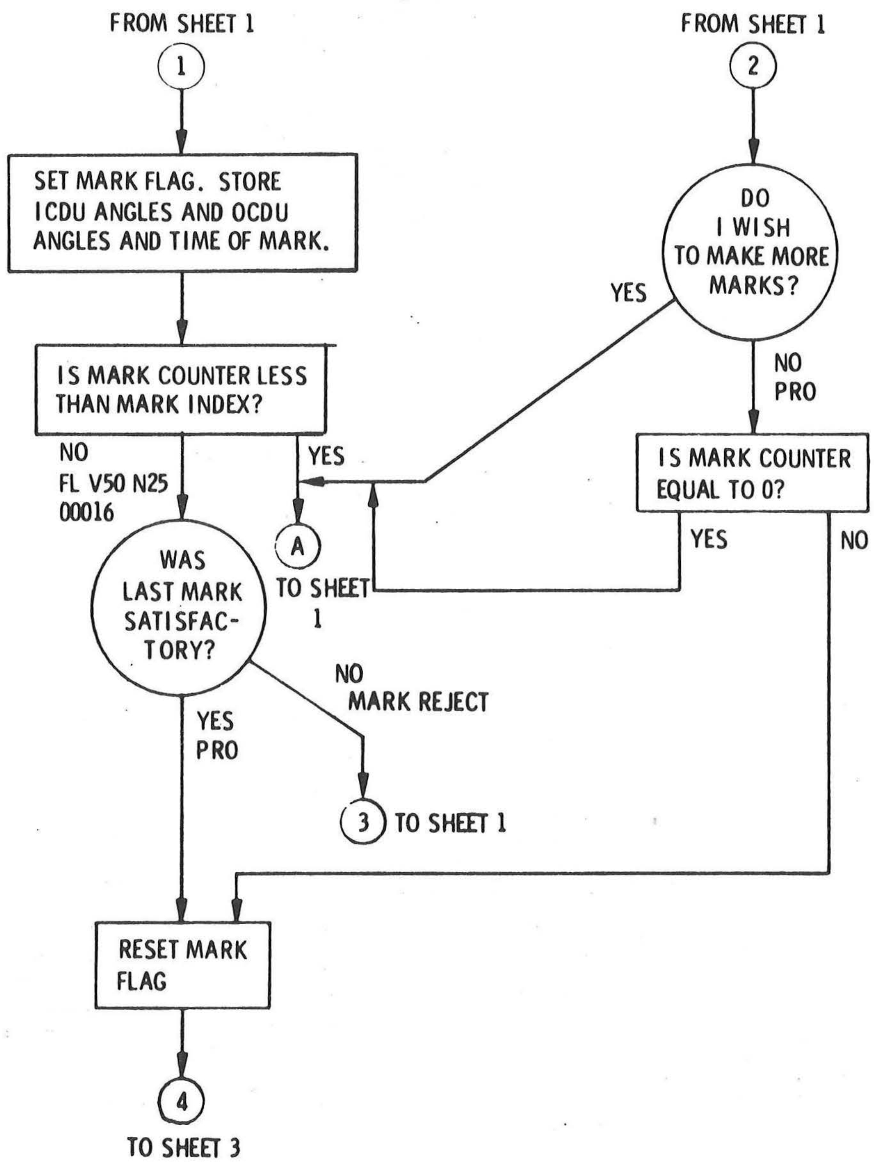


Fig. 5-23. Sighting Mark Routine (R53) (Sheet 2 of 3)

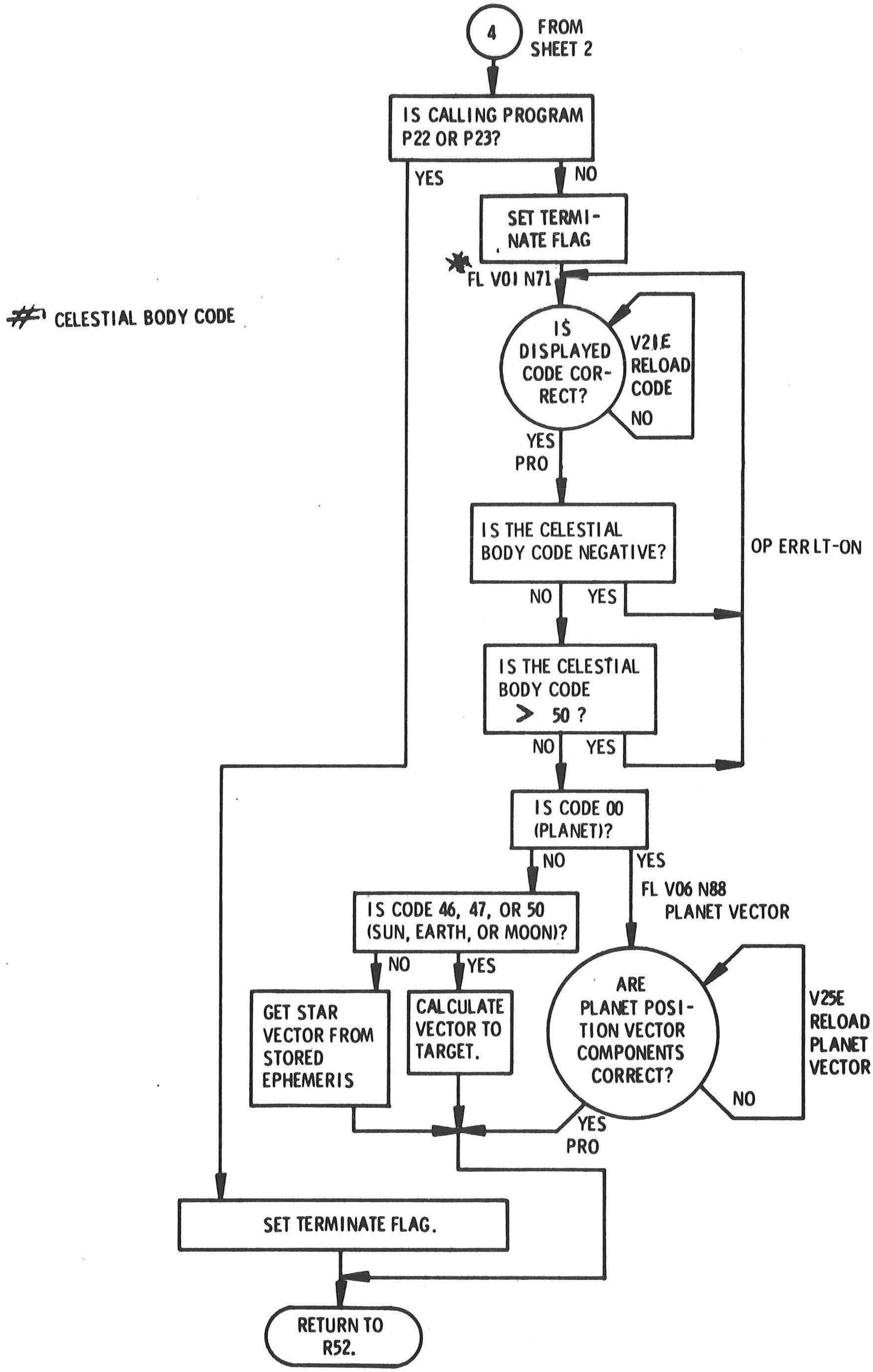


Fig. 5-23. Sighting Mark Routine (R53) (Sheet 3 of 3)

it may be rejected and the routine starts over. In P22 the mark index was set to 5 which allows a maximum of 5 landmark marks. Only one landmark can be used for a given set. For celestial bodies the index is 1, hence only one star mark may be made. The minimum number of marks required on landmarks is one for known and two for unknown. The CMC uses an averaging technique on landmark measurements, hence the more marks made the greater the accuracy. Upon completion of the routine the CMC returns to the calling program or routine.

5.2.3.11 Cislunar Midcourse Navigation Program (P23). The purpose of the cislunar midcourse navigation program (Fig. 5-24) is to provide a navigation fix during the midcourse phases of a lunar mission. This program consists of measuring the angle between a suitable star and an earth or lunar landmark or horizon. (Only the star-lunar landmark case is discussed here, the others are the same except that the correct name should be inserted where necessary.)

The program is entered manually by V37E 23E. The navigator may perform a calibration of the SXT if he wishes. If the REFSMMAT flag is not set, the optics calibration routine (R57) is immediately called, followed by the sighting mark routine. If the REFSMMAT flag is set, the target is identified and an option to do an attitude maneuver (R60) (paragraph 5.2.3.8.3) is provided before performing R57. After optics calibration, the automatic optics positioning and sighting mark routines (R52 and R53) are done (paragraph 5.2.3.10.2 and 3). After the start of R52 and before acceptance of the mark in R53, the astronaut has the option of recycling back to have the CMC aid in reacquiring the target. This is done by keying V94E (paragraph 5.2.3.38.27). After the sighting mark, the target is identified and the change in state vector is displayed for astronaut acceptance.

To make the navigation measurement, the lunar landmark is acquired by the SXT LLOS and the star by the SLOS. The spacecraft and SXT are then maneuvered

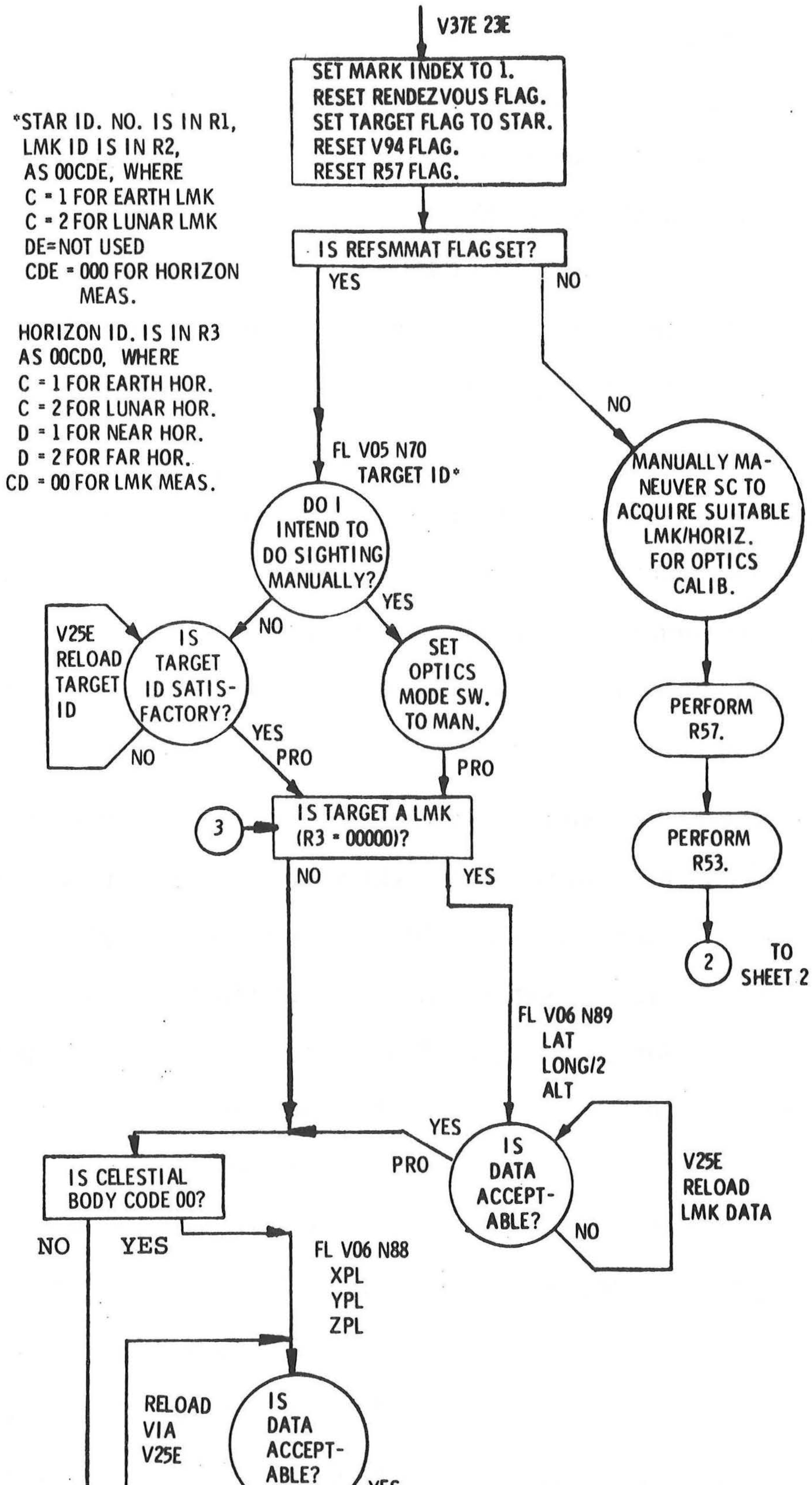


Fig. 5-24. Cislunar Navigation Program (P23) (Sheet 1 of 3)

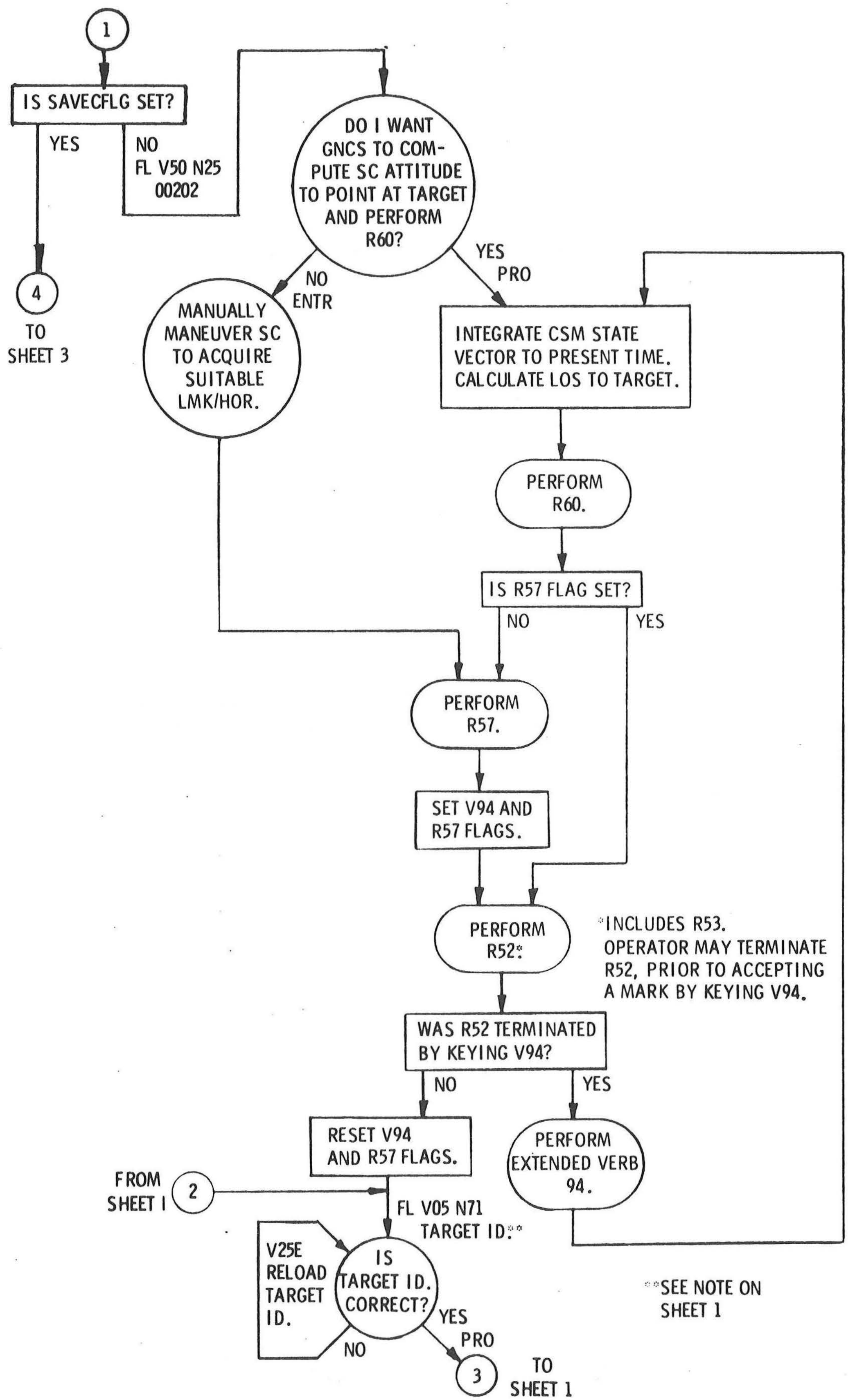


Fig. 5-24. Cislunar Navigation Program (P23) (Sheet 2 of 3)

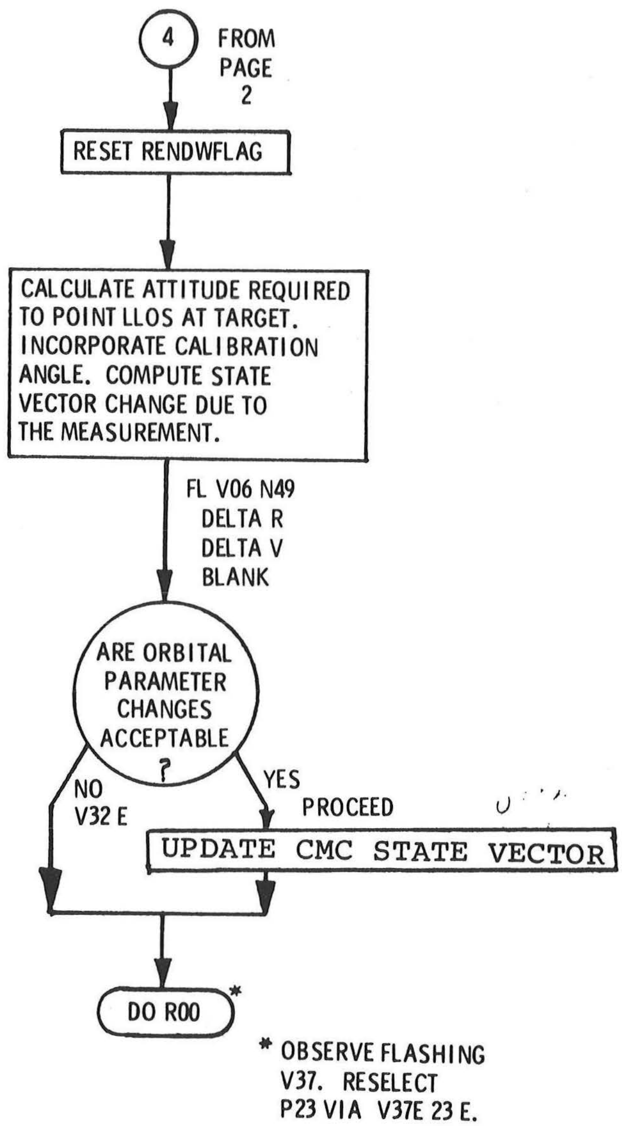


Fig. 5-24. Cislunar Navigation Program (P23) (Sheet 3 of 3)

to superimpose the two images as close to the center of the SXT as possible. A mark is then made. The CMC records the optics angles and the time of mark. The ISS need not be on.

The following is a geometric interpretation of the measurement. The recorded data defines a cone in space with the apex at the landmark (see Fig. 5-25). The cone axis is parallel to the SLOS and the half angle of the cone is equal to the measured star-landmark angle. For all points on the surface of the cone, the angle between the star and landmark is the same. Therefore, one sighting defines the spacecraft position as being on the surface of the cone. If no prior knowledge of position or velocity were available, a measurement to a different star would be needed to define the spacecraft position along the intersection of the two cones. However, prior position and velocity data is available.

The spacecraft is moving in accordance with established laws of dynamics; therefore, departure from a reference is small enough to permit linear reduction of the problem by a "running fix" technique. This technique eliminates dependence on a reference trajectory. Instead, it consists of updating the velocity and position information with each succeeding optical measurement. At the time of translunar or transearth injection the CMC has stored velocity and position, calculated from inertial measurements and gravitational field data. When a navigation measurement is made, the estimated velocity and position information is used with the landmark and star coordinates to predict the angle that should be measured. Weighting factors are applied to the estimated and measured angles and their difference is used to update the estimated values for the next measurement and for use in midcourse correction maneuvers.

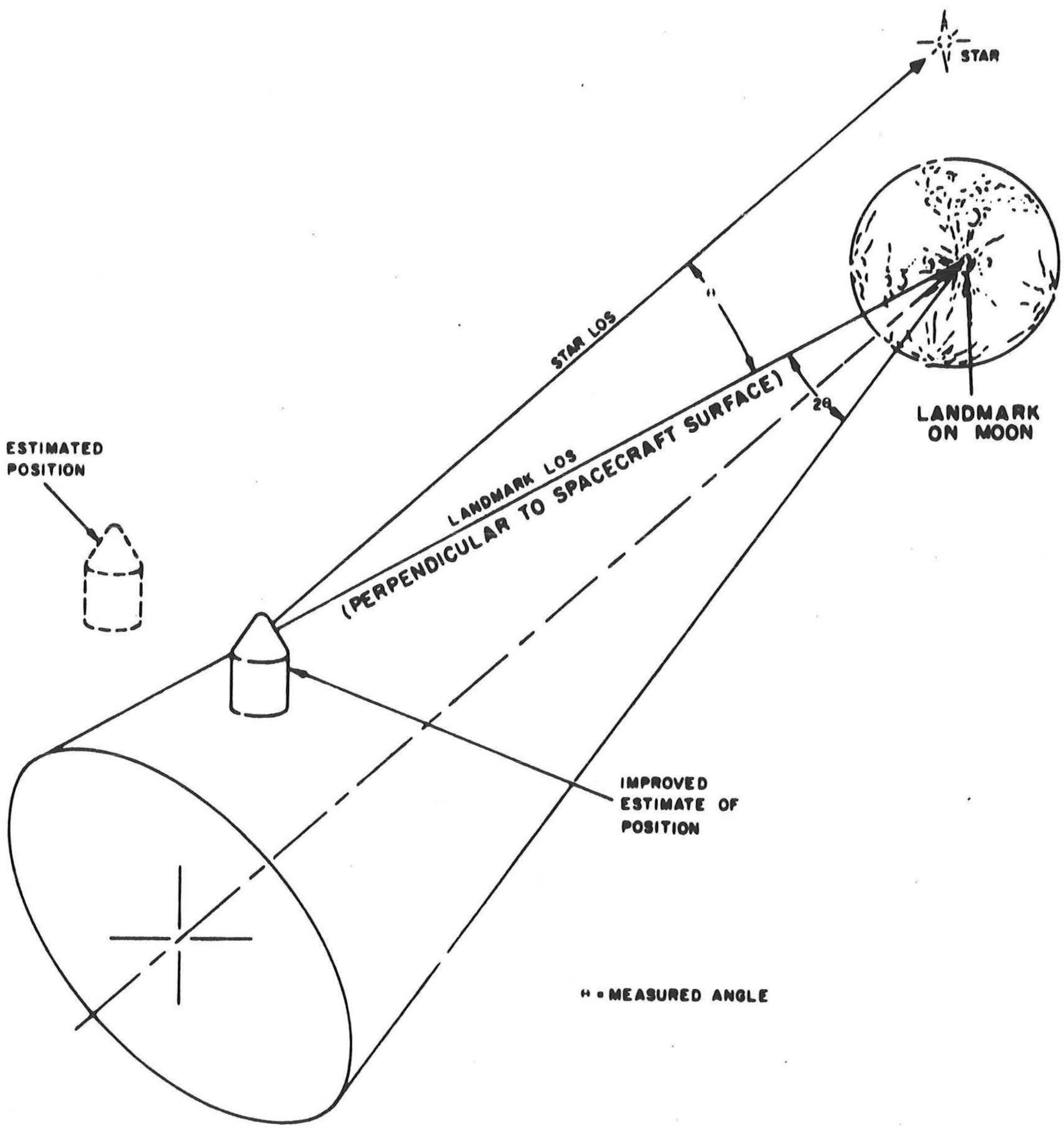


Fig. 5-25 Geometrical Aspects of a Star-Landmark Navigational Measurement

5.2.3.11.1 Optics Calibration Routine (R57). This routine (Fig. 5-26) is entered automatically from P23. The calibration is done by superimposing the SXT LLOS and SLOS on the same target and measuring the trunnion angle. It should be zero, any non-zero reading constitutes a calibration bias. When the bias is displayed, the astronaut may either accept it or redo the calibration. After acceptance, the bias is stored and used in navigation measurements in P23.

5.2.3.12 CMC Update Program (P27)

The purpose of the CMC update program (Fig. 5-27) is to insert update data into the CMC by digital uplink or by DSKY entry. Entry into the program for crew update is by DSKY entry of one of four verbs which designate the type of update. These are:

V70E - Update CMC liftoff time.

V71E - Load a block of sequential erasable locations (1 through 18 locations) whose addresses are specified.

V72E - Load a single erasable location (1 through 9 individually specified locations).

V73E - Octal increment of CMC clock only.

Entry by digital uplink is by the same verbs; however, the crew must have the UP TEL switches for both DSKY's set to ACCEPT. Figure 5-26 shows the logic for manual update. The uplink is the same except that the astronaut functions are performed from the ground.

If a load is verified as correct, a PRO is keyed and the CMC transfers the load for computation. If the contents of one or more registers are in error, V34E may be keyed to terminate or the octal identifier of the register in error may be keyed in and its contents reloaded. This latter procedure may be repeated

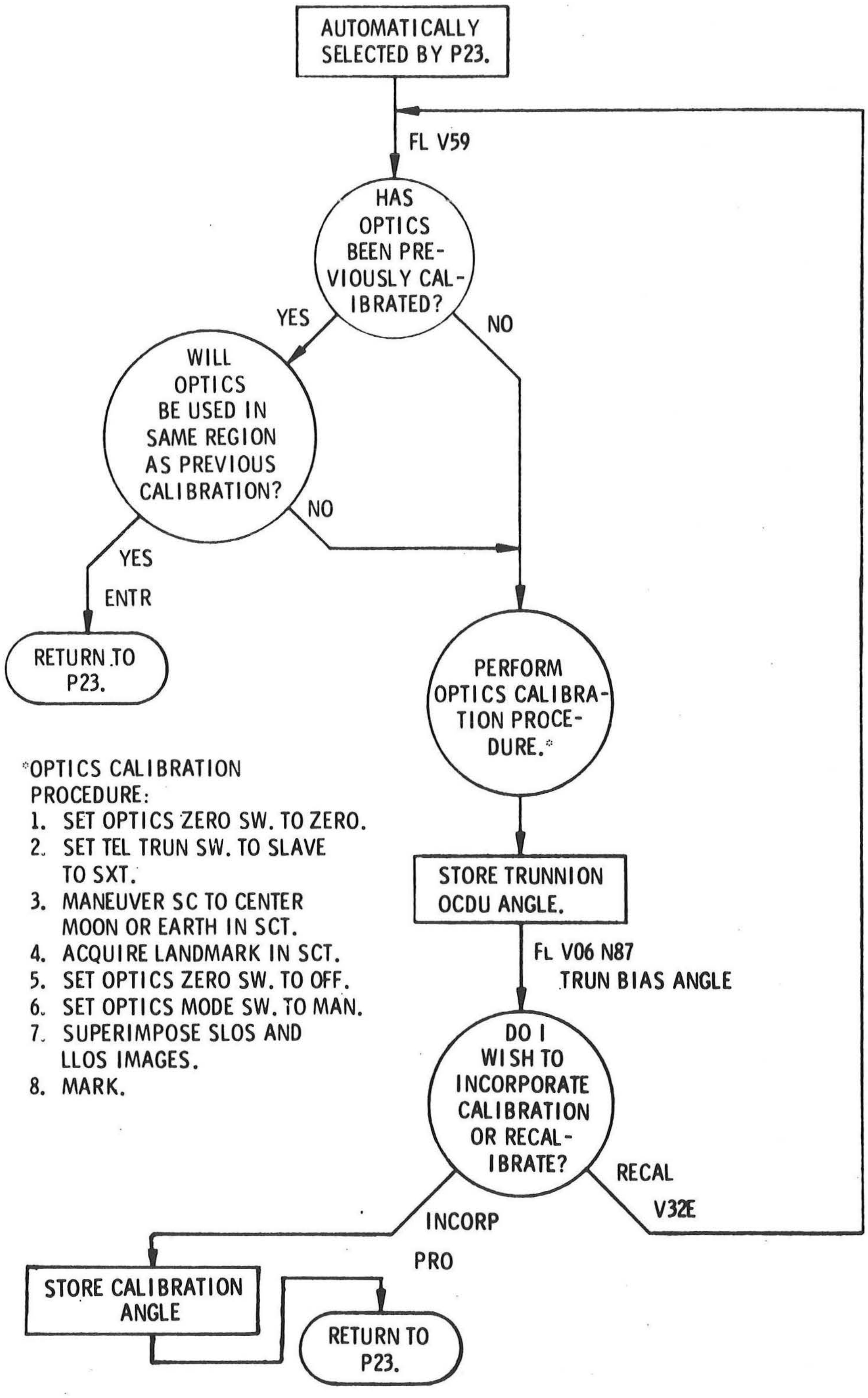


Fig. 5-26. Optics Calibration Routine (R57)

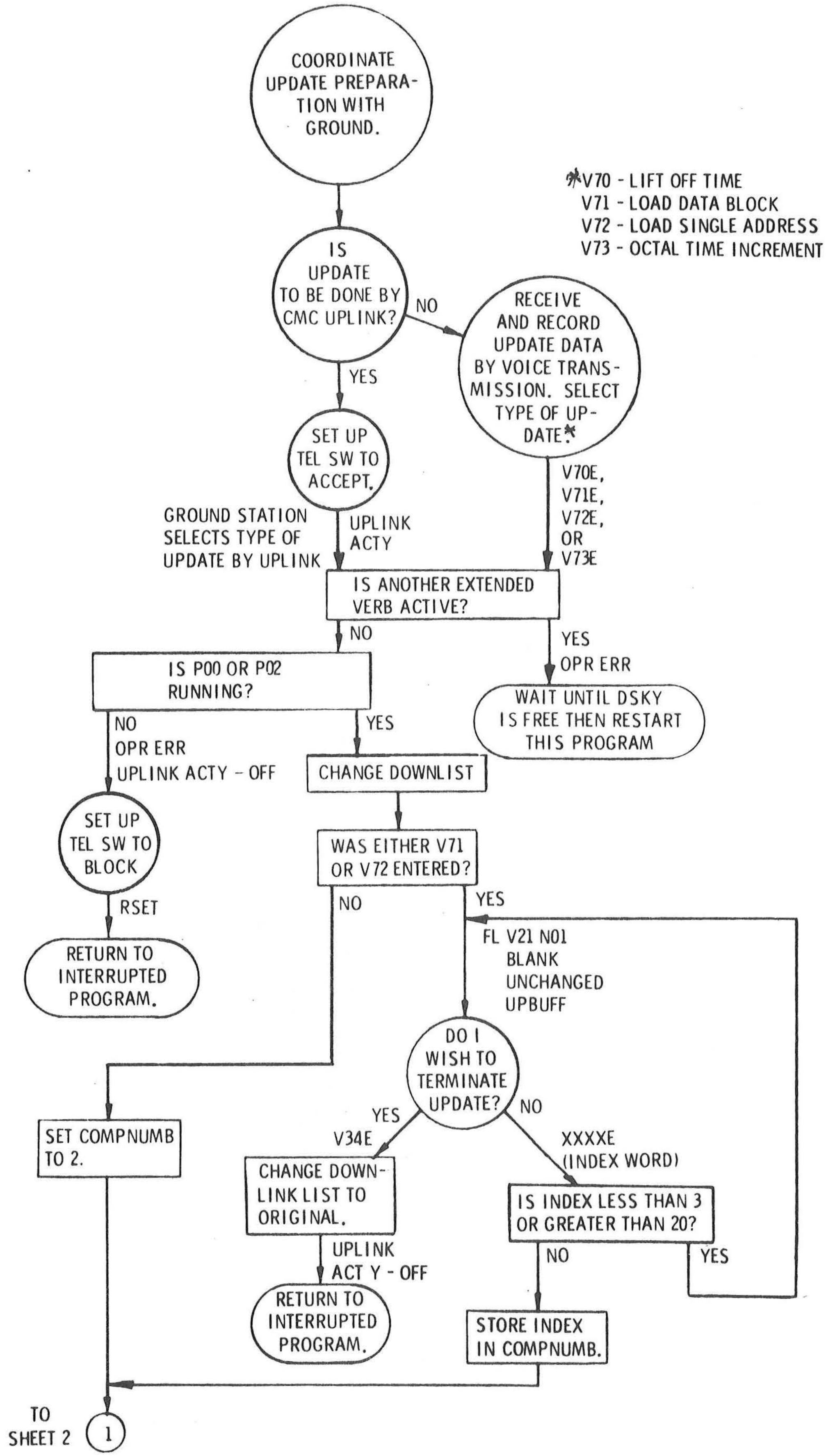


Fig. 5-27. CMC Update Program (P27) (Sheet 1 of 3)

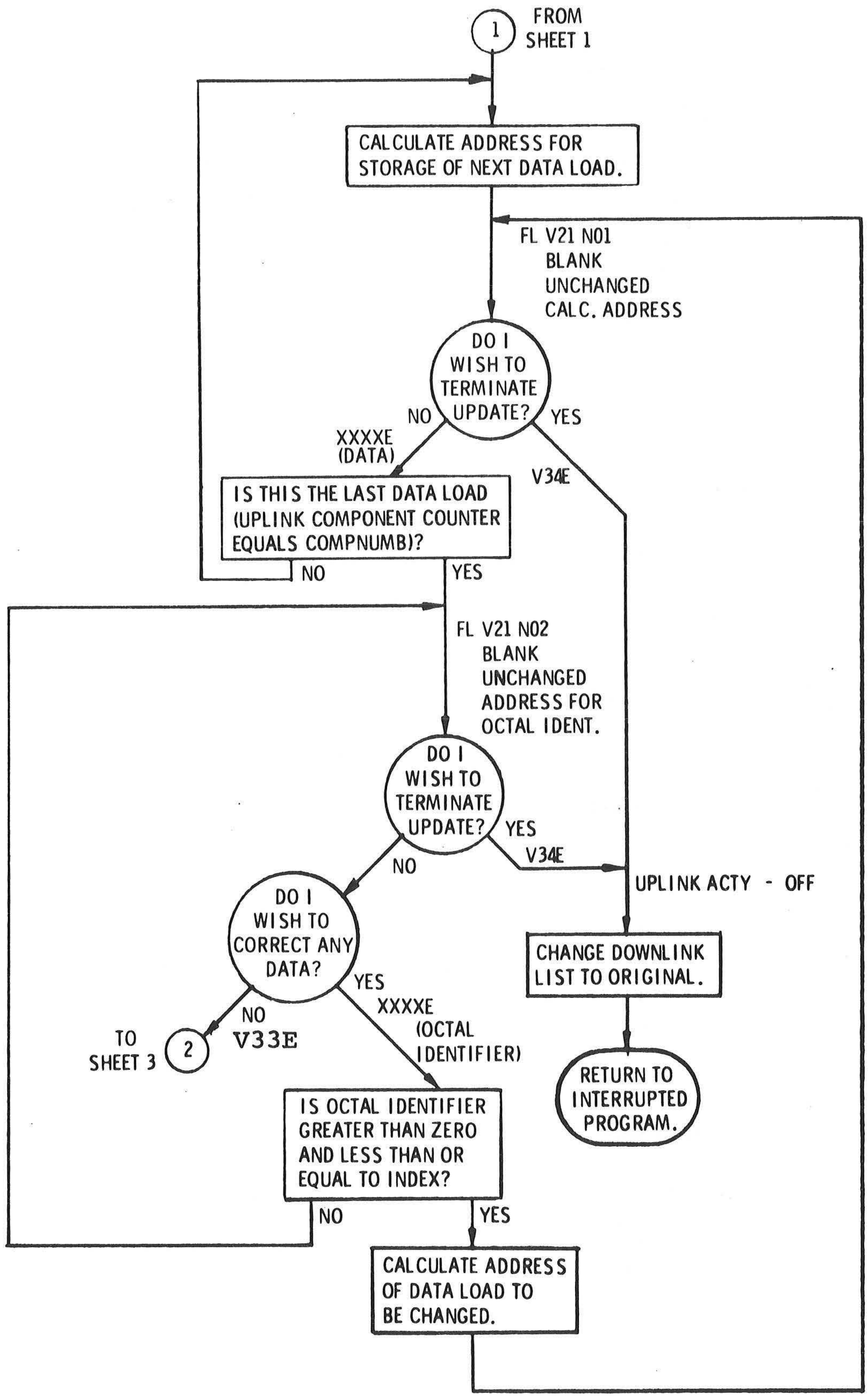


Fig. 5-27. CMC Update Program (P27) (Sheet 2 of 3)

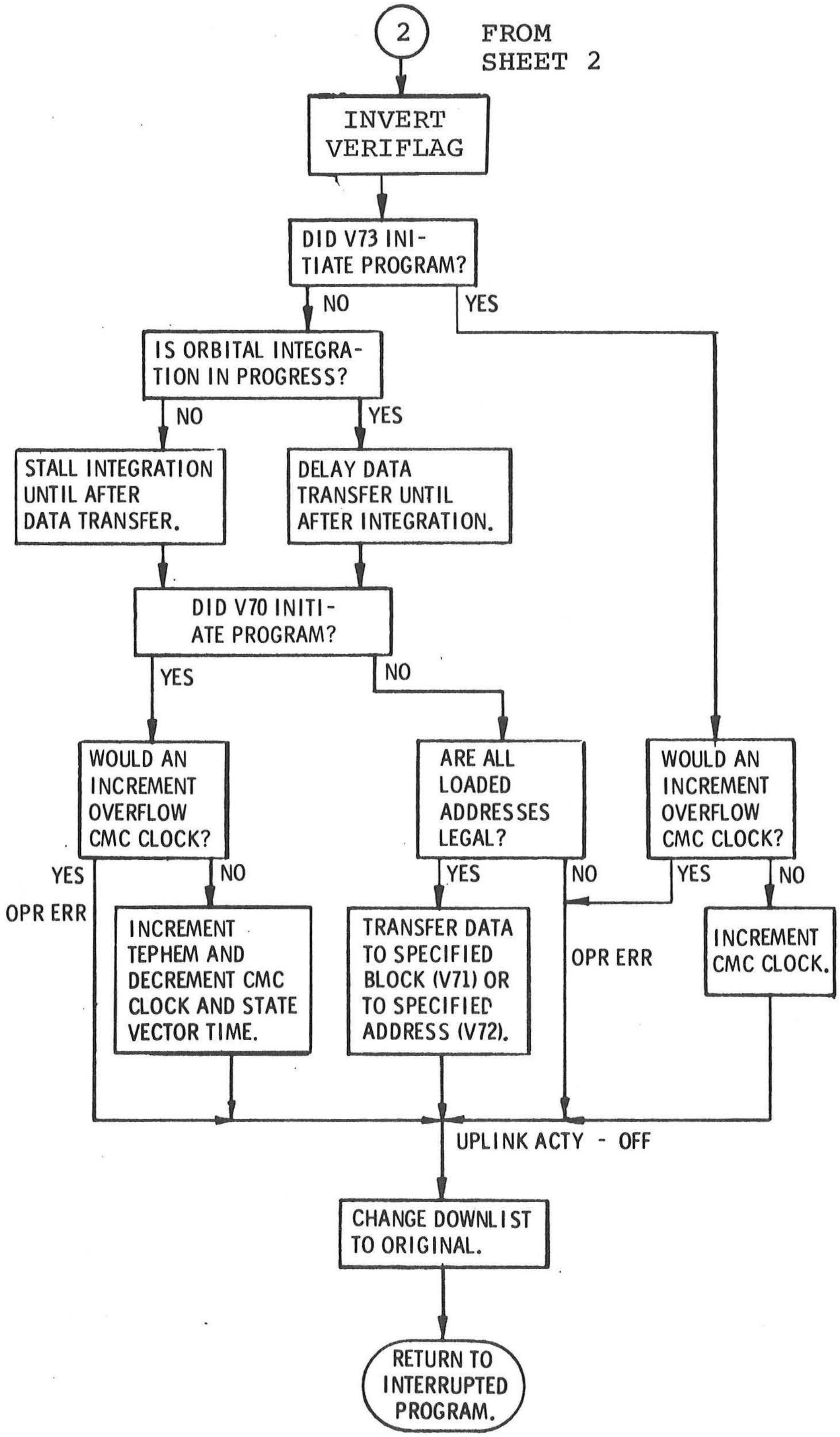


Fig. 5-27. CMC Update Program (P27) (Sheet 3 of 3)

any number of times until all registers are correctly loaded; then PRO is keyed. With automatic update the procedure is the same, except load verification is made by digital downlink.

Following are examples of the use of V71 and V72 updates.

V71 is used to load a sequence of erasable locations; therefore, only the address (ECADR) of the first location is keyed. The ECADR is automatically incremented after each data load. The following example is for state vector update.

Octal Identifier		
1	21E	(index number)
2	AAAAE	(ECADR - address of state vector first component)
3	XXXXXE	(vehicle identifier, CSM or LM)
4	XXXXXE	(most sig. part of X component of position)
5	XXXXXE	(least sig. part of X component of position)
6	XXXXXE	(most sig. part of Y component of position)
7	XXXXXE	(least sig. part of Y component of position)
10_8	XXXXXE	(most sig. part of Z component of position)
11_8	XXXXXE	(least sig. part of Z component of position)
12_8	XXXXXE	(most sig. part of X component of velocity)
13_8	XXXXXE	(least sig. part of X component of velocity)
14_8	XXXXXE	(most sig. part of Y component of velocity)
15_8	XXXXXE	(least sig. part of Y component of velocity)
16_8	XXXXXE	(most sig. part of Z component of velocity)
17_8	XXXXXE	(least sig. part of Z component of velocity)
20_8	XXXXXE	(most sig. part of time)
21_8	XXXXXE	(least sig. part of time)

V72 is used for nonsequential addresses. An ECADR must be loaded for each data load, as shown in the following example.

Octal Identifier		
1	XXE	(index number)
2	AAAAE	(ECADR*)
3	XXXXXE	(first data load)
4	AAAE	(ECADR*)
5	XXXXXE	(second data load)
6	AAAE	(ECADR*)
7	XXXXXE	(third data load)
.	.	.
.	.	.
etc.		
.	.	.
.	.	.
.	.	.
22_8	AAAAE	(ECADR*)
23_8	XXXXXE	(ninth data load) (maximum possible number of loads, loading may be terminated after any lesser number)

*Address of following data word.

5.2.3.13 External Delta V Program (P30)

The purpose of the external delta V program (Fig. 5-28) is to accept targeting parameters from a source outside the CMC and calculate from

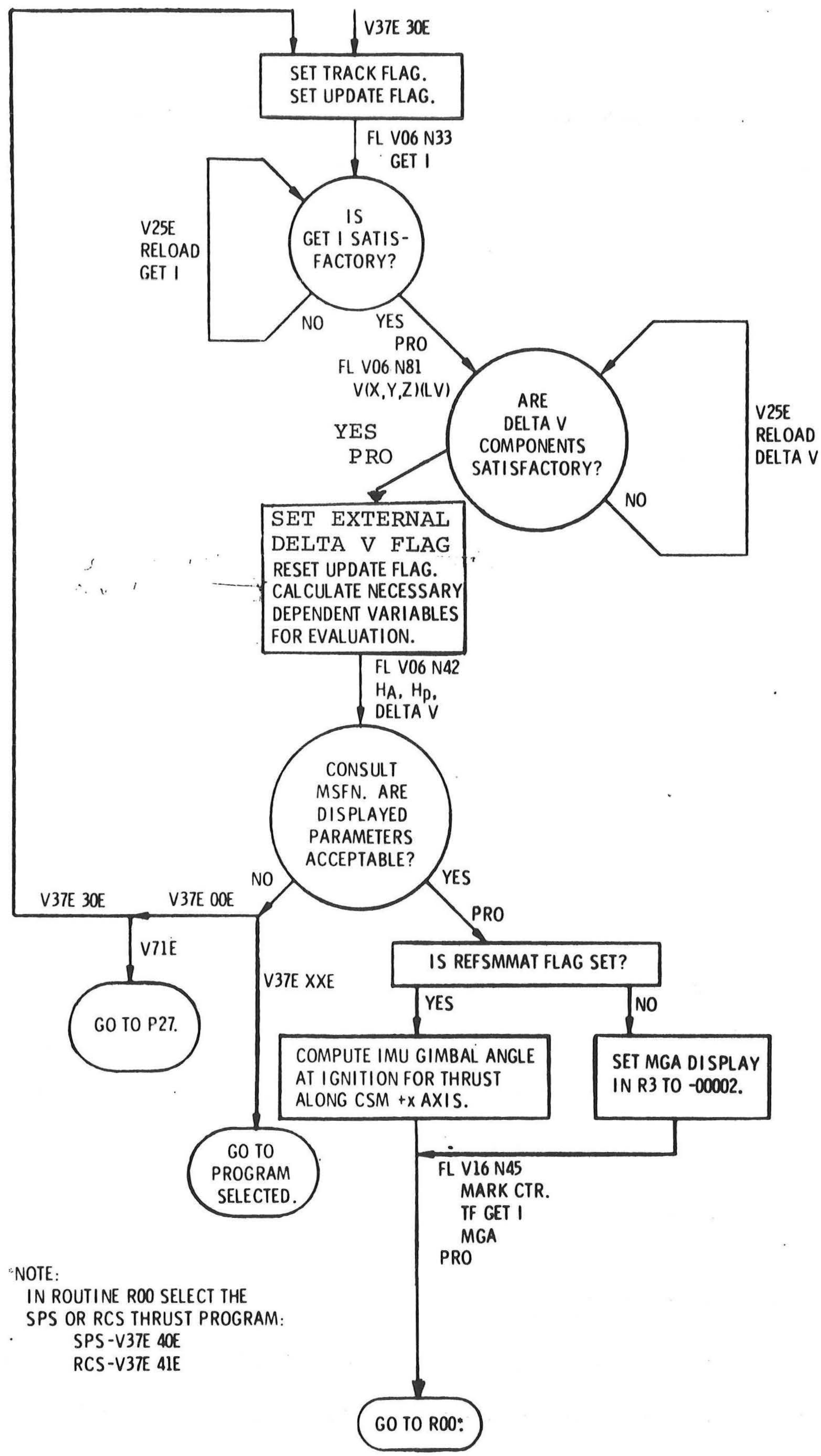


Fig. 5-28. External Delta V Program (P30)

them the required velocity and other initial conditions for execution of the desired delta V maneuver. The parameters loaded are the time of ignition and the impulsive delta V along CSM local vertical axes at time of ignition. From these parameters the CSM computes and displays apogee and perigee altitudes, number of marks processed by R22, time to ignition, and IMU middle gimbal angle at ignition. The targeting parameters may have been previously loaded by P27 or by DSKY entry.

5.2.3.14 Lambert Aim Point Guidance Program (P31)

The purpose of the Lambert aim point guidance program (Fig. 5-29) is to accept targeting parameters from a source outside the CMC and calculate from them the required velocity and other initial conditions for execution of the desired Lambert steering maneuver. The parameters loaded are: the time of ignition, ECSTEER (cross product steering constant), target vector, and time from ignition until target is reached. These are loaded from the ground by a prior performance of P27. From these parameters the CMC computes and displays apogee and perigee altitudes, number of marks processed by R22, time to ignition, and IMU middle gimbal angle at ignition.

5.2.3.14A. Co-Elliptic Sequence Initiation (CSI) Program (P32)

The purpose of (P32) is to calculate parameters associated with the following concentric flight plan maneuvers: the CSI and CDH maneuvers, for delta V burns. These parameters are based upon maneuver data approved and keyed into the CMC by the astronaut. This program (Fig. 5-29A) stores the CSI target parameters for use by the desired thrusting program. This program is selected by DSKY entry (V37E 32E).

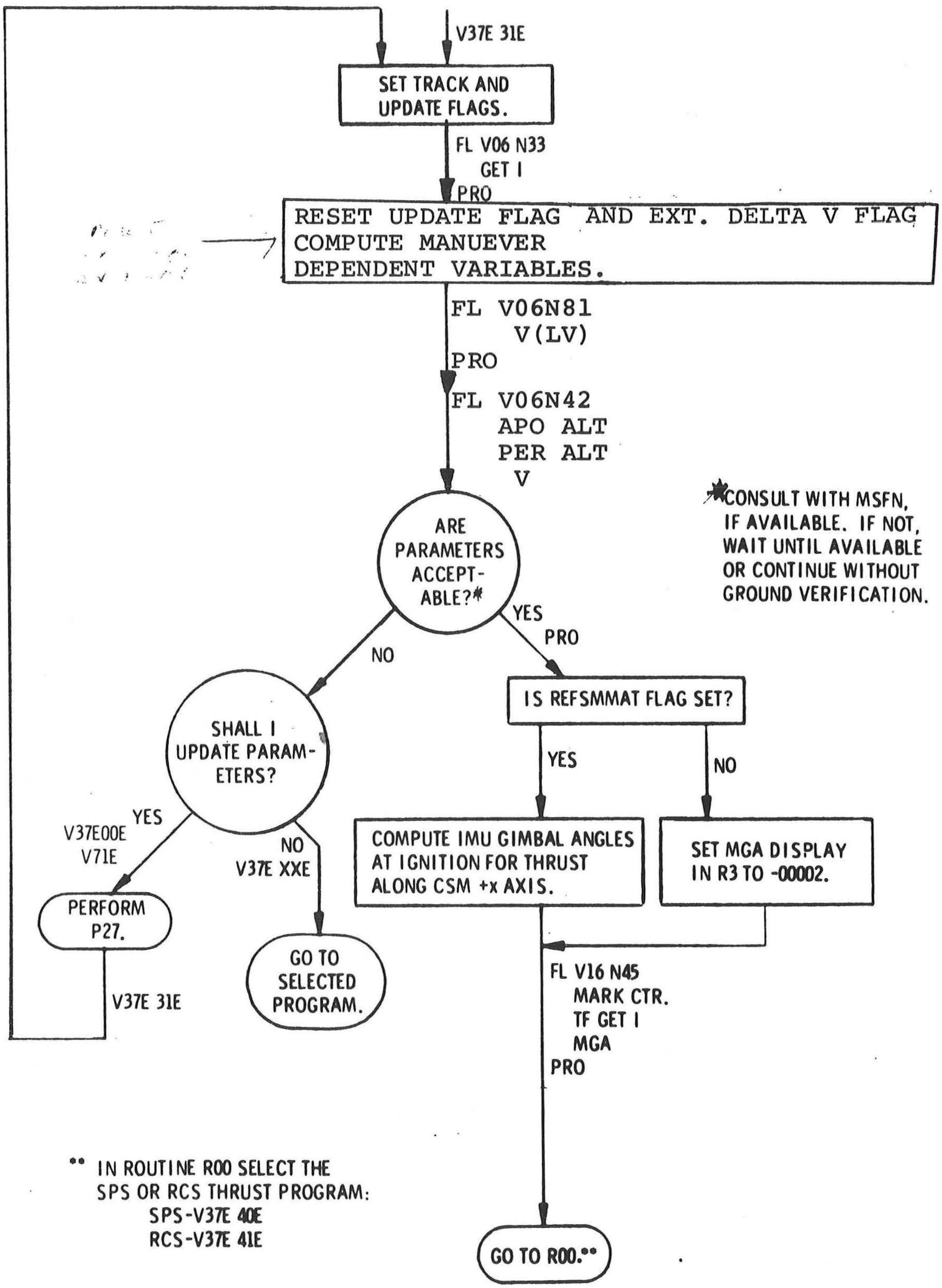


Fig. 5-29. Lambert Aimpoint Guidance Program (P31)

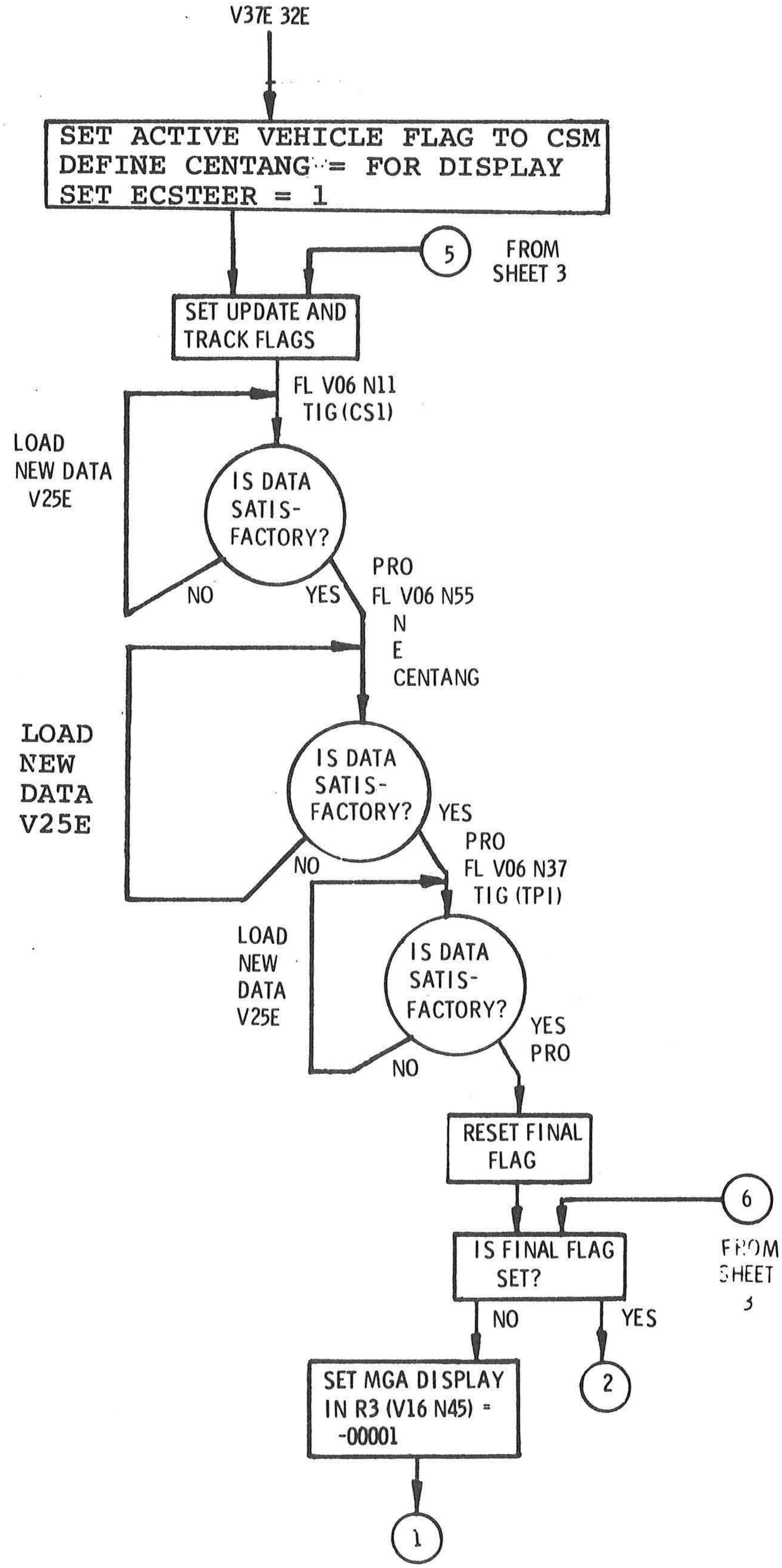


Fig. 5-29A. Co-Elliptic Sequence Initiation (CSI) (P32) (Sheet 1 of 3)

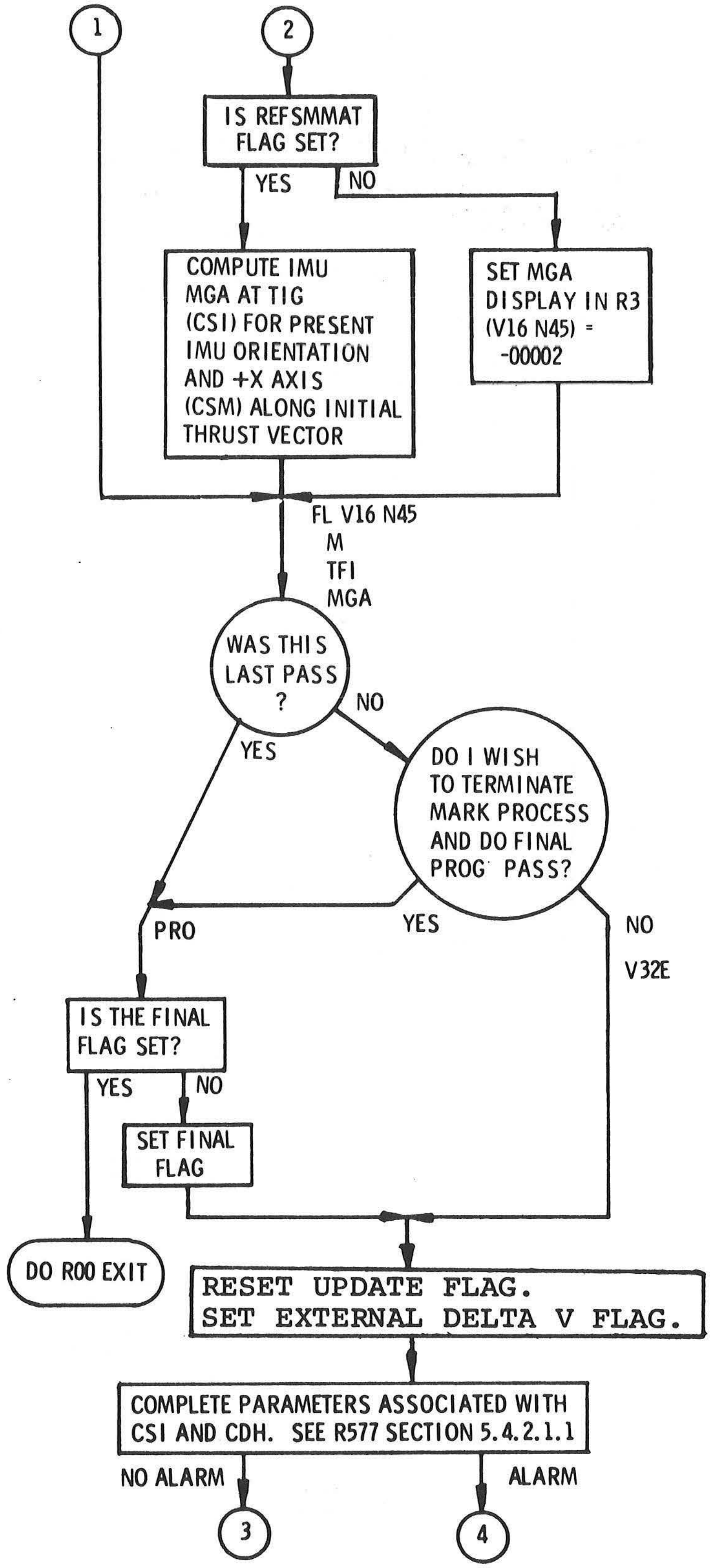


Fig. 29A. Co-Elliptic Sequence Initiation (CSI) (P32) Sheet 2 of 3)

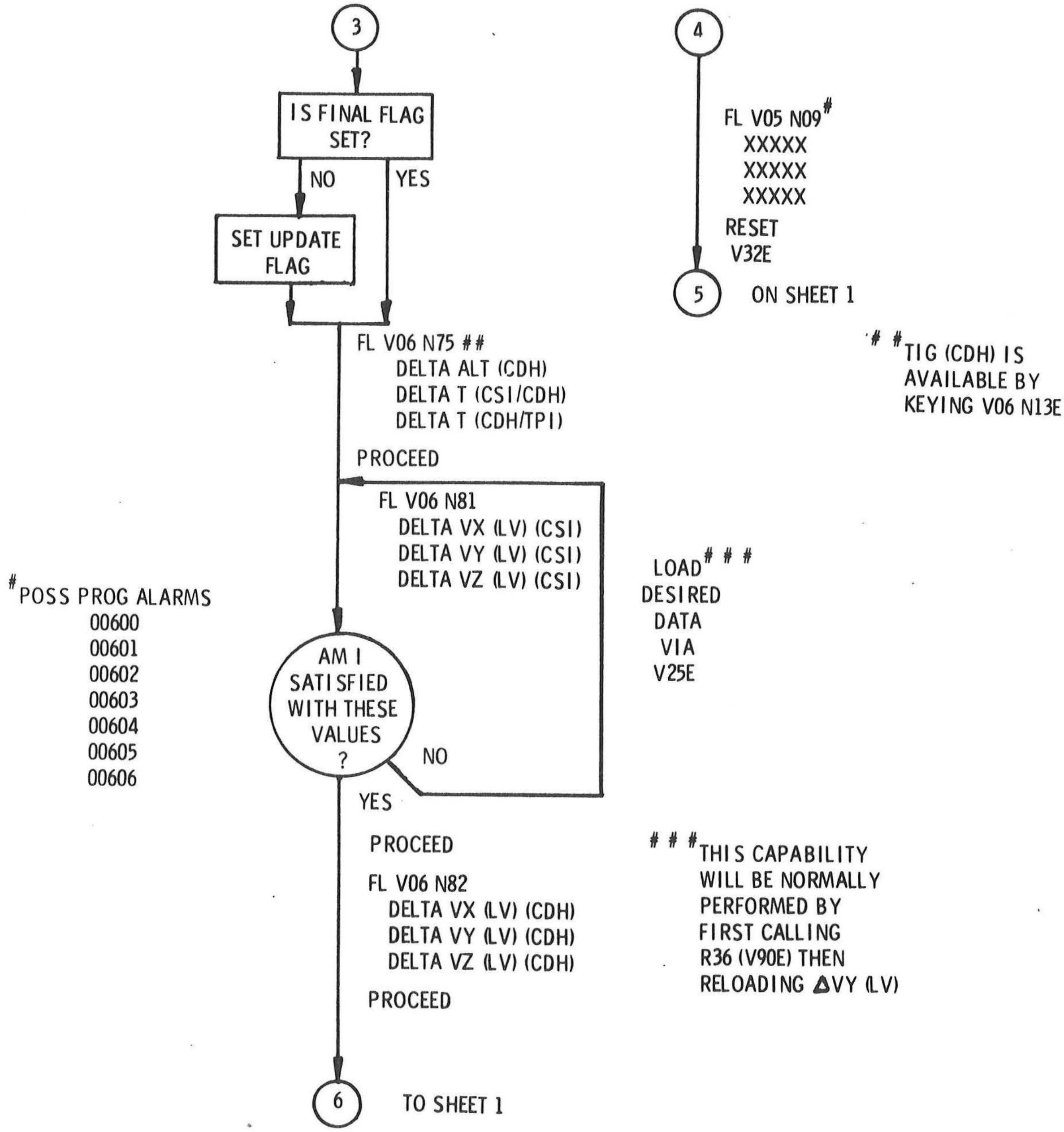


Fig. 29A. Co-Elliptic Sequence Initiation (CSI) (P32) (Sheet 3 of 3)

5.2.3.14B Constant Delta Altitude (CDH) Program (P33)

The purpose of this program (fig. 5-29B) is to calculate parameters associated with the Constant Delta Altitude Maneuver, for delta V burns. These parameters are based upon maneuver data approved and keyed into the DSKY by the astronaut. It also stores the CDH target parameters for use by the desired thrusting program. The program is selected manually by DSKY entry (V37E 33E).

5.2.3.15 Transfer Phase Initiation Program (P34)

The transfer phase initiation program (Fig. 5-30) calculates the required delta V and other initial conditions required by the CMC for CSM execution of the TPI maneuver, given the time of ignition (GET I (TPI)) or the elevation angle (E) of the CSM/LM LOS at GET I (TPI), and the central angle of transfer (centang) from GET I (TPI) to intercept time. The program calculates E when given GET I (TPI), and GET I (TPI) when given E. The parameters are calculated based on data approved and keyed into the DSKY by the astronaut.

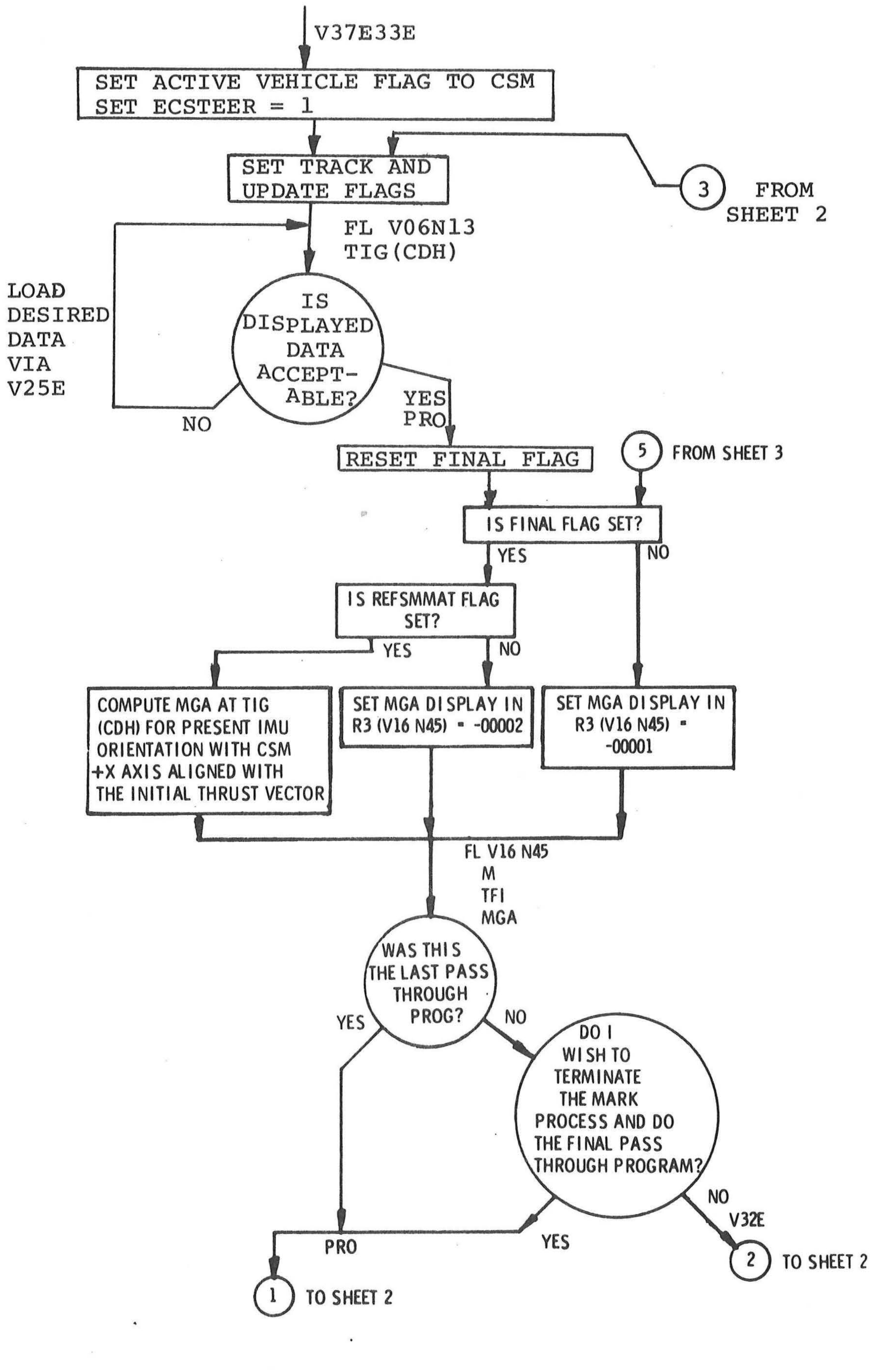


Fig. 5-29B. Constant Delta Altitude (CDH) Program (P33) (Sheet 1 of 3)

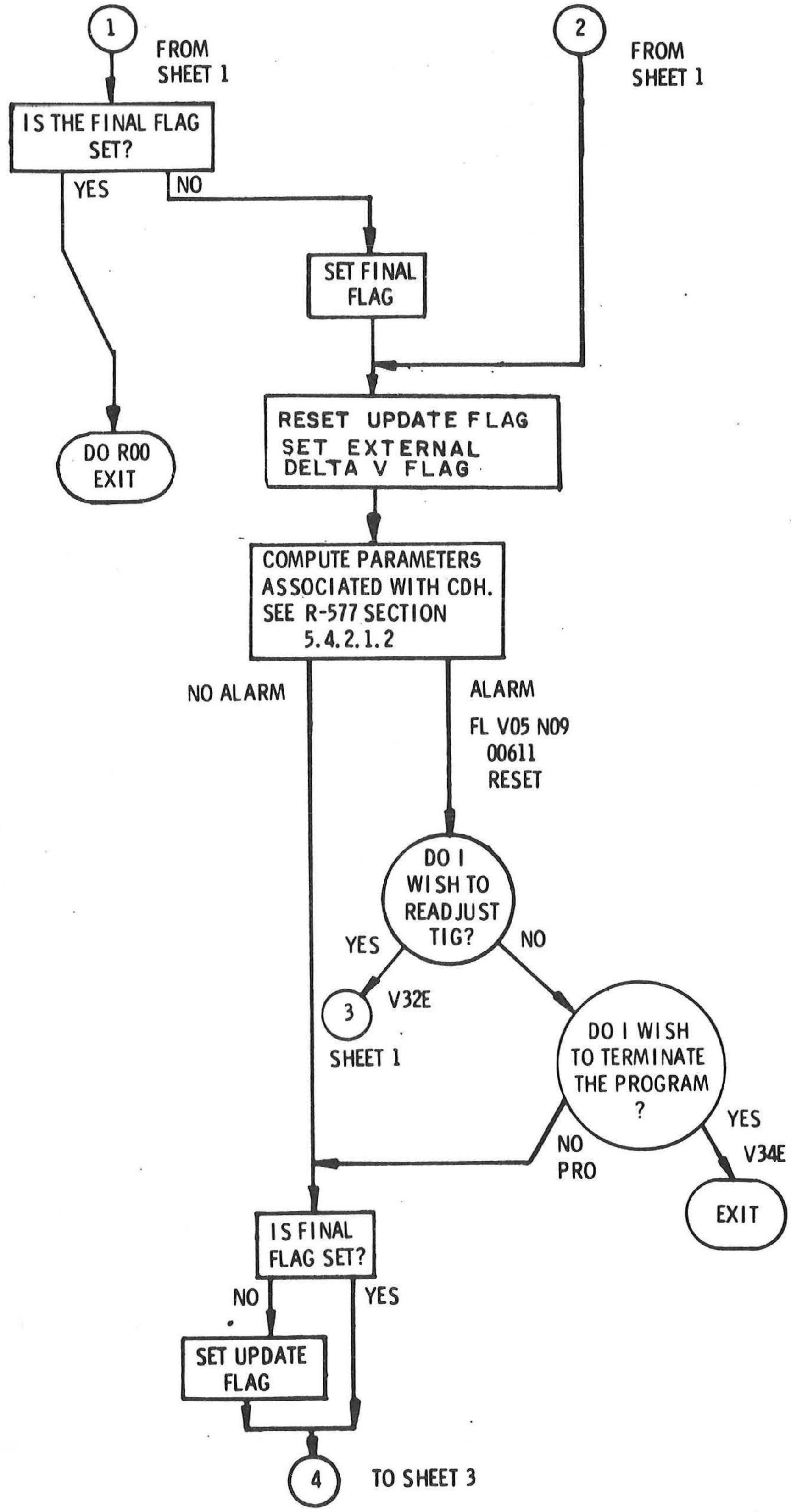
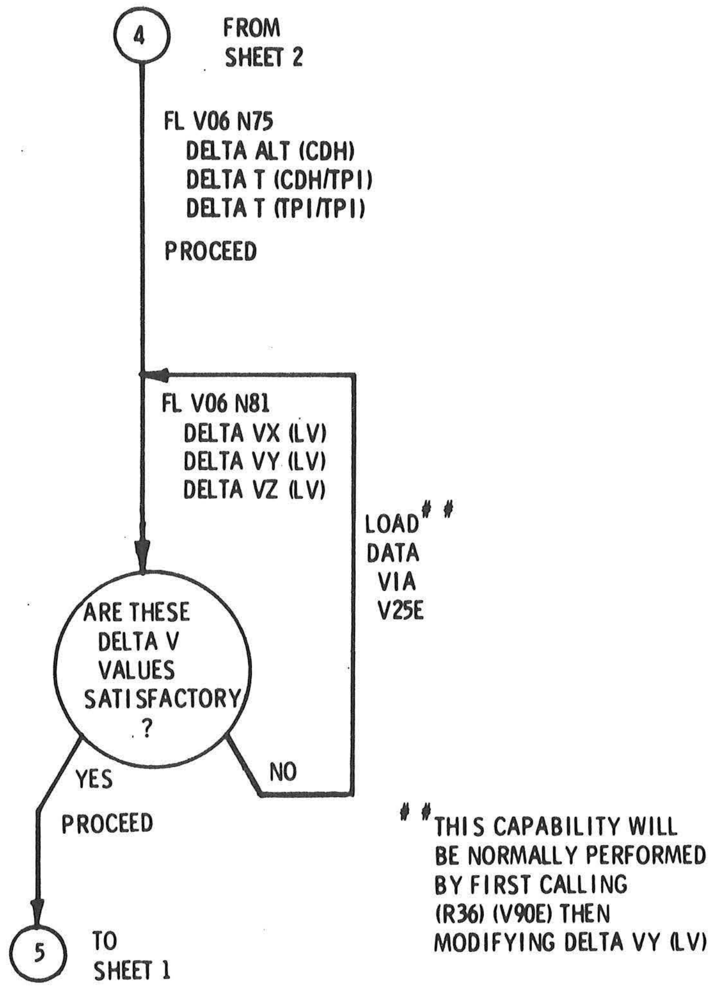


Fig. 5-29B. Constant Delta Altitude (CDH) Program (P33) (Sheet 2 of 3)



NOTE: GETI (TPI) AVAILABLE VIA N37.

Fig. 5-29B. Constant Delta Altitude (CDH) Program (P33) (Sheet 3 of 3)

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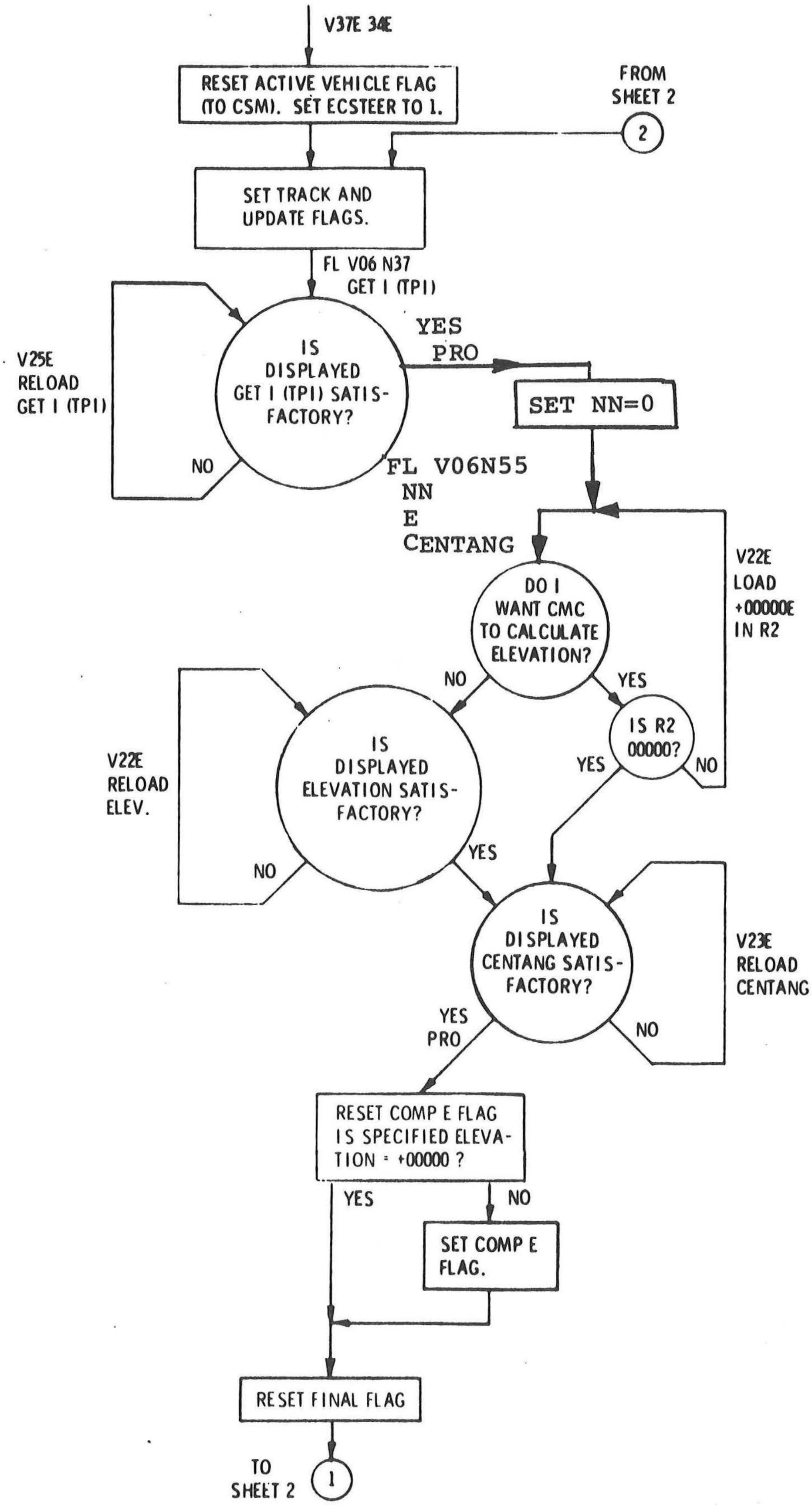


Fig. 5-30. Transfer Phase Initiation Program (P34) (Sheet 1 of 3)

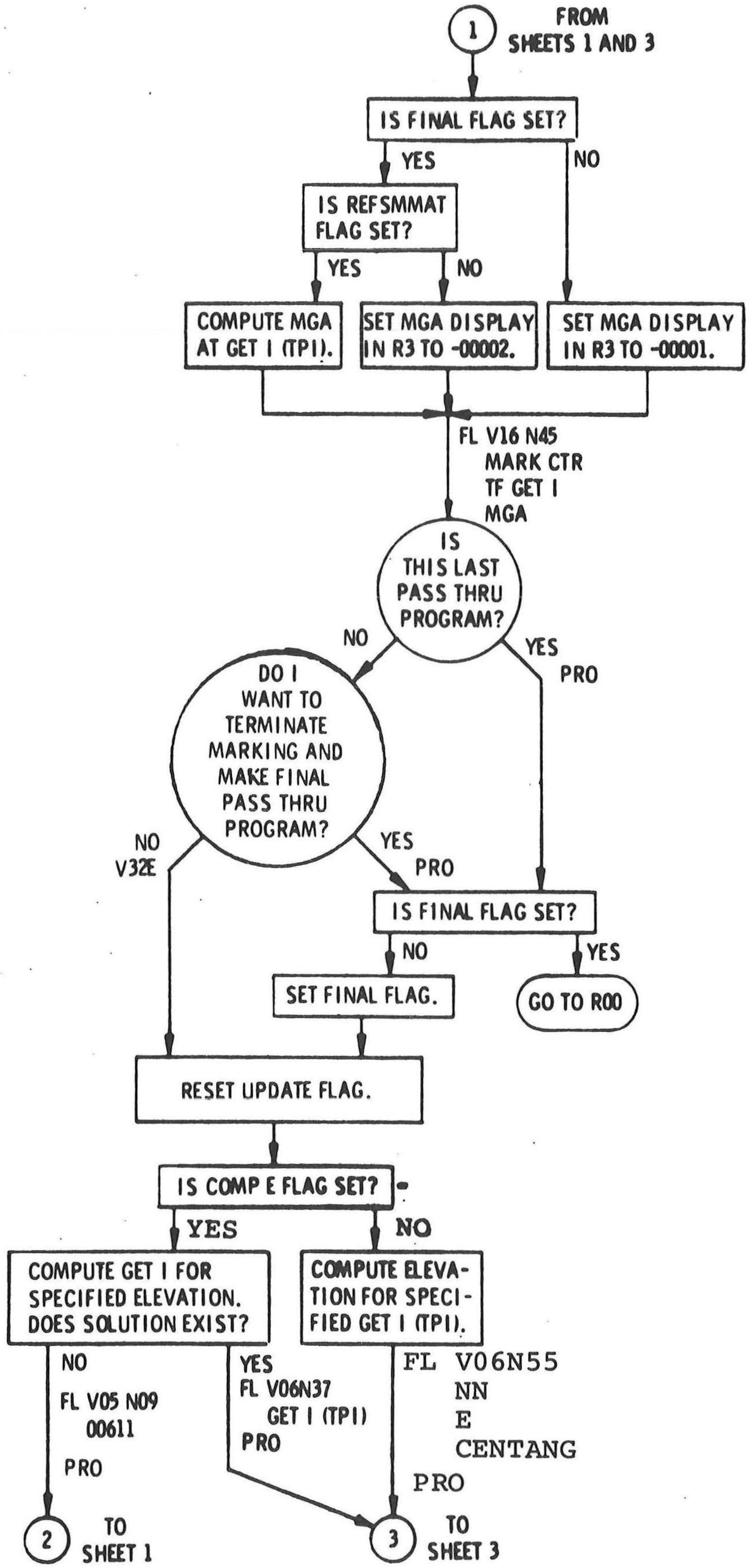


Fig. 5-30. Transfer Phase Initiation Program (P34) (Sheet 2 of 3)

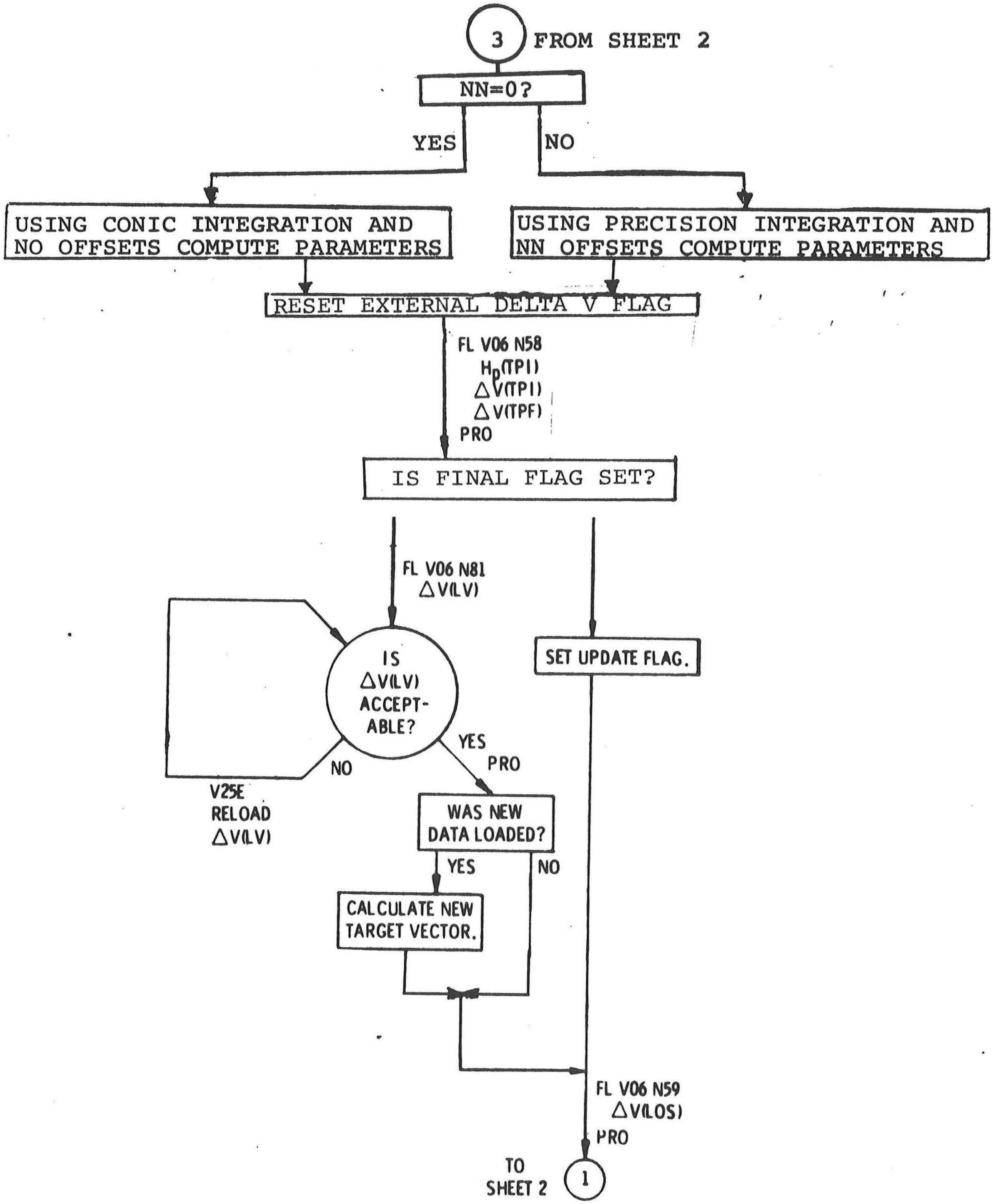


Fig. 5-30. Transfer Phase Initiation Program (P34) (Sheet 3 of 3)

The CMC displays to the astronaut and the ground: TPI perigee altitude, delta V (TPI), delta V (TPF), delta V local vertical components, delta V line-of-sight components, number of marks processed by R22, time to ignition, and IMU middle gimbal angle at ignition.

During program P34, the rendezvous tracking program, P20, may be running to provide optical tracking of the LM. IF P20 is in process, tracking marks may be made, at any time the CMC holds for a flashing verb-noun display, by keying V57E. Upon completion of the marking routine, the CMC returns to P34 at the interrupted display.

5.2.3.16 Transfer Phase Midcourse Program (P35)

The transfer phase midcourse program (Fig. 5-31) calculates the initial conditions required by the CMC for CSM execution of the next possible midcourse correction of the transfer phase of an active CSM rendezvous. It displays delta V (TPM) and delta V (LOS), number of marks processed by R22, time to ignition, and IMU middle gimbal angle.

Program P20 may also run concurrently with this program in the same manner as with P34.

5.2.3.17 Return to Earth Program (P37)

This program (Fig. 5-32) computes the return-to-earth trajectory. The computation is based on astronaut specified time of ignition, maximum velocity change, and reentry angle. The program computes time from ignition to reentry, reentry inertial velocity, reentry flight path angle, latitude and longitude of landing point, and local vertical components of delta V. After initial acceptance of these parameters by the crew, they are recomputed using applicable perturbations to the conic trajectory and redisplayed. After final acceptance they are stored for use by the thrusting programs. The IMU middle gimbal angle at ignition, time of ignition, and time to ignition are then displayed.

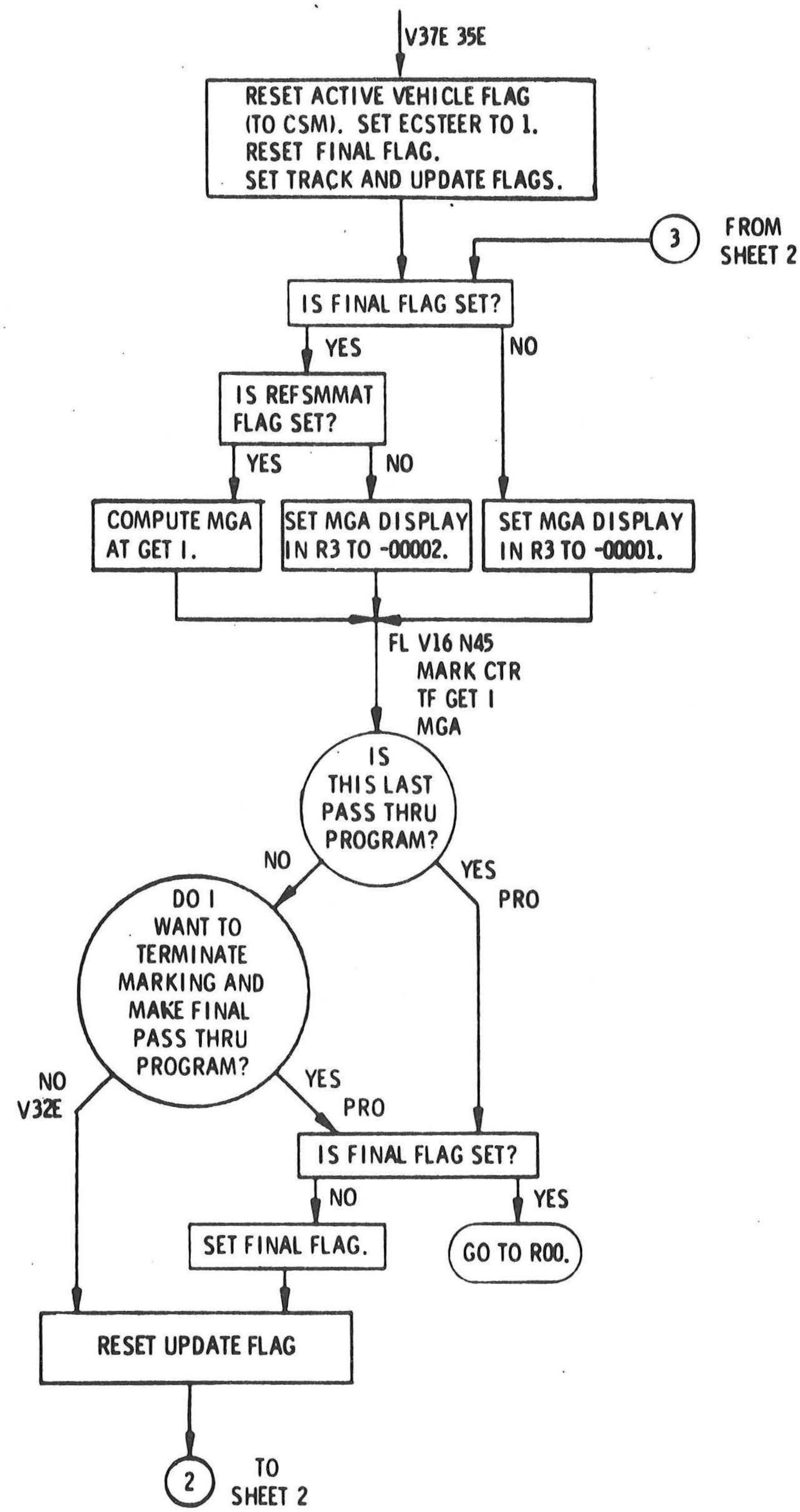


Fig. 5-31. Transfer Phase Midcourse Program (P35) (Sheet 1 of 2)

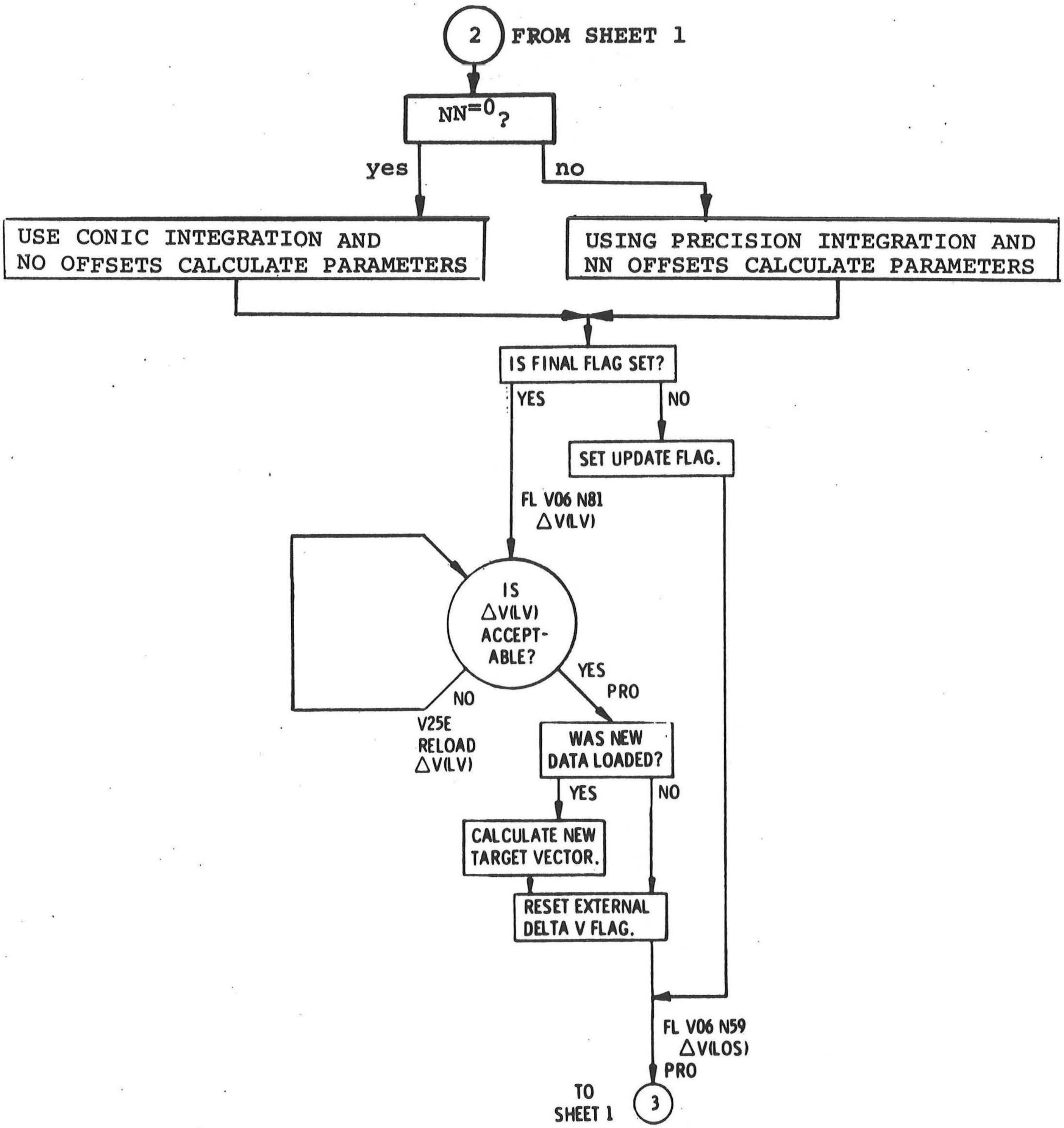


Fig. 5-31. Transfer Phase Midcourse Program (P35) (Sheet 2 of 2)

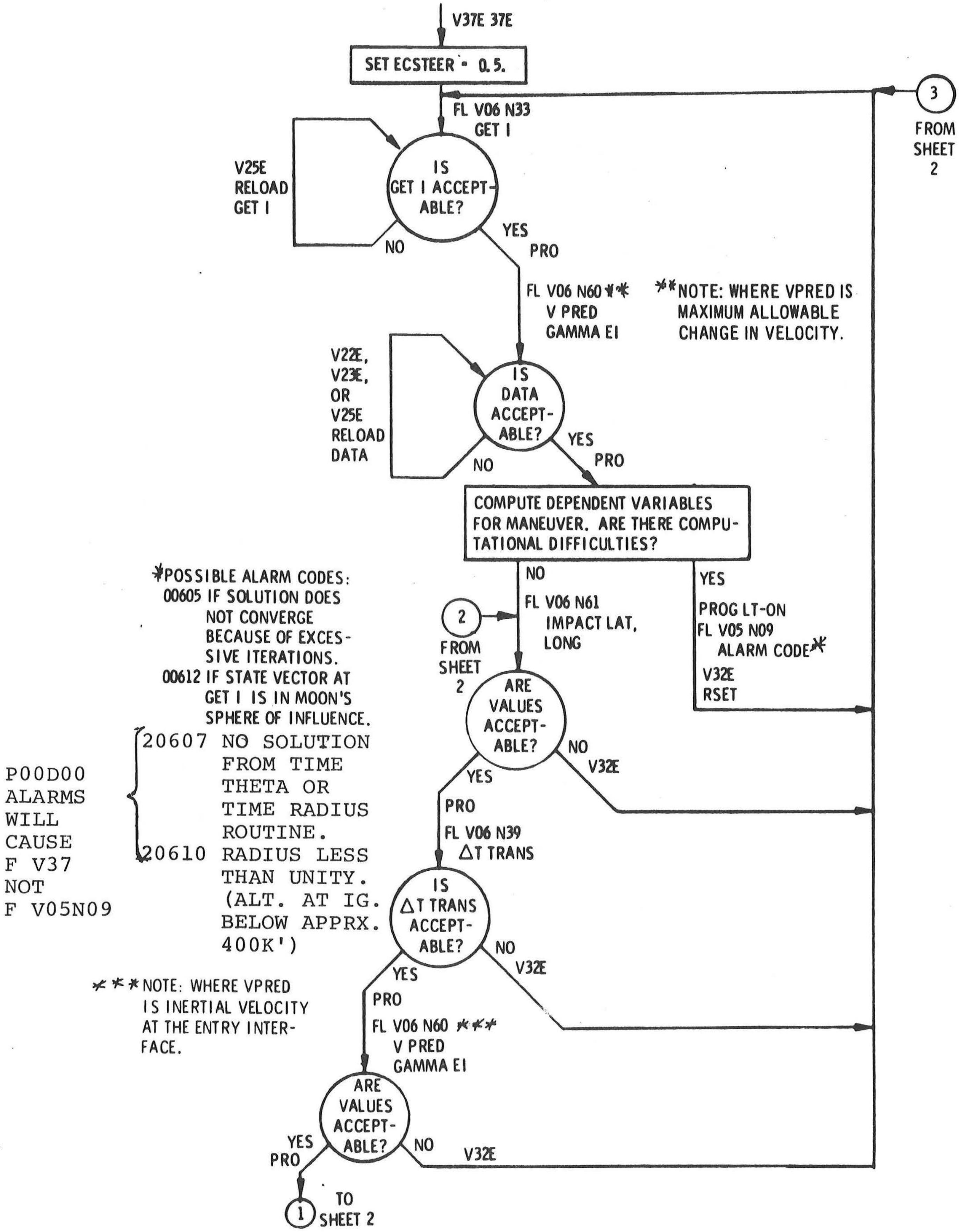


Fig. 5-32. Return To Earth Program (P37) (Sheet 1 of 2)

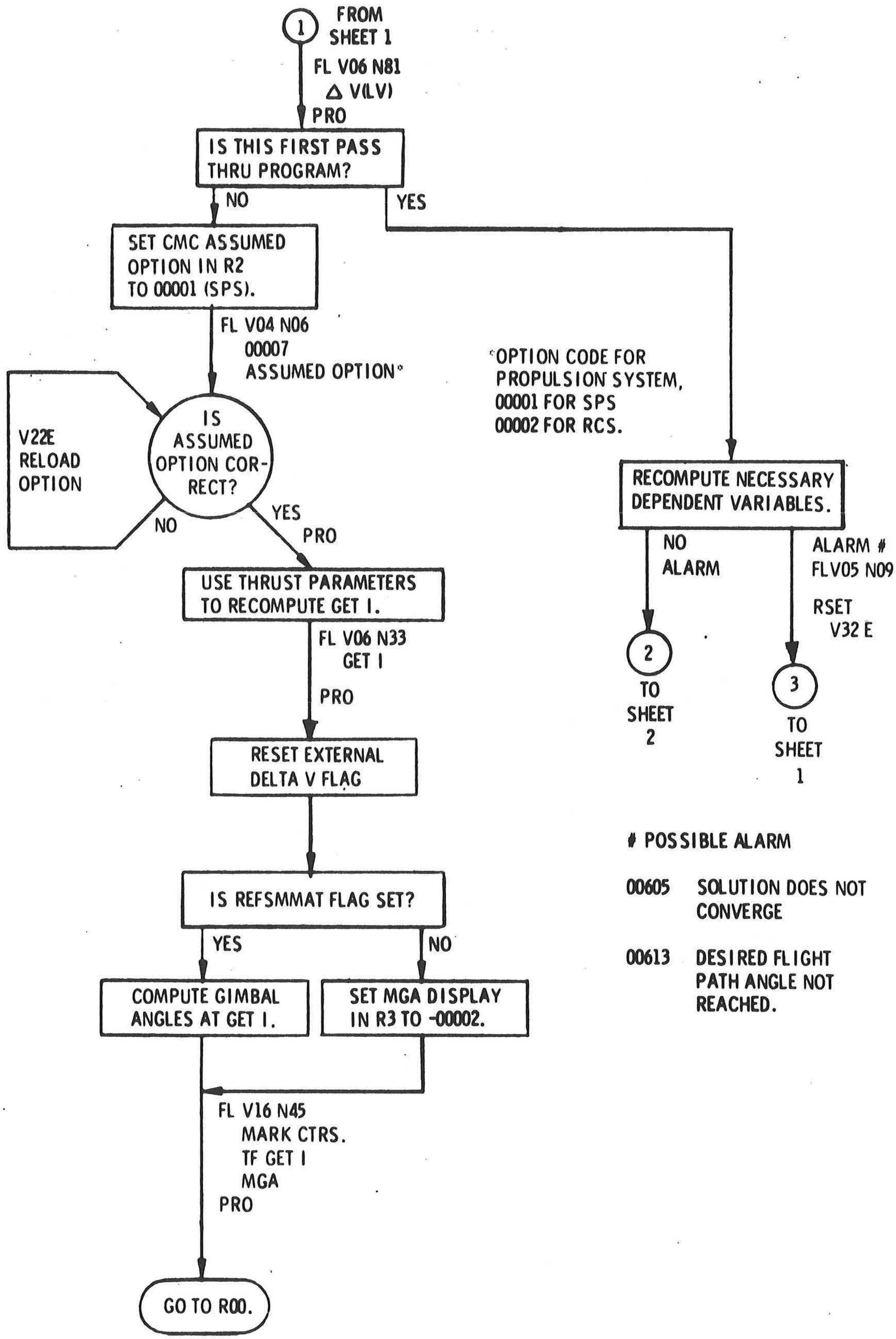


Fig. 5-32. Return To Earth Program (P37) (Sheet 2 of 2)

5.2.3.18 Stable Orbit Rendezvous Program (P38)

The stable orbit rendezvous program (Fig. 5-33) calculates initial conditions required by the CMC for CSM execution of the first phase of a stable orbit rendezvous maneuver. The calculation is based on loaded values of time of ignition, central angle of transfer from time of ignition to intercept time, and the offset of the stable orbit point specified as a distance along the passive vehicle orbit. The program also calculates the initial conditions for the second phase of the stable orbit rendezvous using a respecification of the loaded parameters. The CMC displays calculated values of time of arrival at stable orbit, perigee altitude of stable orbit, delta V at time of ignition, delta V at time of intercept, local vertical components of delta V, number of marks processed by R22, time to ignition, and IMU middle gimbal angle.

Program P20 may run concurrently with this program in the same manner as with P34.

5.2.3.19 Stable Orbit Midcourse Program (P39)

The stable orbit midcourse program (Fig. 5-34) calculates the initial conditions required by the CMC for CSM execution of the next possible midcourse correction of the stable orbit transfer phase of an active CSM rendezvous. It displays delta V (LV), number of marks processed by R22, time to ignition, and IMU middle gimbal angle at ignition.

Program P20 may run concurrently with this program in the same manner as with P34.

5.2.3.20 SPS Program (P40)

The SPS program (Fig. 5-35) provides GNCS control during countdown, ignition, thrusting, and thrust termination of an SPS maneuver. It computes a

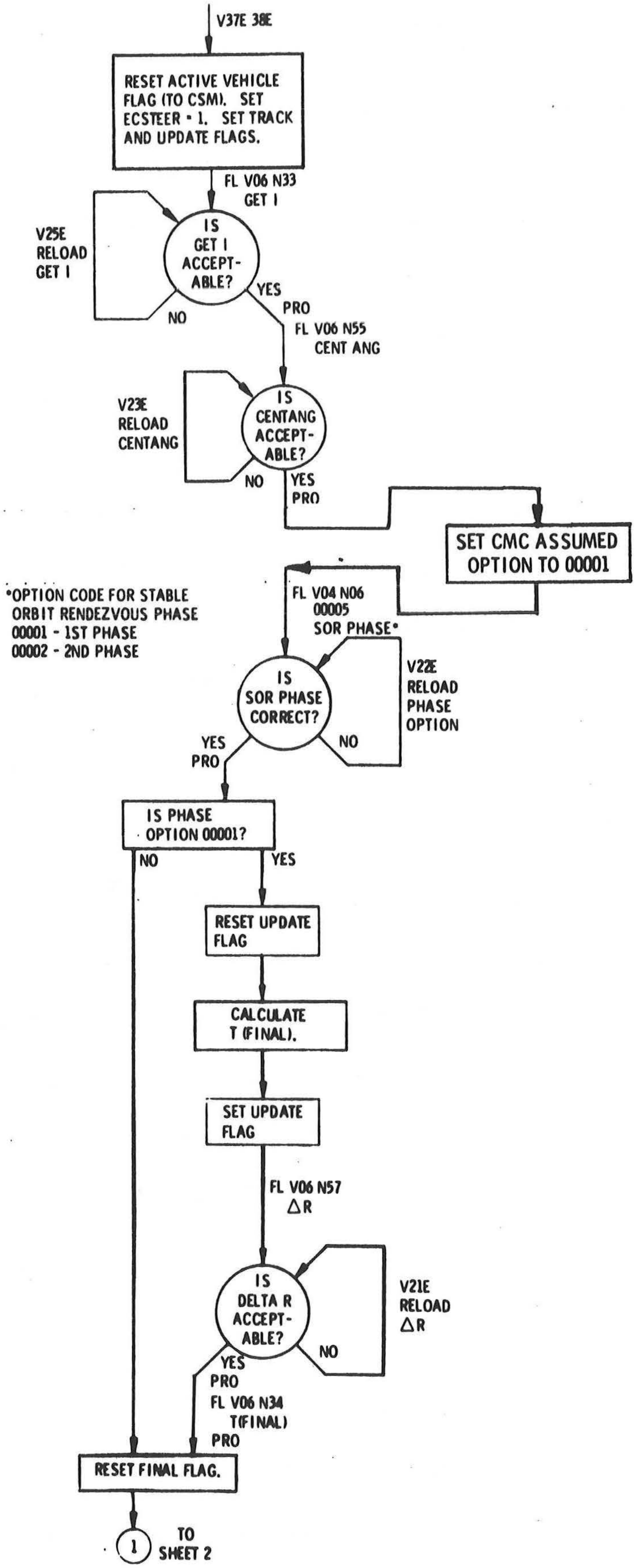


Fig. 5-33. Stable Orbit Rendezvous Program (P38) (Sheet 1 of 3)

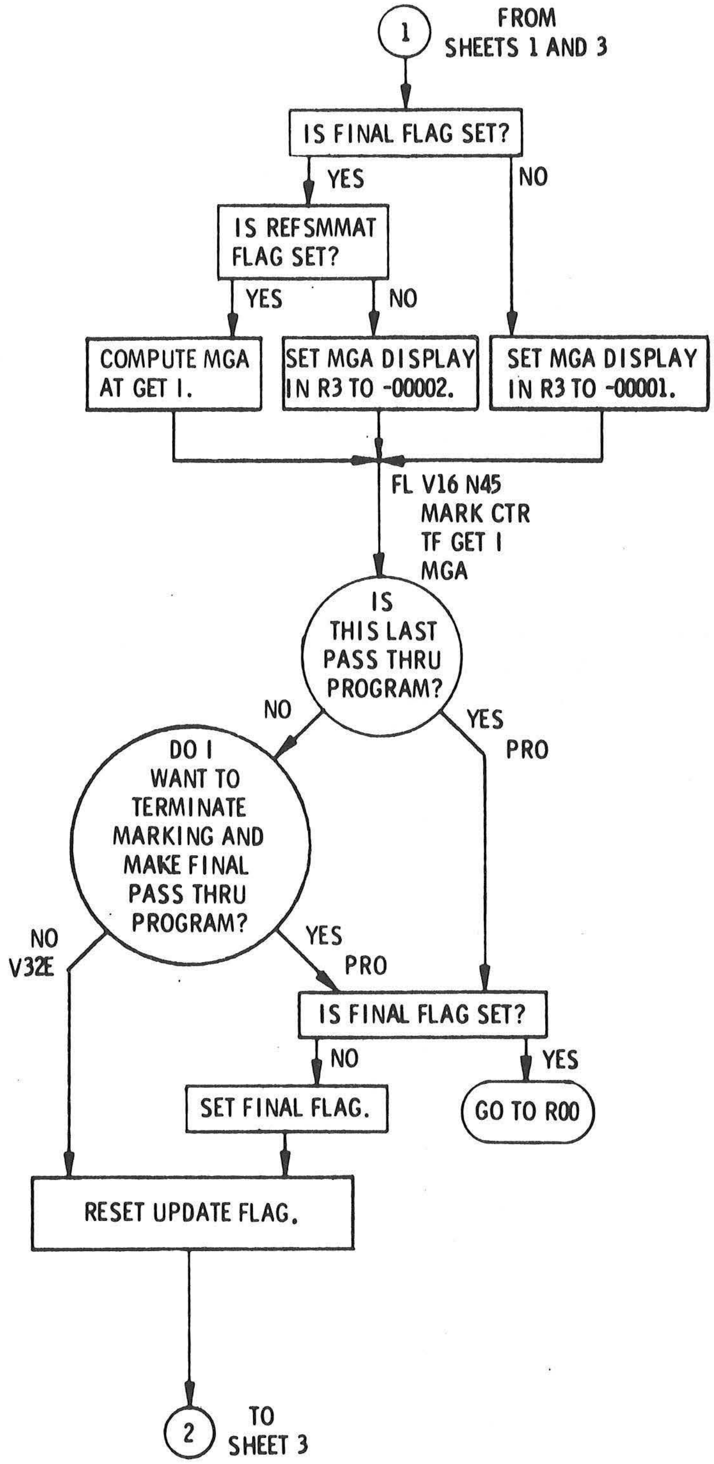


Fig. 5-33. Stable Orbit Rendezvous Program (P38) (Sheet 2 of 3)

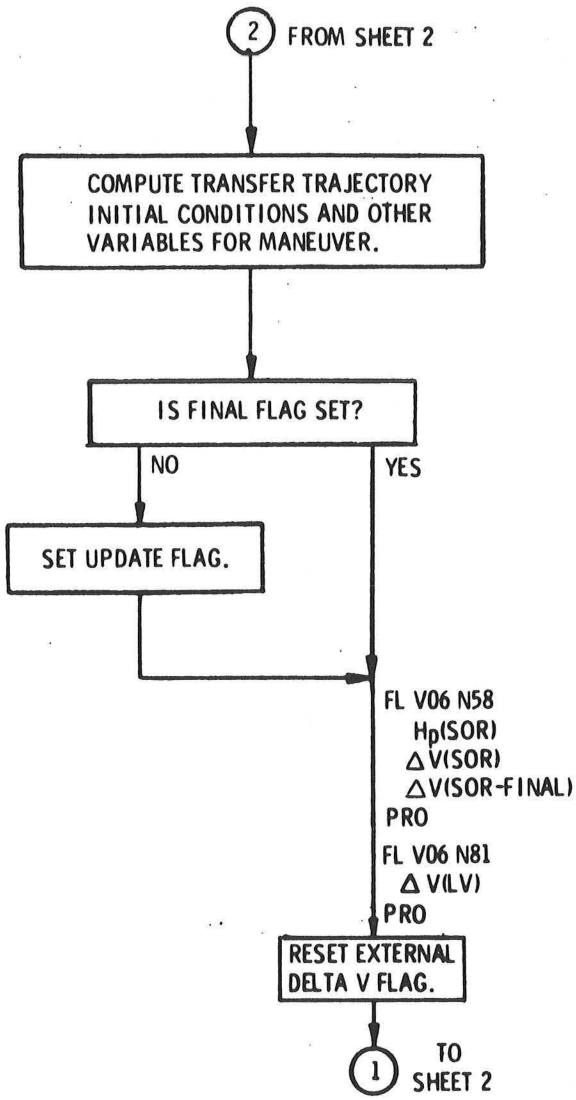


Fig. 5-33. Stable Orbit Rendezvous Program (P38) (Sheet 3 of 3)

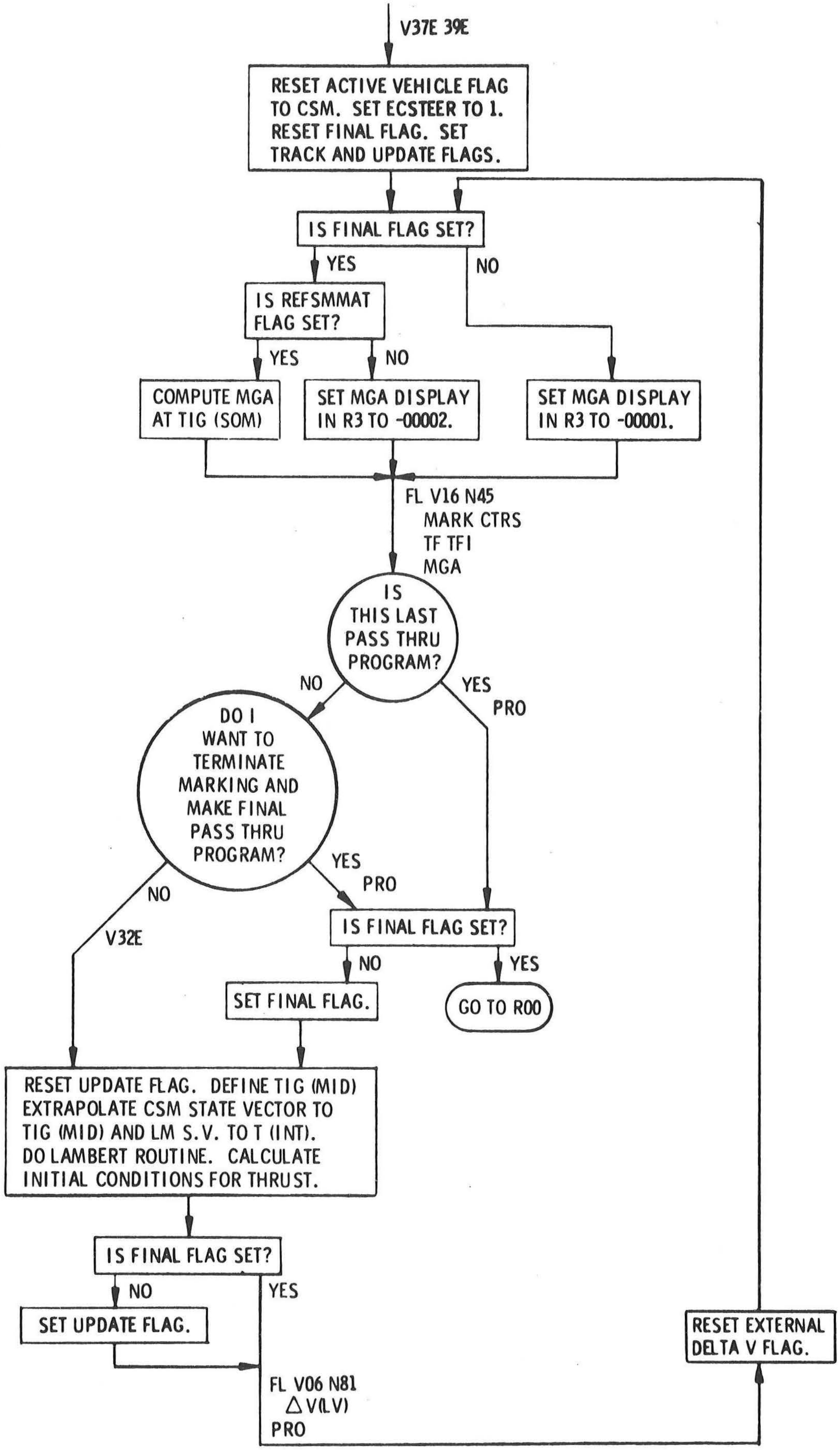


Fig. 5-34. Stable Orbit Midcourse Program (P39)

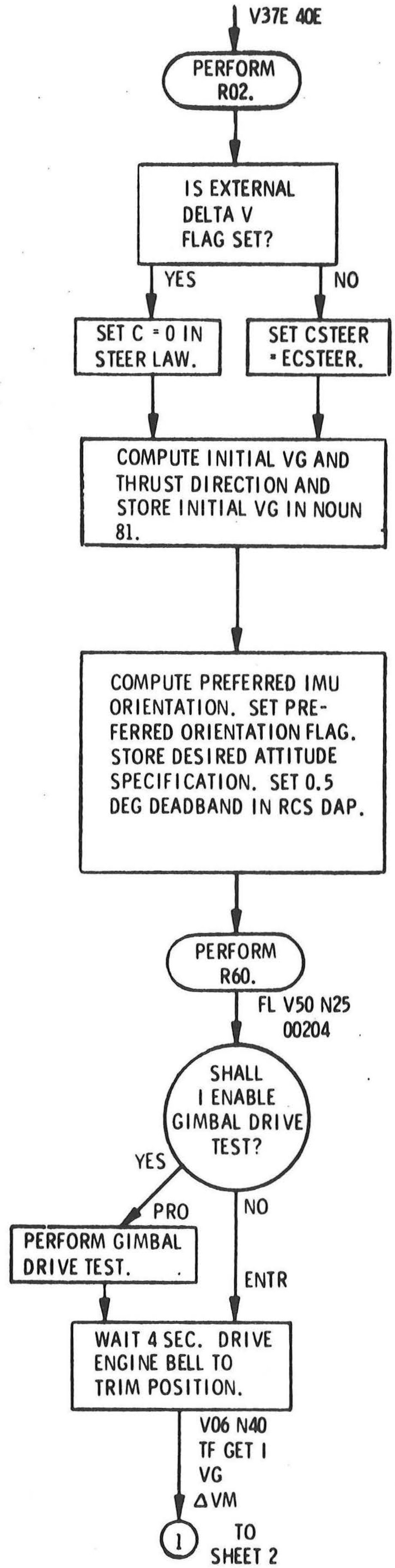


Fig. 5-35. SPS Program (P40) (Sheet 1 of 3)

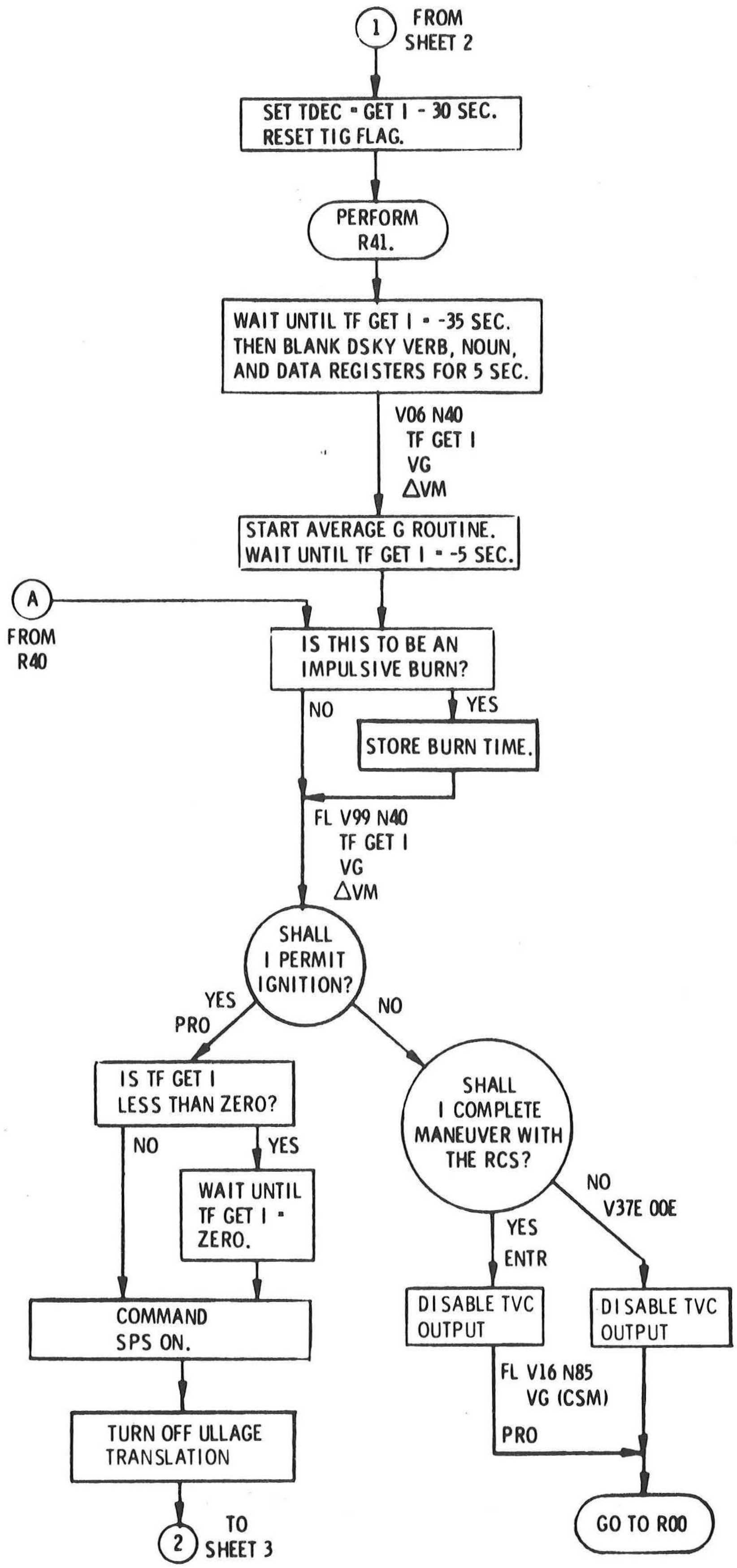
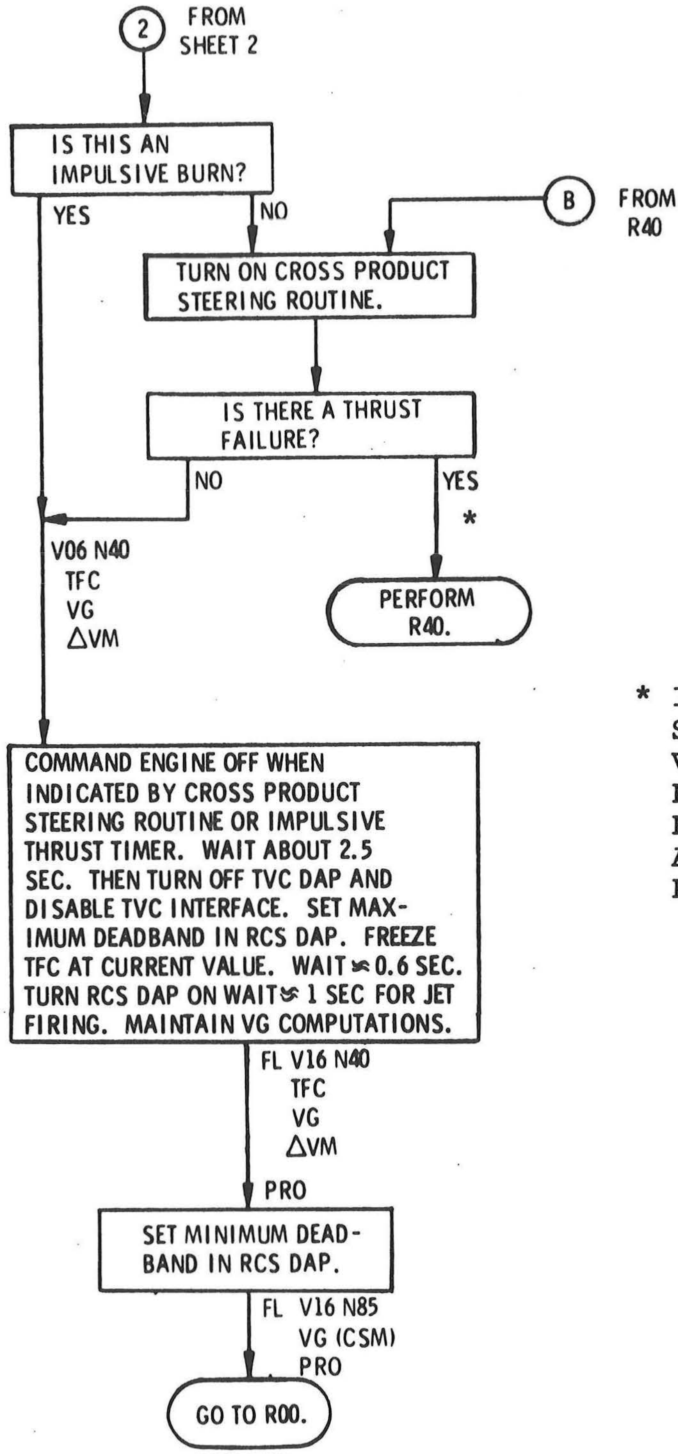


Fig. 5-35. SPS Program (P40) (Sheet 2 of 3)



* IF CROSS PRODUCT STEERING DETECTS VG INCREASING PROG LT--ON. FOR DISPLAY OF ALARM CODE 1407 KEY V5N9E.

Fig. 5-35. SPS Program (P40) (Sheet 3 of 3)

preferred IMU orientation and preferred CSM attitude for the thrusting maneuver. Prior to P40 entry, the IMU has been in the operate state for at least 15 minutes, the DAP data load routine (R03) has been performed, and the target parameters have been calculated and stored by prior execution of a prethrusting program (P30's). The required steering equations have been identified by this prethrust program as either lambert or external delta V steering.

Program P40 is selected at least five minutes before ignition time. The preferred IMU orientation is computed, for the initial thrust direction. The IMU gimbal angles with the present inertial orientation and preferred vehicle attitude are then computed. The minimum deadband is set in the RCS DAP, and a CSM attitude maneuver (R60) (paragraph 5.2.3.8.3) is performed. The engine gimbal drive test is performed, if desired. A display is made of time to SPS ignition, velocity to be gained, and measured delta V. The state vector integration routine (R41) (paragraph 5.2.3.20.1) is performed.

At 20 (or 15) seconds before SPS ignition, 2 jet (or 4 jet) +X-ullage is started. At 5 seconds before ignition time the DSKY flashes a request for engine on enable. This is enabled by keying PRO. SPS ignition and termination is monitored by the crew and backed up by use of the thrust switches. If the thrust should fail before cutoff, a V97 is flashed and the SPS thrust fail routine (R40) (paragraph 5.2.3.20.2) is performed. Upon successful completion of the maneuver, the orbit parameter display routine (R30) (paragraph 5.2.3.20.3) may be called.

5.2.3.20.1 State Vector Integration Routine (R41). This routine (Fig. 5-36) integrates the state vector ahead to the time that the average g routine will be turned on by the thrusting program. If the state vector can not be integrated to the specified time, a program alarm is generated and the time of ignition is slipped.

5.2.3.20.2 SPS Thrust Fail Routine (R40). This routine (Fig. 5-37) notifies the astronaut that the SPS thrusting has failed. If the engine comes back on, the astronaut commands a return to the thrust program (P40) to continue the thrust by keying PRO. If the engine does not come back on, there are three options available: attempt to re-ignite the engine, continue the maneuver with the RCS, or terminate the maneuver.

5.2.3.20.3 Orbit Parameter Display Routine (R30). The orbit parameter display routine (Fig. 5-38) is entered manually by V82E, usually just after a thrusting maneuver. This routine displays perigee and apogee altitudes, and time of free fall to 300,000 feet (35,000 feet for lunar orbit). If perigee altitude is greater than 300,000 feet in earth orbit or 35,000 ft in lunar orbit, or if the trajectory does not interface the altitude, time to free fall is displayed as -59 min, 59 sec; in which case time from perigee may be called by keying V16N32E. During earth orbit insertion (P11), miss distance to target point may be called by keying V16N50E. It is also computed in (P00).

5.2.3.21 RCS Program (P41)

The RCS program (Fig. 5-39) computes a preferred IMU orientation and a preferred CSM attitude for an RCS thrusting maneuver. It will perform the vehicle maneuver to the thrusting position or will provide suitable displays for manual execution in attitude hold. It also calculates and displays the gimbal angles which would result from the present IMU orientation if the vehicle is

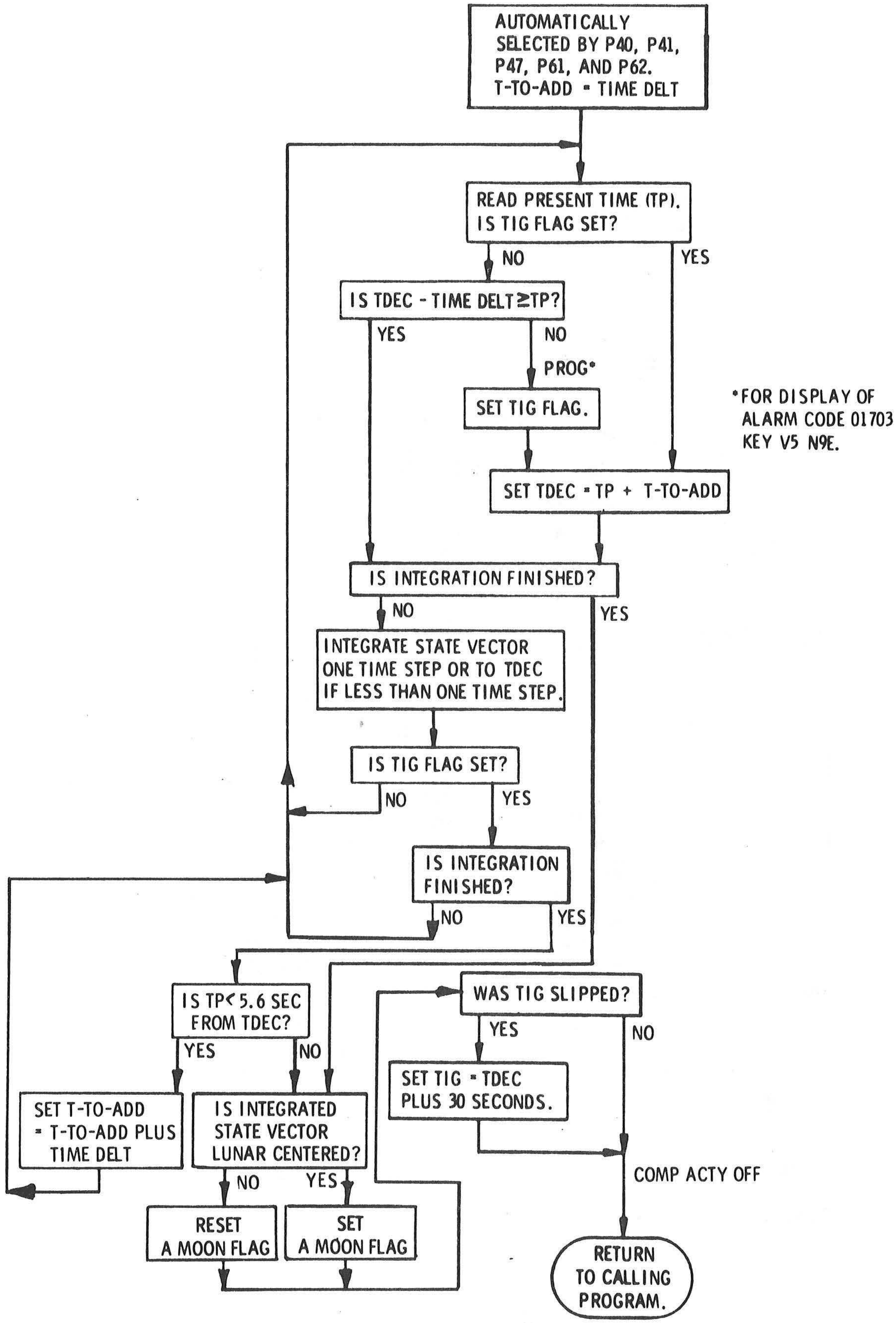


Fig. 5-36. State Vector Integration Routine (R41)

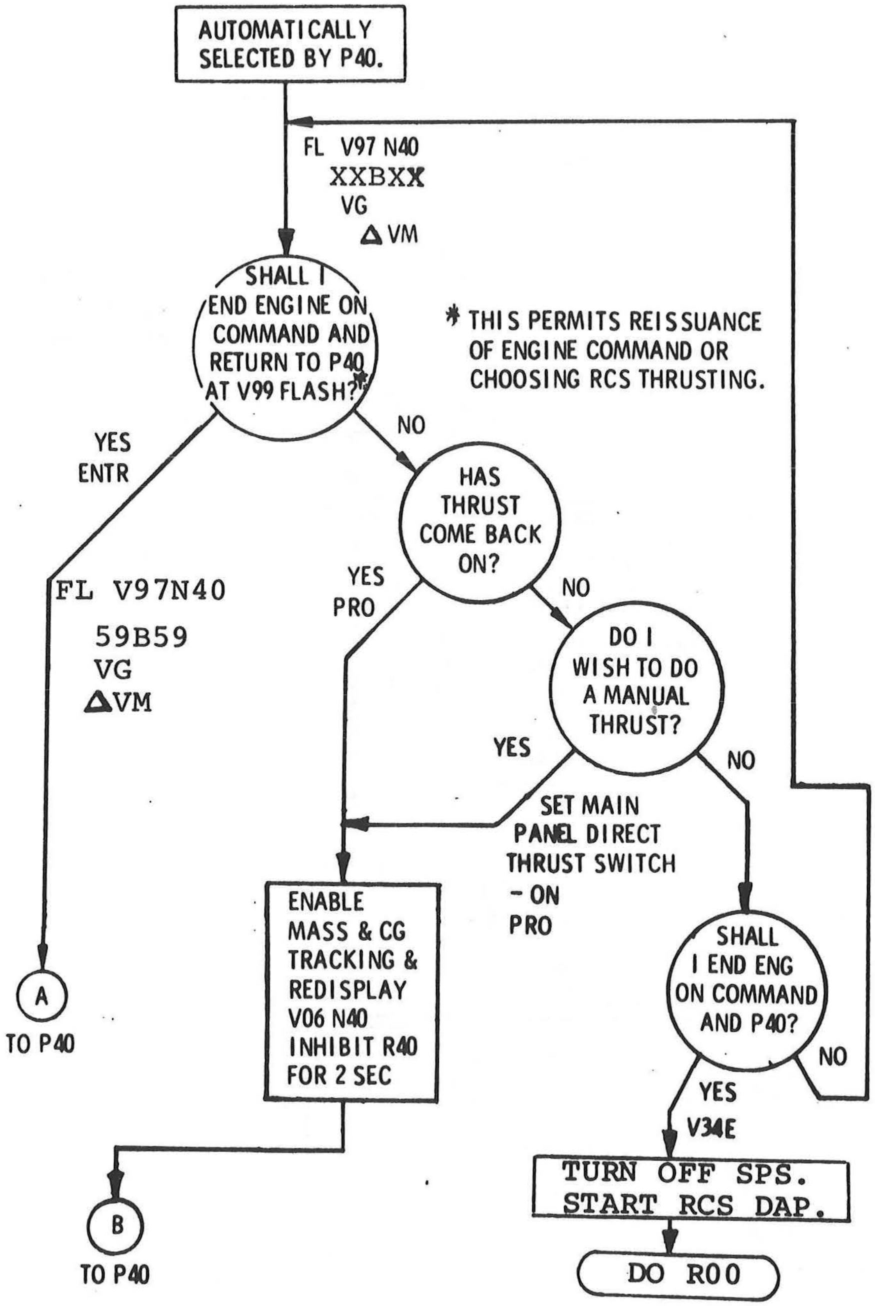


Fig. 5-37. SPS Thrust Fail Routine (R40)

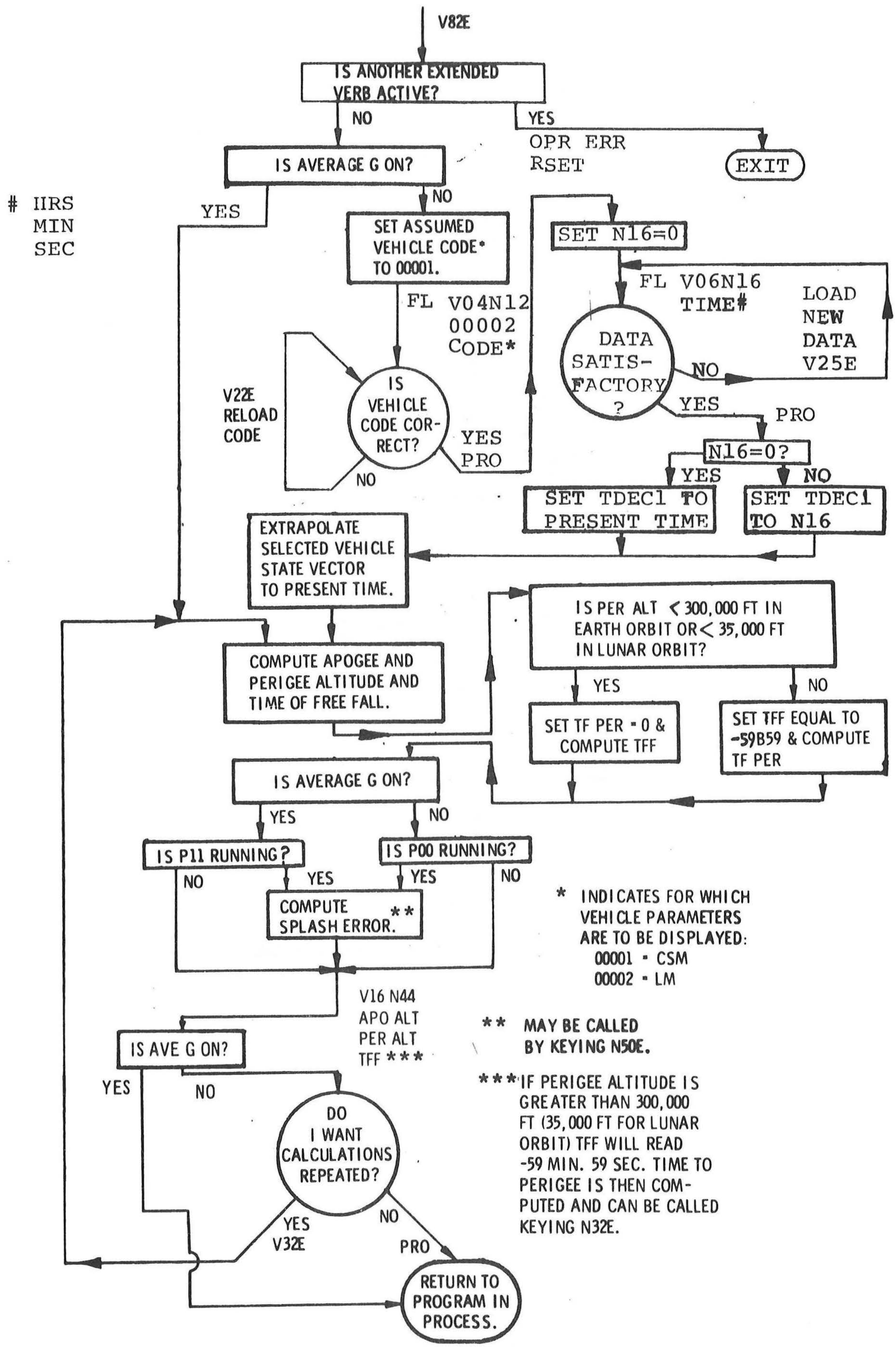


Fig. 5-38. Orbital Parameter Display Routine (R30)

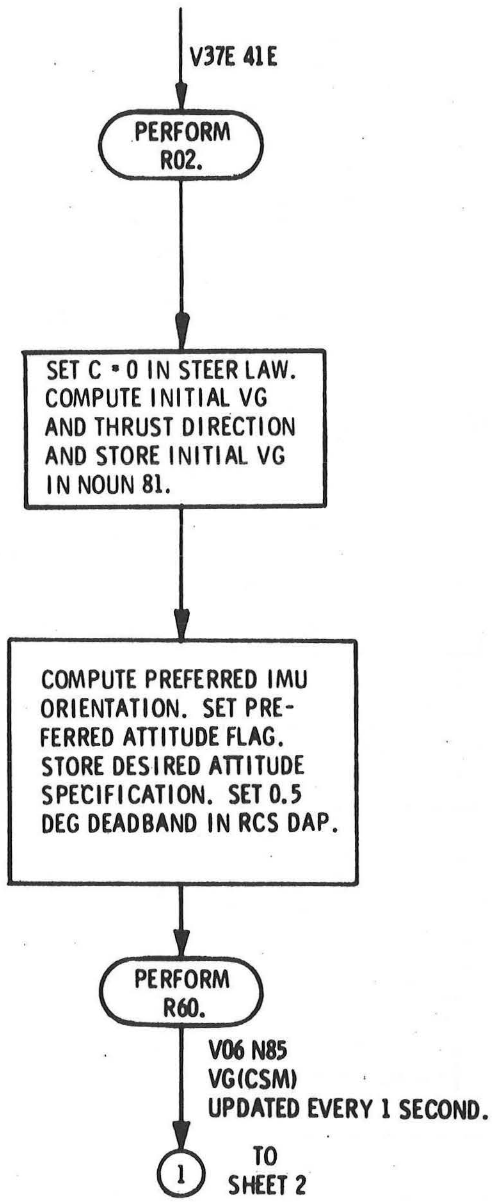


Fig. 5-39. RCS Program (P41) (Sheet 1 of 2)

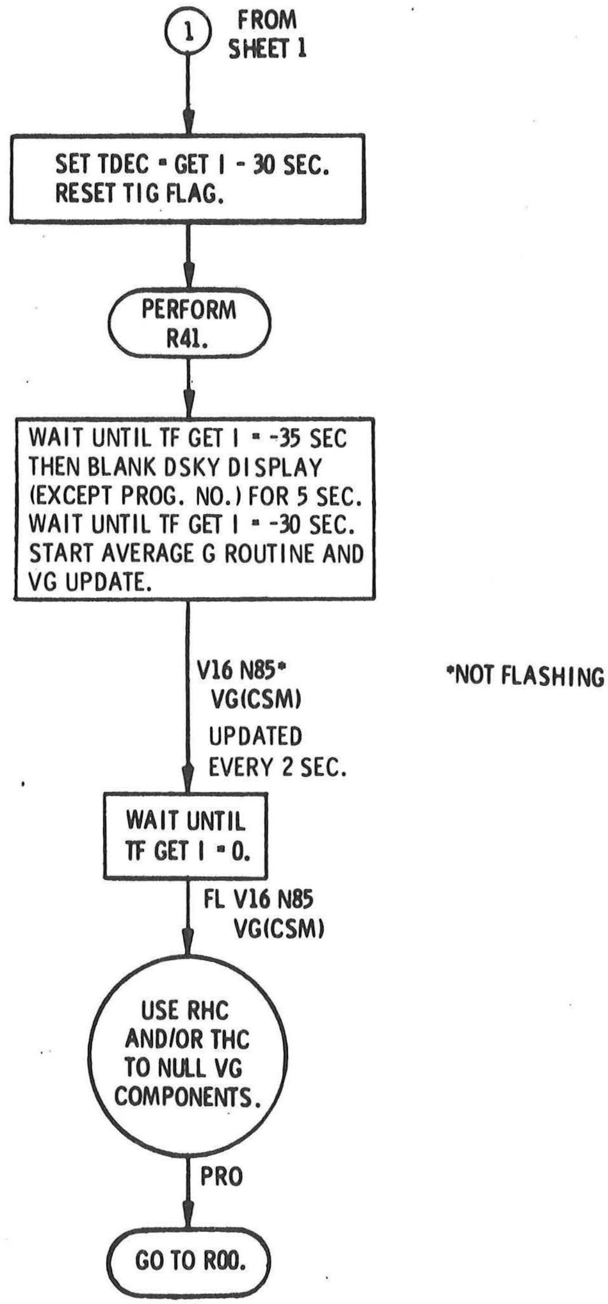


Fig. 5-39. RCS Program (P41) (Sheet 2 of 2)

maneuvered to the preferred CSM attitude for thrusting. Prior to P41 entry, the IMU has been in the operate state for at least 15 minutes, the DAP data load routine (R03) has been performed, and the target parameters have been calculated and stored in the CMC by prior execution of a prethrusting program (P30's). The required steering equations have been identified by this prethrust program as either lambert or external delta V steering.

Program P41 is selected at least five minutes before ignition time. The 0.5-degree deadband is set in the RCS DAP and an attitude maneuver (R60) (paragraph 5.2.3.8.3) is performed. The velocity to be gained (VG) is then displayed and state vector integration routine (R41) (paragraph 5.2.3.20.1) is performed. At ignition time, monitoring of VG components begins. VG components are nulled manually. After completion of the maneuver, (R30) (paragraph 5.2.3.20.3) may be entered to check the orbital parameters.

5.2.3.22 Thrust Monitor Program (P47)

The purpose of the thrust monitor program (Fig. 5-40) is to monitor vehicle acceleration during a maneuver not controlled by the GNCS and to display the delta V applied by the maneuver. Prior to the delta V monitoring, state vector integration routine (R41) (paragraph 5.2.3.20.1) is performed. The astronaut must monitor for gimbal lock during this maneuver.

5.2.3.23 IMU Orientation Determination Program (P51)

The IMU orientation determination program (Fig. 5-41) is used to determine the inertial orientation of the IMU. This program is performed after ISS start up or when orientation is unknown (no REFSMMAT).

Upon entry into the program, by V37E 51E, the ISS operate bit is checked to ensure that the IMU is on. The astronaut must then decide on one of two logic

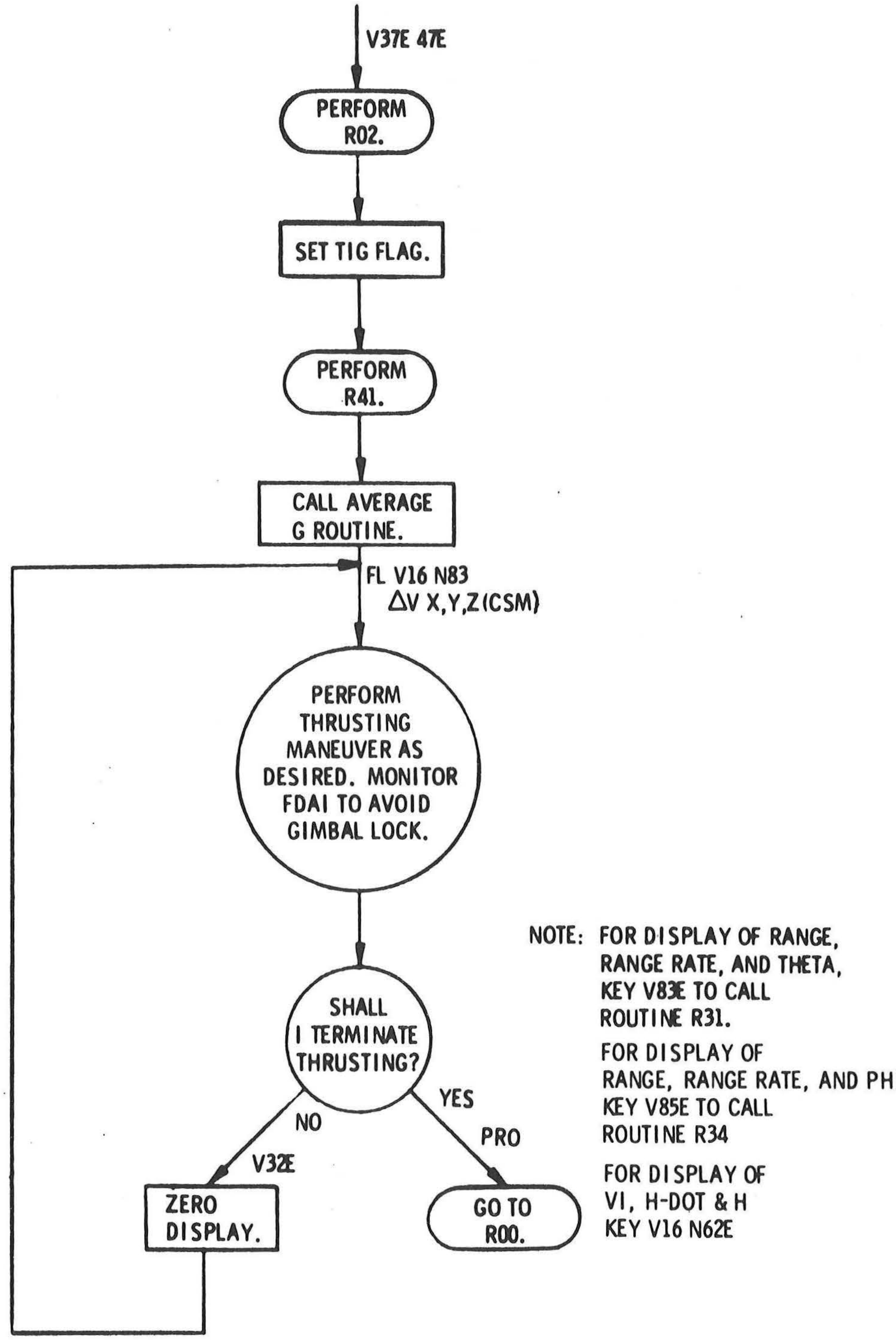


Fig. 5-40. Thrust Monitor Program (P47)

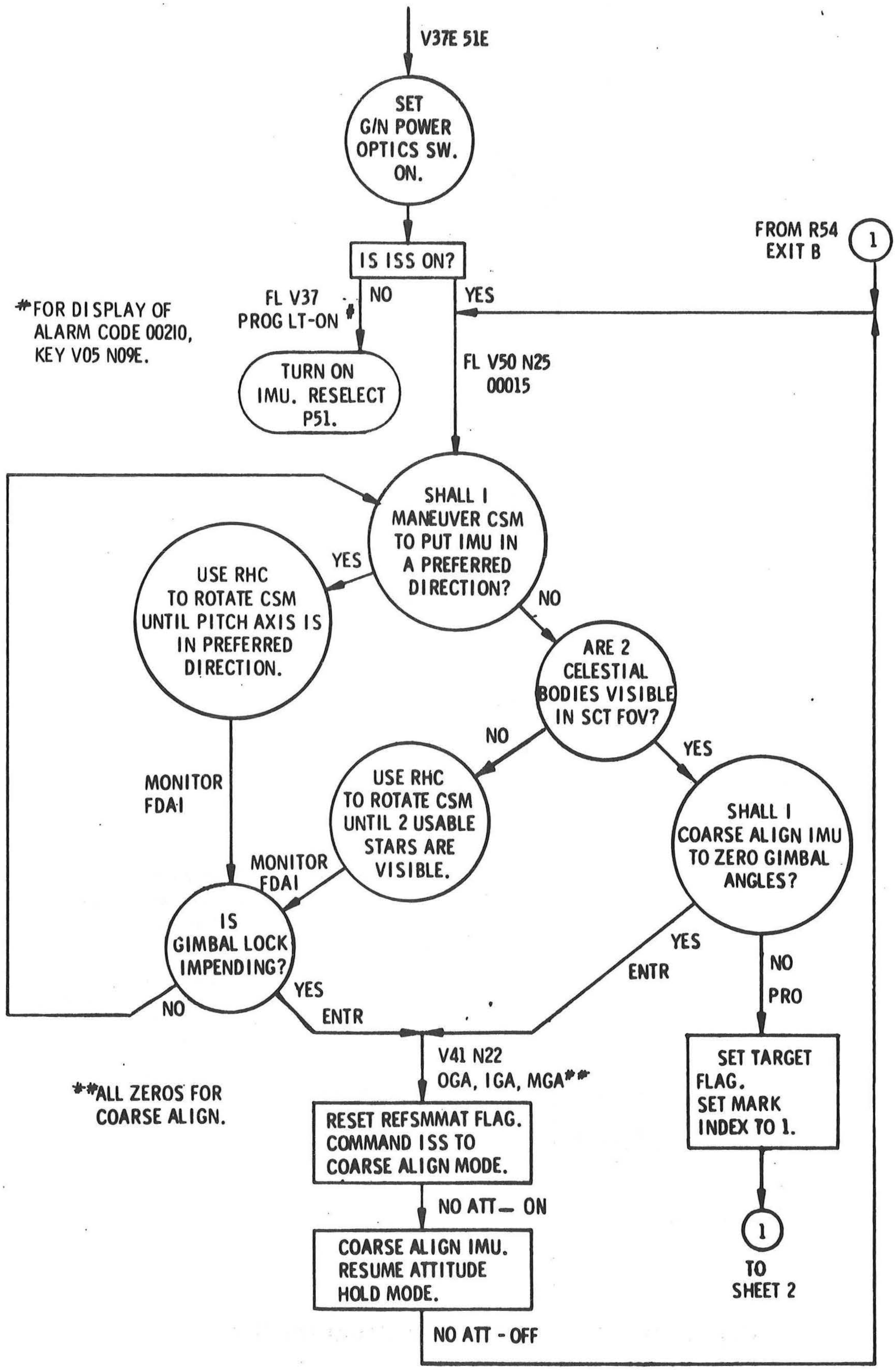


Fig. 5-41. IMU Orientation Determination Program (P51) (Sheet 1 of 2)

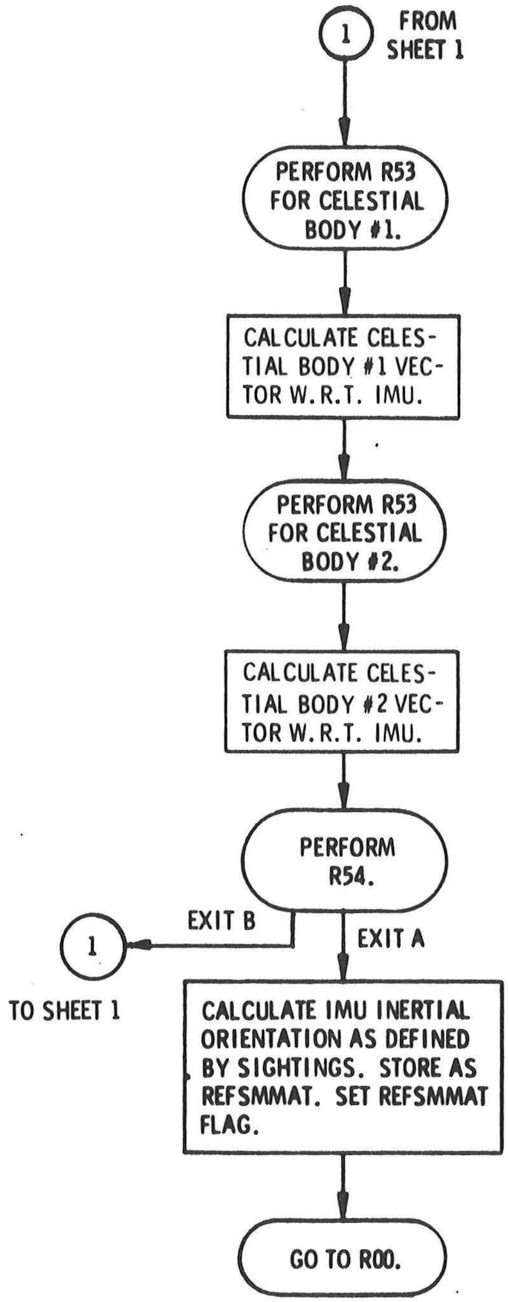


Fig. 5-41. IMU Orientation Determination Program (P51) (Sheet 2 of 2)

flows. Subsequent IMU alignment decisions are greatly simplified if P51 is performed in a manner that leaves the IMU inertially stabilized at an orientation as close as possible to the optimum required for future CMC programs. Time and RCS fuel may be saved if a preferred direction can be obtained with two stars visible in SCT FOV. In which case, a coarse alignment would probably be performed to obtain 0, 0, 0, gimbal angles at this preferred direction. The coarse alignment, thereby, provides an inertially fixed platform in an orientation advantageous to future maneuvers and reading of the FDAI ball.

The alternate logic flow normally is taken when a preferred direction is not known or is not desired. A maneuver is then made to obtain two stars in the SCT FOV and coarse alignment is probably not performed.

In any logic flow case, sighting marks are then taken on two stars and the star vectors are used to calculate the IMU inertial orientation which is stored as REFSMMAT. The sighting mark routine (R53) is discussed in paragraph 5.2.3.10.3

After making sightings on the two stars, the sighting data display routine R54 is performed (paragraph 5.2.3.23.1). If the data was accepted, P51 is terminated; if not, it is redone.

5.2.3.23.1 Sighting Data Display Routine (R54). The sighting data display routine (Fig. 5-42) is called by programs P51, P52, P53 and P54 to check the accuracy of celestial body sightings. This routine calculates and displays the angle difference between two celestial bodies using the measured data versus the actual data. If the data is acceptable, the astronaut keys PRO; if not, he keys V32E. In either case, a return is made to the calling program, at different places.

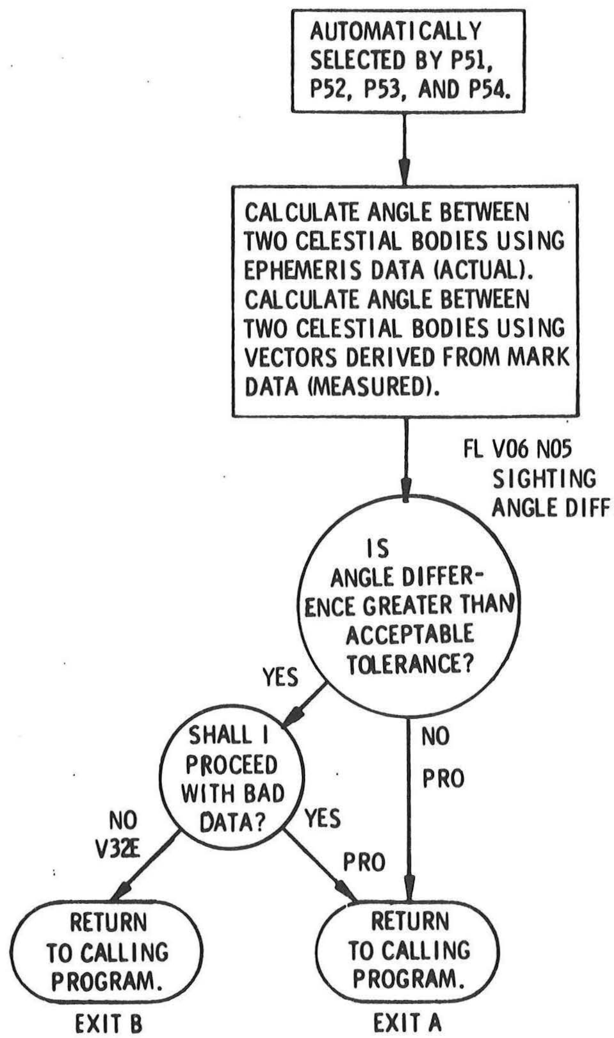


Fig. 5-42. Sighting Data Display Routine (R54)

5.2.3.24 IMU Realign Program (P52)

The IMU realign program (Fig. 5-43) is used to align the IMU from a known orientation to one of four orientations selected by the crew. The four orientations are preferred, nominal, REFSMMAT, and landing site.

The preferred orientation is an optimum orientation to be used for a previously calculated maneuver. The IMU is aligned with its axes (X_{SM}, Y_{SM}, and Z_{SM}) parallel to the CSM X, Y, and Z axes, respectively. With this orientation, the gimbal angles can be monitored directly on the FDAI. The preferred orientation is calculated and the preferred orientation flag is set in the thrusting programs P40 and P41.

The nominal orientation is an alignment to local vertical which provides a heads-up orientation at time of alignment. The Z_{SM} axis is aligned to the negative direction of the geocentric radius vector for earth orbit or selenocentric radius vector for moon and the Y_{SM} axis is aligned to the cross product of the geocentric radius vector for earth orbit or selenocentric radius vector for moon and the inertial velocity vector.

The REFSMMAT orientation is the stored matrix required for coordinate transformation from the basic reference system to the IMU stable member. This value is stored at start of (P11) and completion of programs P51, P52, P53, and P54.

The landing site orientation aligns the X_{SM} axis to the position vector at time of alignment of the most recently defined landing site and aligns the Z_{SM} to the cross product of the CSM angular momentum vector and the X_{SM}.

After entry into P52, the astronaut loads the IMU orientation desired. If the landing site or nominal orientation is selected, the displayed T(Align) time is zero and indicates that the present time has been selected for defining the alignment. If another time is desired, it must be loaded. With any orientation selected, except REFSMMAT, coarse align routine (R50) (paragraph 5.2.3.24.1) is performed, by

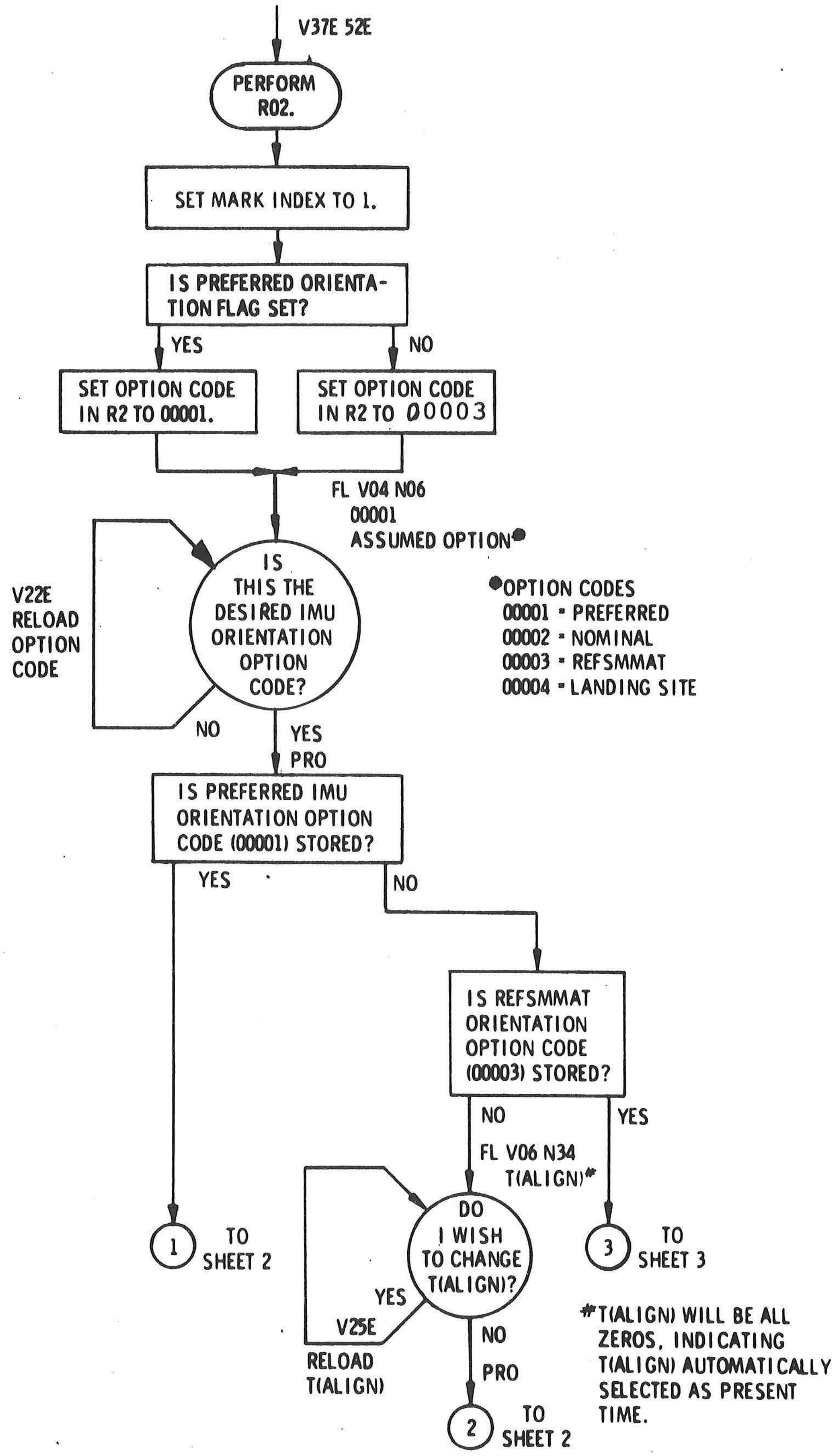


Fig. 5-43. IMU Realign Program (P52) (Sheet 1 of 4)

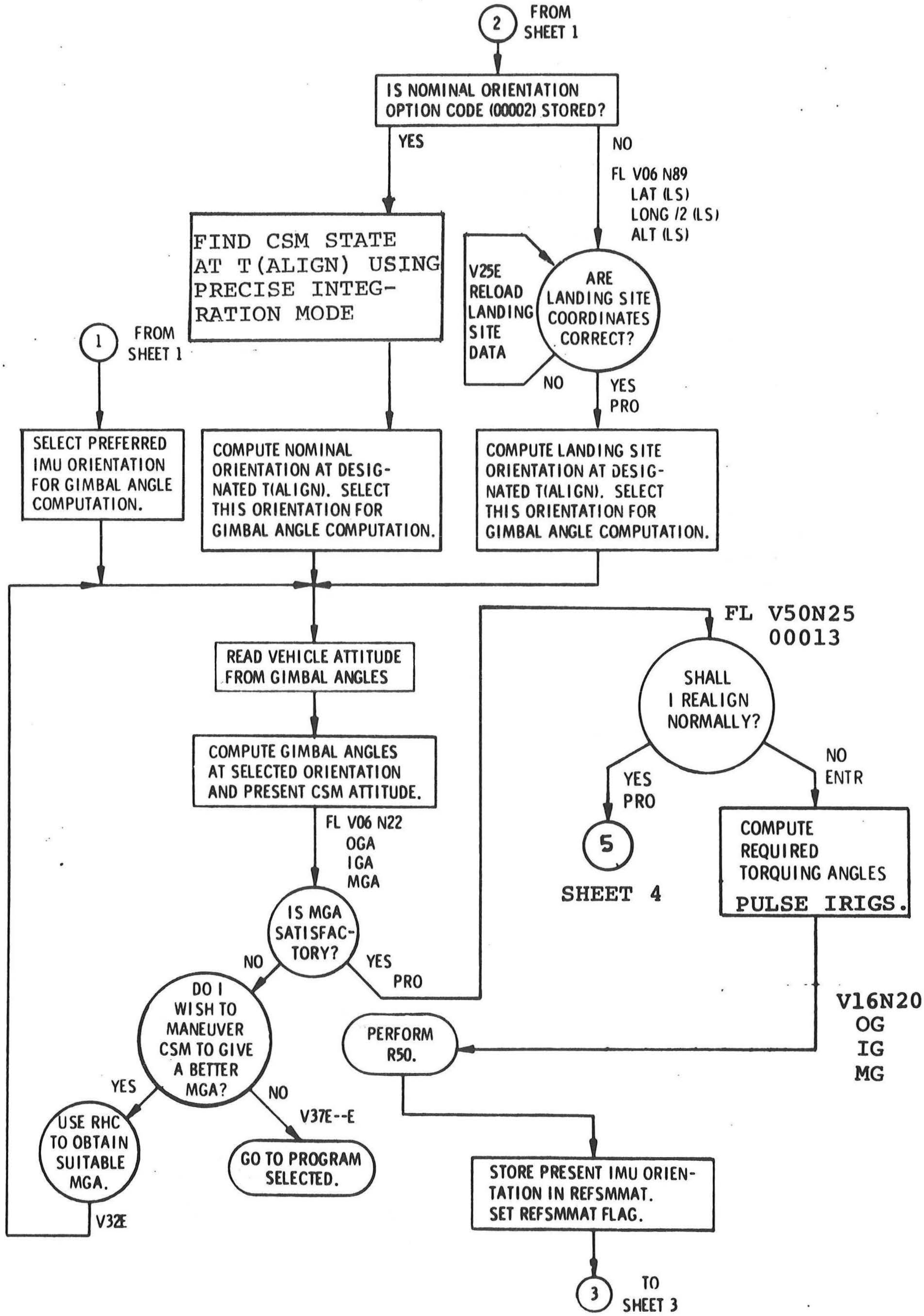


Fig. 5-43. IMU Realign Program (P52) (Sheet 2 of 4)

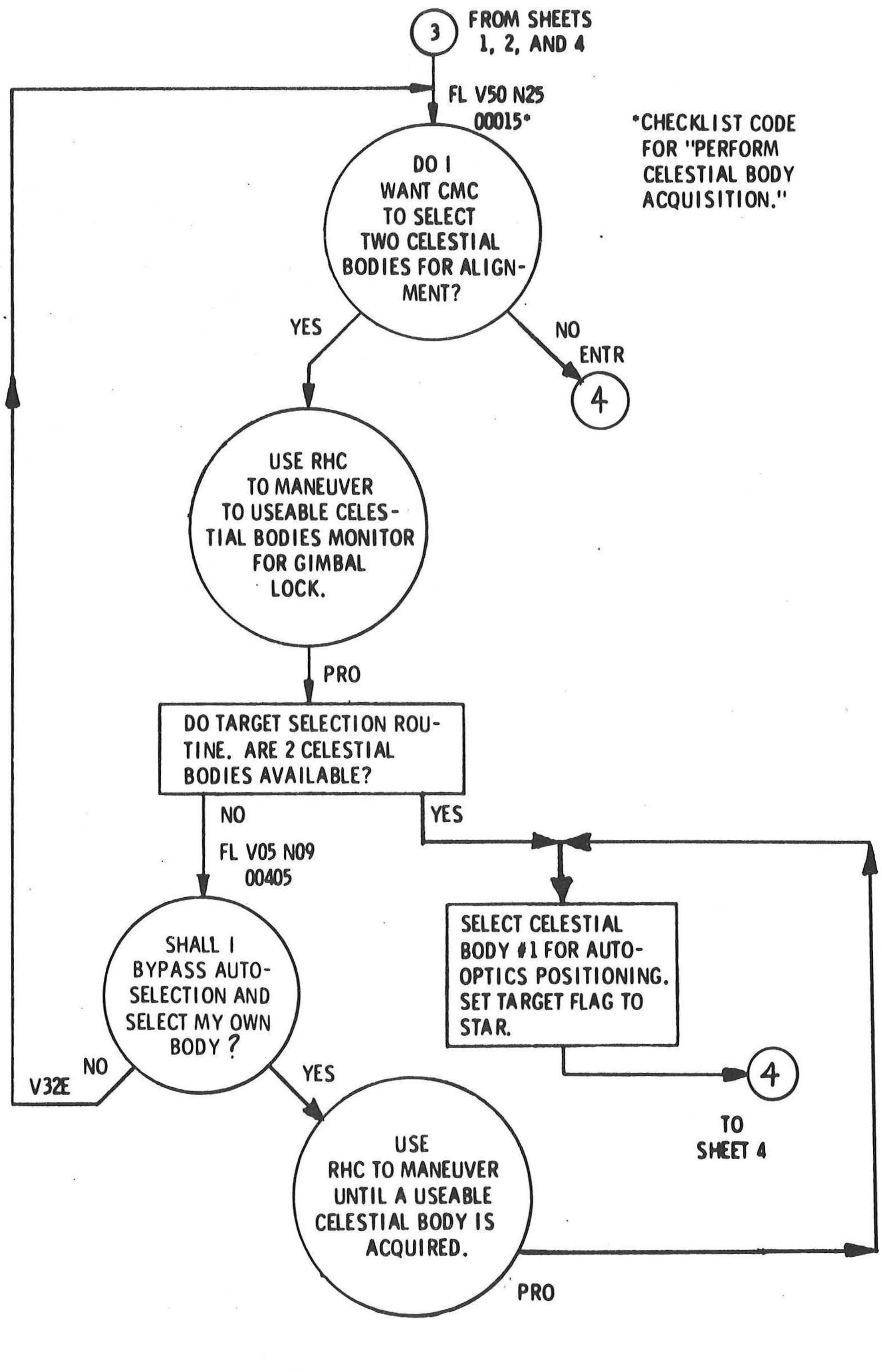


Fig. 5-43. IMU Realign Program (P52) (Sheet 3 of 4)

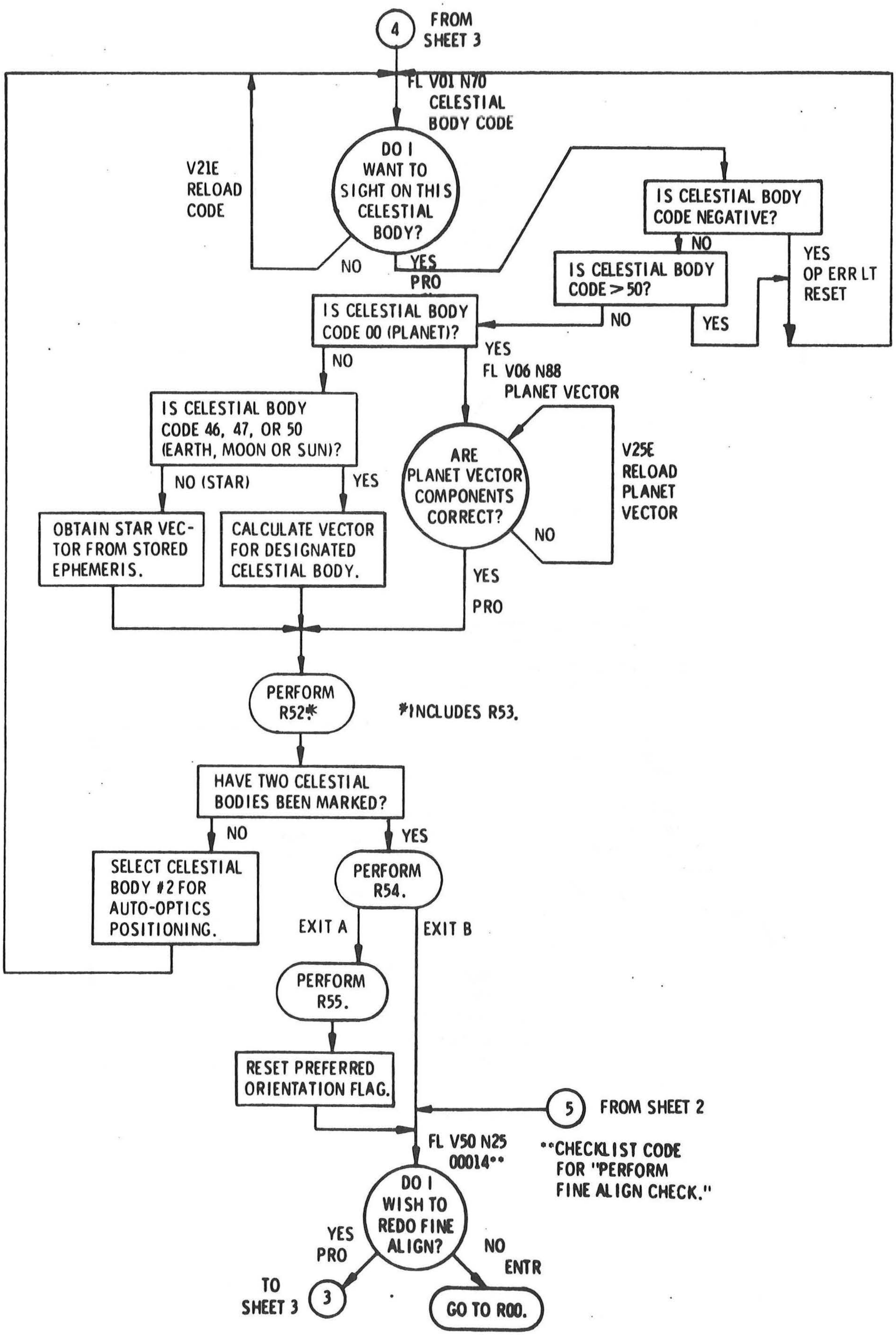


Fig. 5-43. IMU Realign Program (P52) (Sheet 4 of 4)

a PRO response to CHECKLIST 13_8 flash, to inertially stabilize the platform at the selected orientation. The REFSMMAT flag is then set as the orientation is now known. If the REFSMMAT orientation is selected, coarse alignment is not performed as the system varies from the previous alignment only by gyro drift.

If required, a maneuver is then made to acquire two suitable celestial bodies for alignment. At astronaut option, an internal celestial body selection routine aids the selection of the best pair of stars for fine alignment, taking into consideration the amount of propellant required for the attitude maneuver. The routine tests each pair of stars to find two within the 76 degree viewing cone centered on the SXT shaft axis. It then checks if they are separated by at least 30 degrees and are not occulted by earth, moon, or sun. The routine then chooses the pair with the greatest separation. Fine alignment is the aligning of the IMU to a desired inertial orientation by the use of star sightings. The automatic optics positioning routine R52 and the sighting mark routine R53 (paragraphs 5.2.3.10.2 and 5.2.3.10.3, respectively) are called for sighting marks on the first selected (by CMC or crew) star. These routines are then repeated for a second star selected by the star selection routine or one selected by the crew.

After two stars have been marked, the sighting data display routine (R54) (paragraph 5.2.3.23.1) is performed to check the accuracy of the measurement. Then the gyro torquing routine (R55) (paragraph 5.2.3.24.2) is performed to torque the gyros, if desired, to the calculated stable member orientation. After torquing, the IMU orientation may be checked by performing another set of sightings. If the mode switch is in ATT Hold during (R55) the DAP will maneuver the vehicle to follow the platform.

5.2.3.24.1 Coarse Align Routine (R50). Coarse alignment of the IMU is performed by this routine (Fig. 5-44). This routine is automatically selected

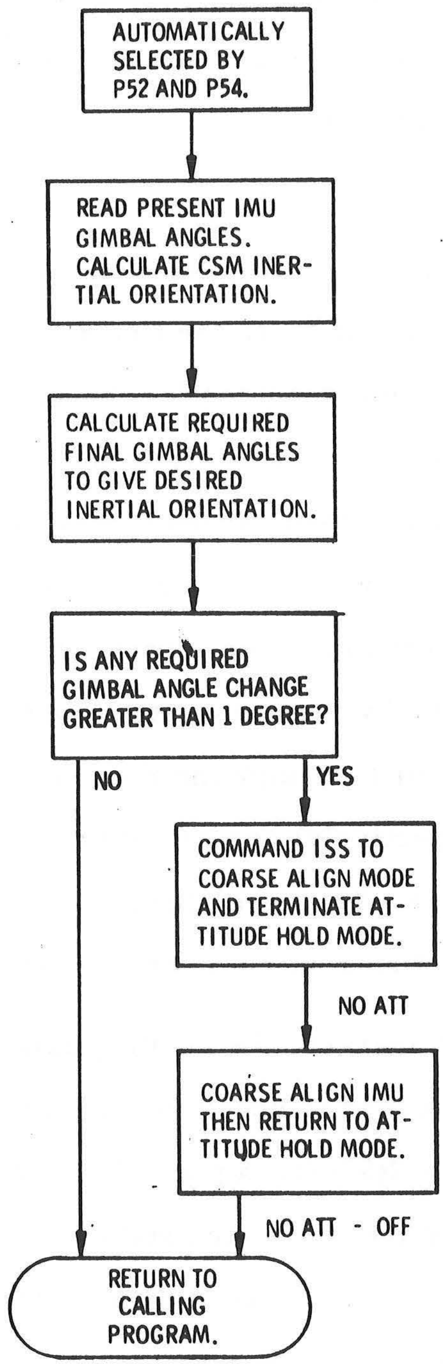


Fig. 5-44. Coarse Align Routine (R50)

by programs P52 and P54 to inertially stabilize the stable member at the preferred, landing site, or nominal orientation. It obtains present IMU orientation from the ICDU's and calculates the inertial orientation of the CSM. The desired orientation is obtained from storage and the required final gimbal angle changes are determined. If any of the gimbal angle changes are greater than one degree, the ISS is switched to the coarse align mode by the ISS error counter enable and coarse align discretes. The CMC provides to each error counter the number of pulses necessary to produce the desired analog drive signals. The NO ATT light is on for approximately 15 seconds. At the conclusion of this period the error counters are zeroed and the discretes removed and the ISS returns to the inertial mode.

5.2.5.24.2 Gyro Torquing Routine (R55). The gyro torquing routine (Fig. 5-45) is called automatically by P52 and P54, if necessary, after R54. This routine calculates the torquing angles required for each gyro and displays them. The present gimbal angles are obtained from the ICDU's. The required angles are obtained by transformation of the star sighting data obtained in R53 or R56. The CMC computes the rotation required about each axis to align the stable member to the desired orientation. The angle through which each gyro must be torqued is displayed on the DSKY. If the crew wishes the gyro to be torqued, the CMC generates the necessary pulses to each gyro.

5.2.3.25 Backup IMU Orientation Determination Program (P53)

This program (Fig. 5-46) is identical to P51 except that routine R56 is called instead of R53 and the optical sighting is done with the crew optical alignment sight (COAS). The program is used as a backup in case of OSS failure.

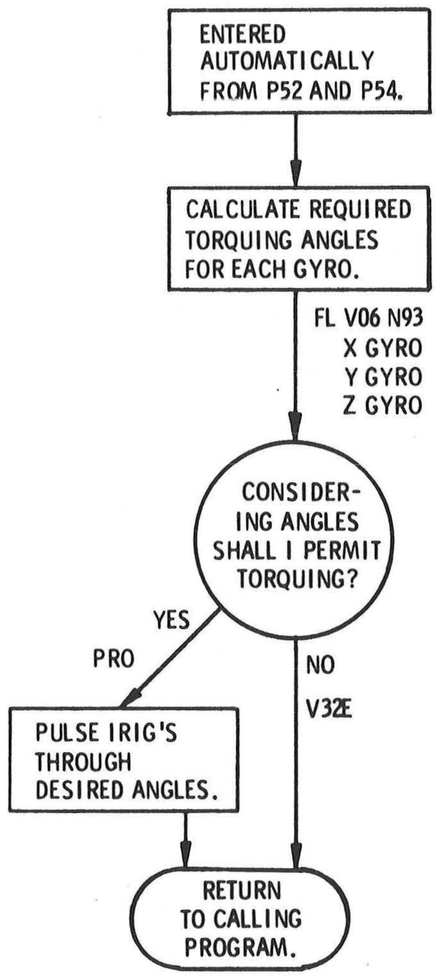


Fig. 5-45. Gyro Torquing Routine (R55)

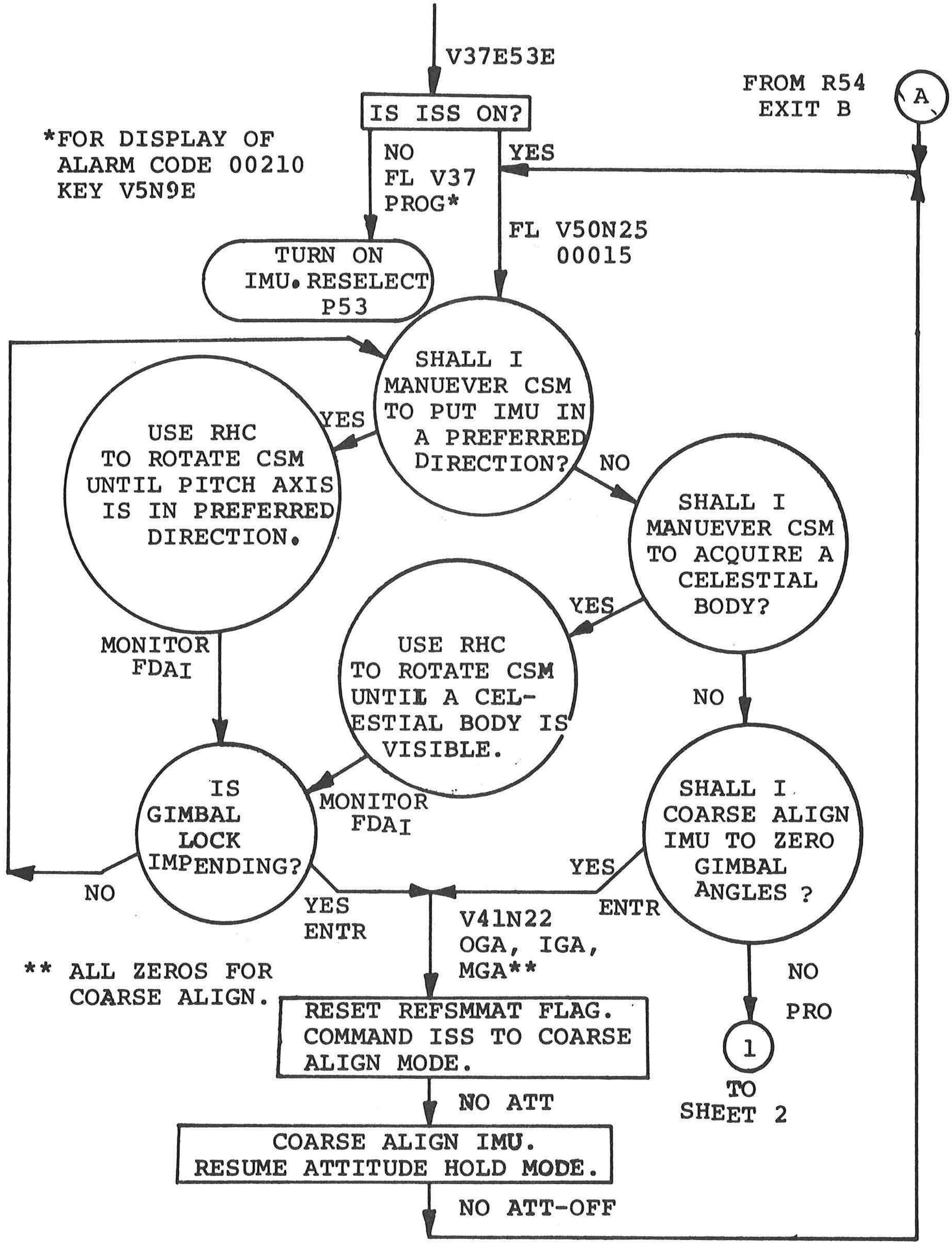


Fig. 5-46. Backup IMU Orientation Determination Program (P53). (Sheet 1 of 2)

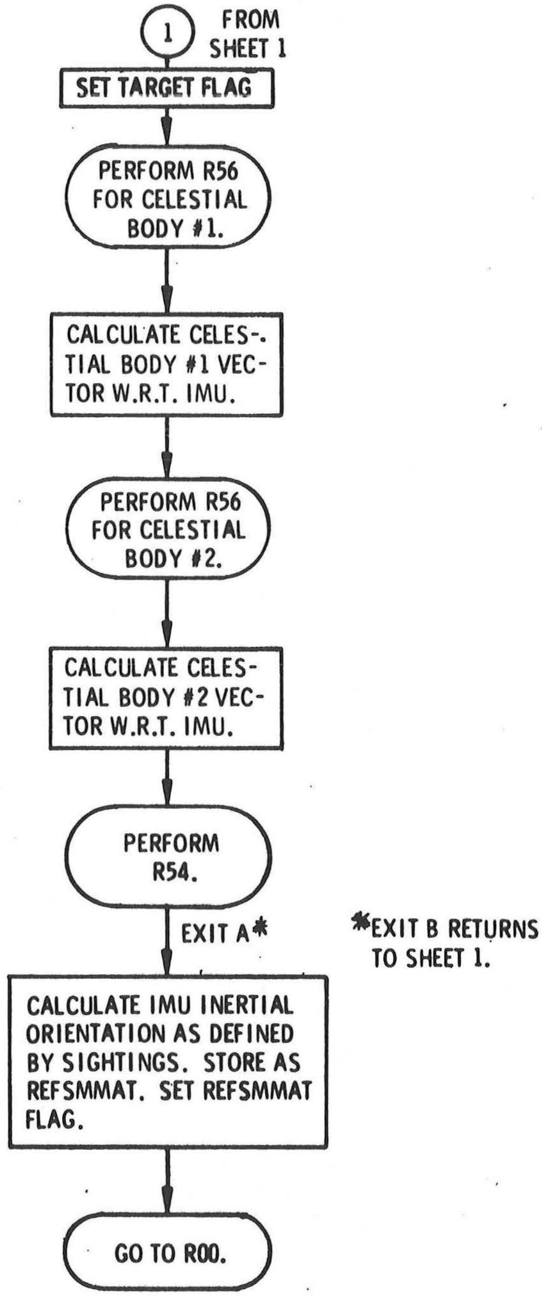


Fig. 5-46. Backup IMU Orientation Determination Program (P53) (Sheet 2 of 2)

5.2.3.26 Backup IMU Realign Program (P54)

This program (Fig. 5-47) is identical to P52 except that during fine alignment, routine R56 is called instead of R52 and R53 and optical sighting is done with the COAS. This program is used as a backup in case of OSS failure.

5.2.3.26.1 Alternate LOS Sighting Mark Routine (R56). This routine (Fig. 5-48) is used when the COAS is used for optical sightings (in programs P53 and P54). The COAS LOS is initially aligned with the SXT so that when a star sighting is made with the COAS, the CMC can transform the angles to SXT angles. These angles are used by the CMC for IMU alignment as if they were obtained by OSS sightings.

5.2.3.27 Entry Programs

The entry programs are performed in numerical sequence. During entry, the CMC controls the CM roll attitude which, in turn, controls the direction of aerodynamic lift and must be controlled such that the CM will land at the designated landing point. The SCS pitch and yaw attitude control loops are rendered inoperative. Lift is varied by rolling the CM about the entry roll axis, which is parallel to the navigation base and CM X axis. Because of the critical nature of the entry phase, it is necessary that the roll control loop respond rapidly to an error signal. This rapid response is obtained by scaling changes accomplished by switching from the RCS DAP to the entry DAP.

The entry programs include the following seven programs.

5.2.3.27.1 Entry Preparation Program (P61). This program (Fig. 5-49) starts navigation, checks IMU alignment, and provides entry monitor initialization data. This program calls state vector integration routine (R41) (paragraph 5. 2. 3. 20. 1) then displays impact latitude and longitude and entry roll attitude, parameters which the crew may change if unsatisfactory. The program then displays G max,

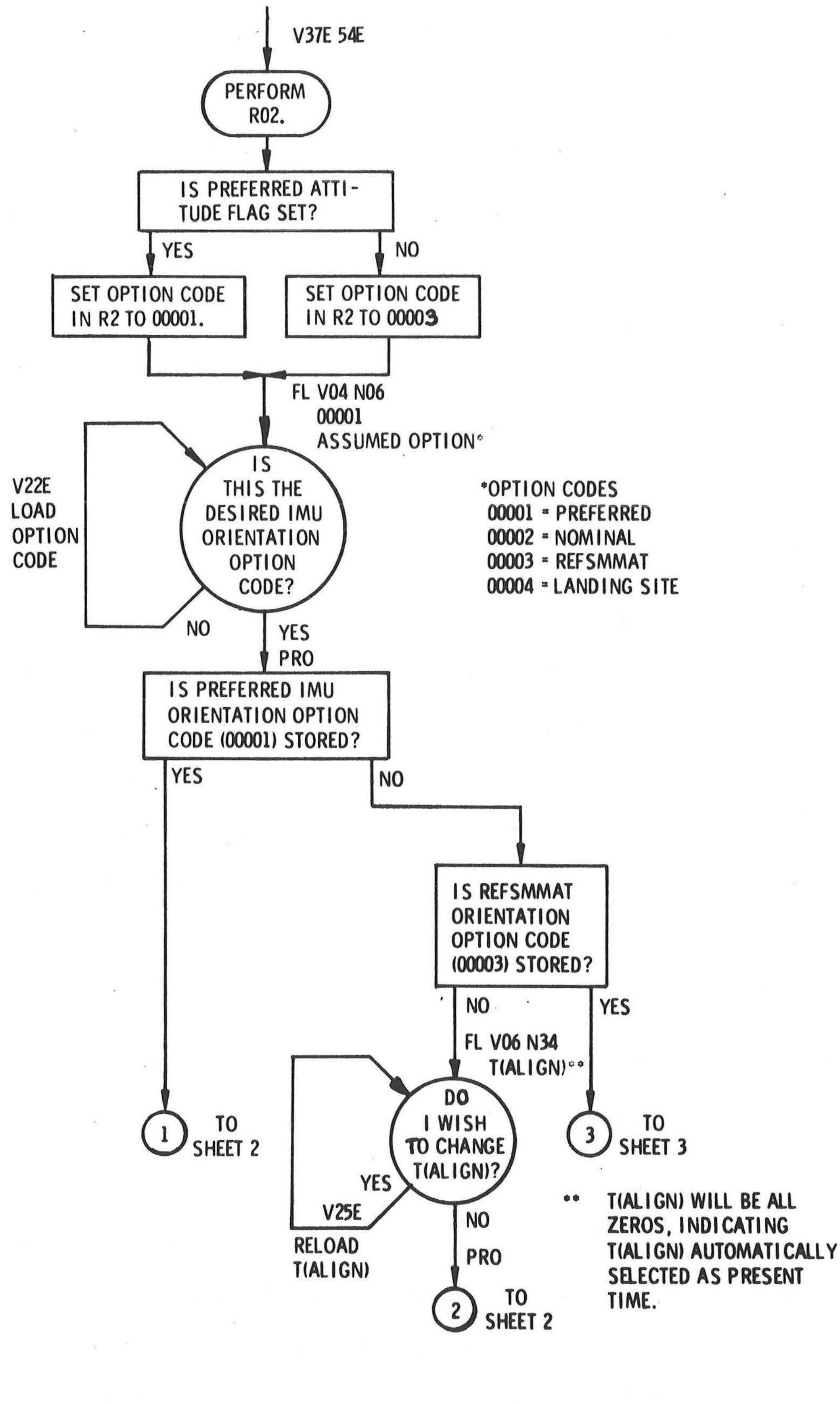


Fig. 5-47. Backup IMU Realign Program (P54) (Sheet 1 of 4)

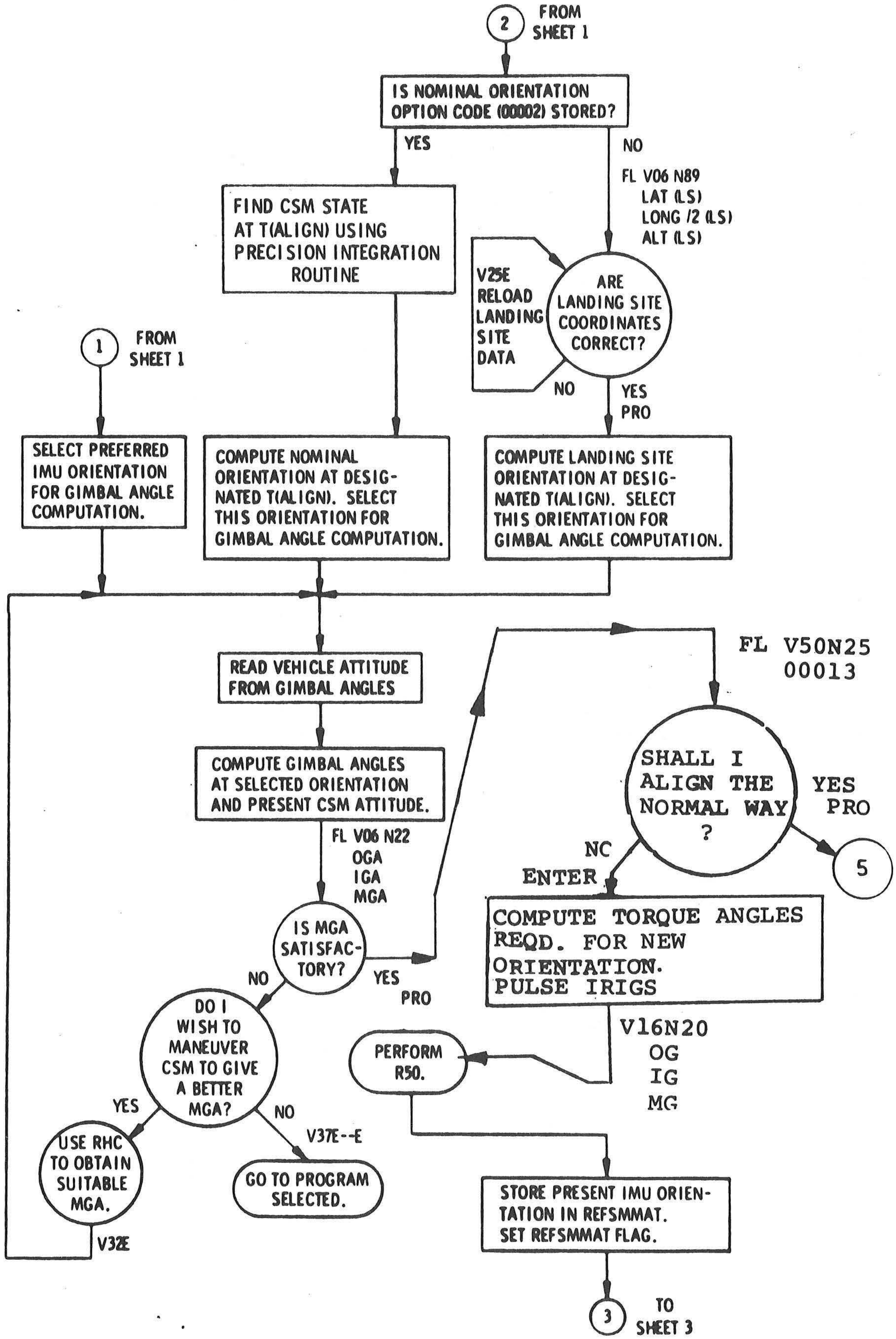


Fig. 5-47. Backup IMU Realign Program (P54) (Sheet 2 of 4)

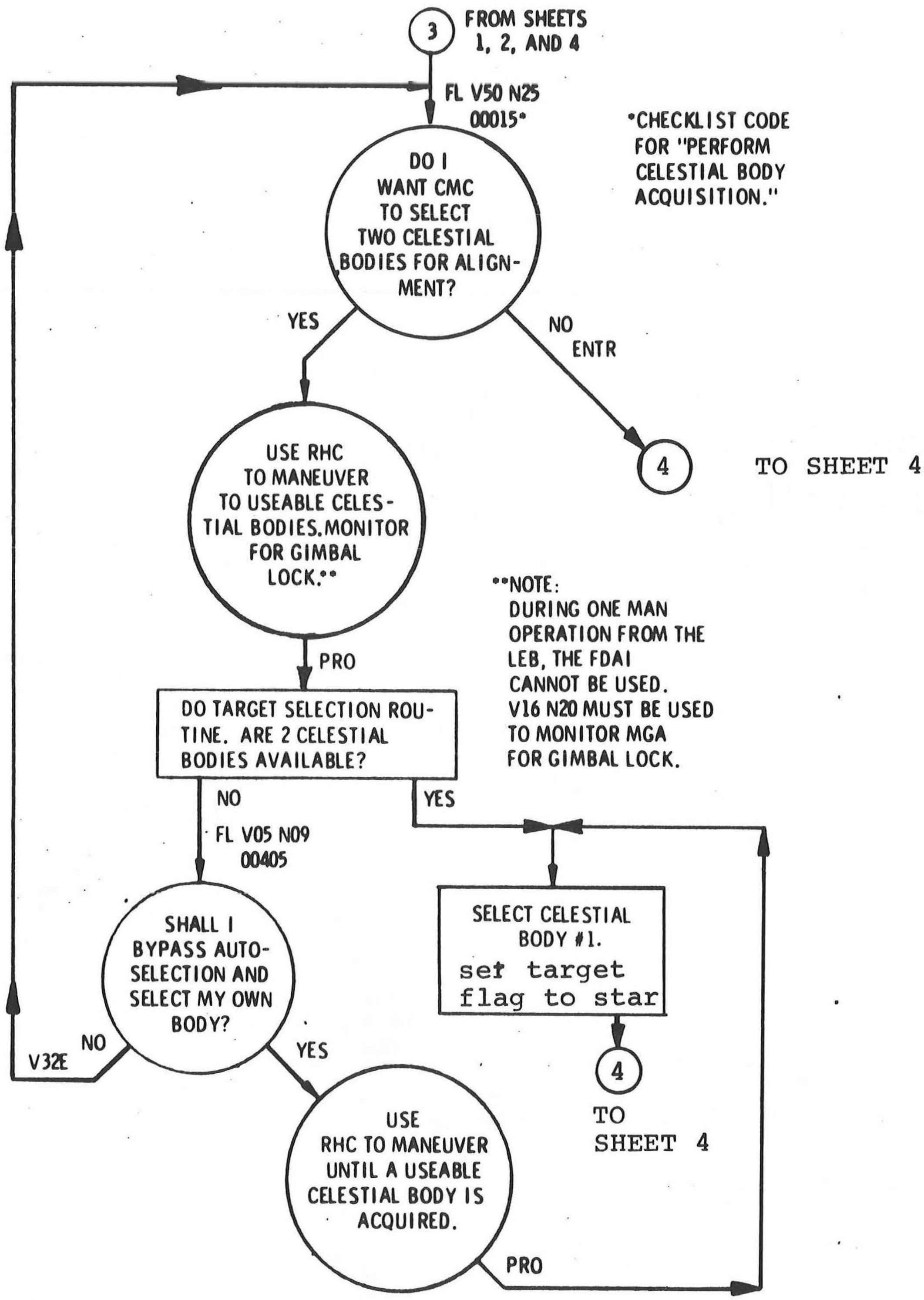


Fig. 5-47. Backup IMU Realign Program (P54) (Sheet 3 of 4)

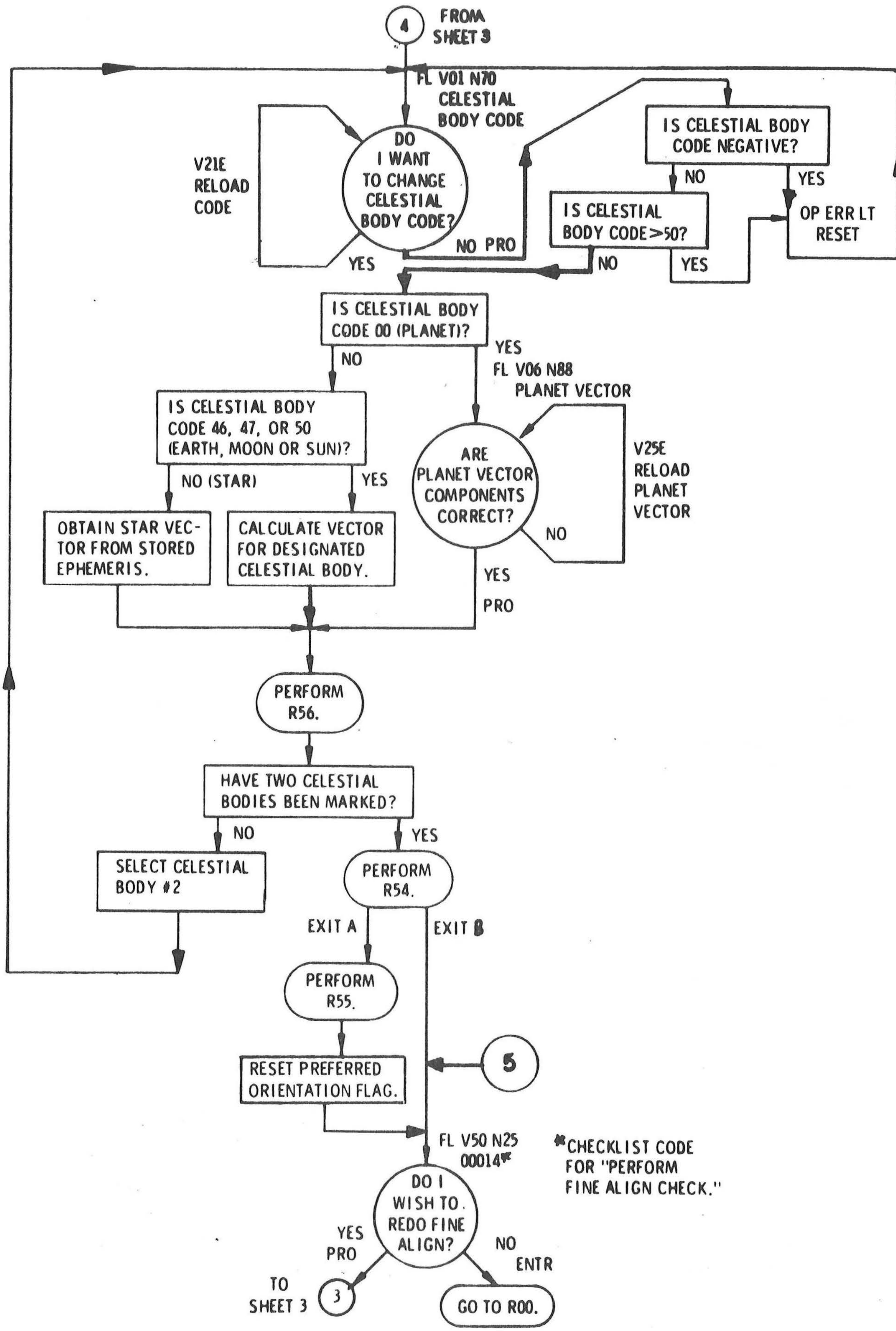


Fig. 5-47. Backup IMU Realign Program (P54) (Sheet 4 of 4)

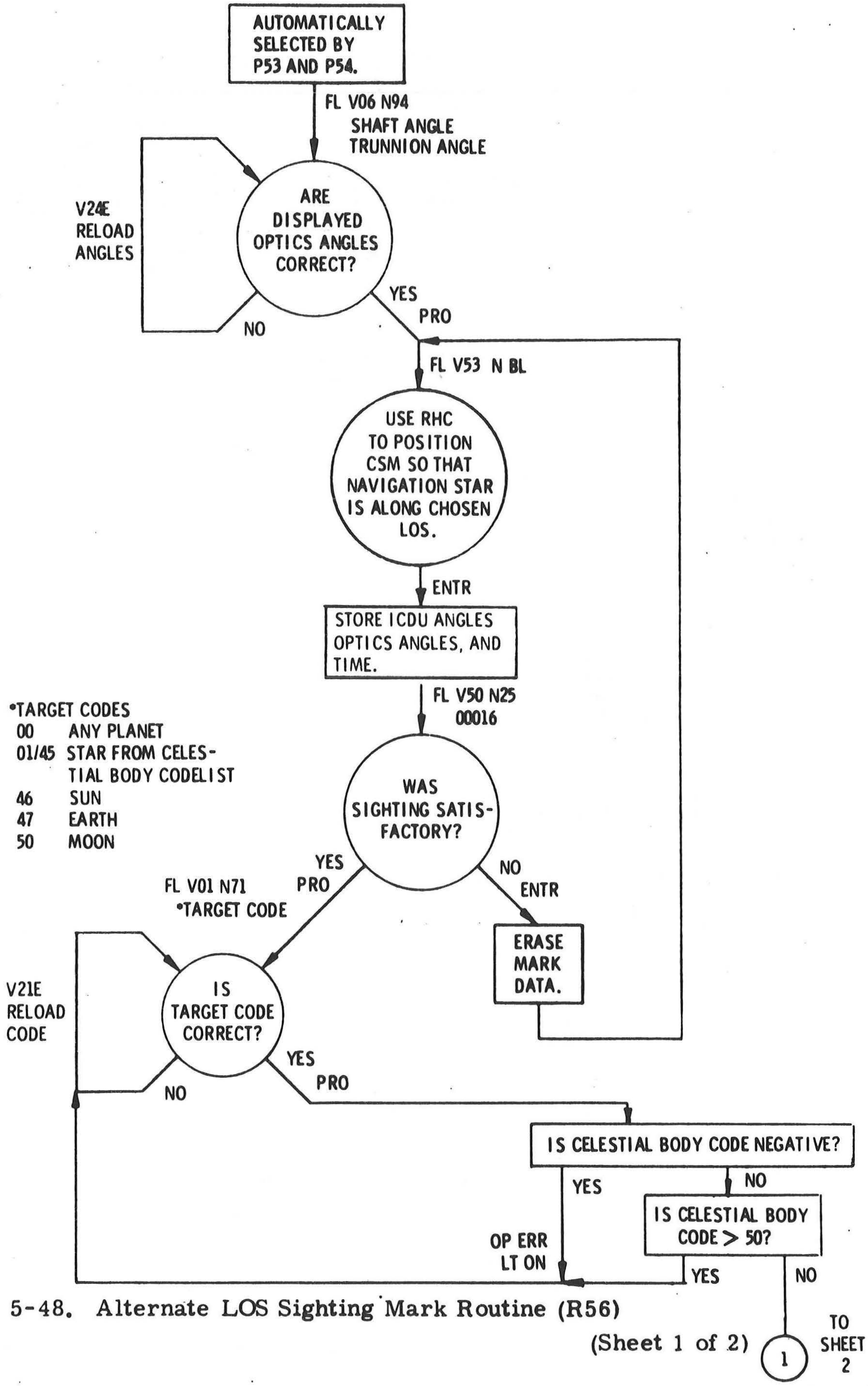


Fig. 5-48. Alternate LOS Sighting Mark Routine (R56)

(Sheet 1 of 2)

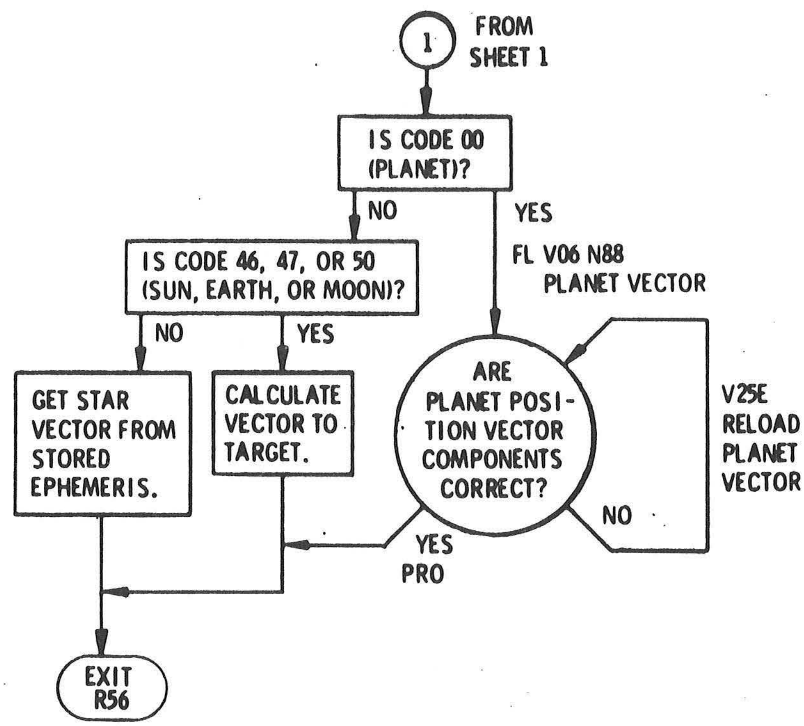


Fig. 5-148. Alternate LOS Sighting Mark Routine (R56) (Sheet 2 of 2)

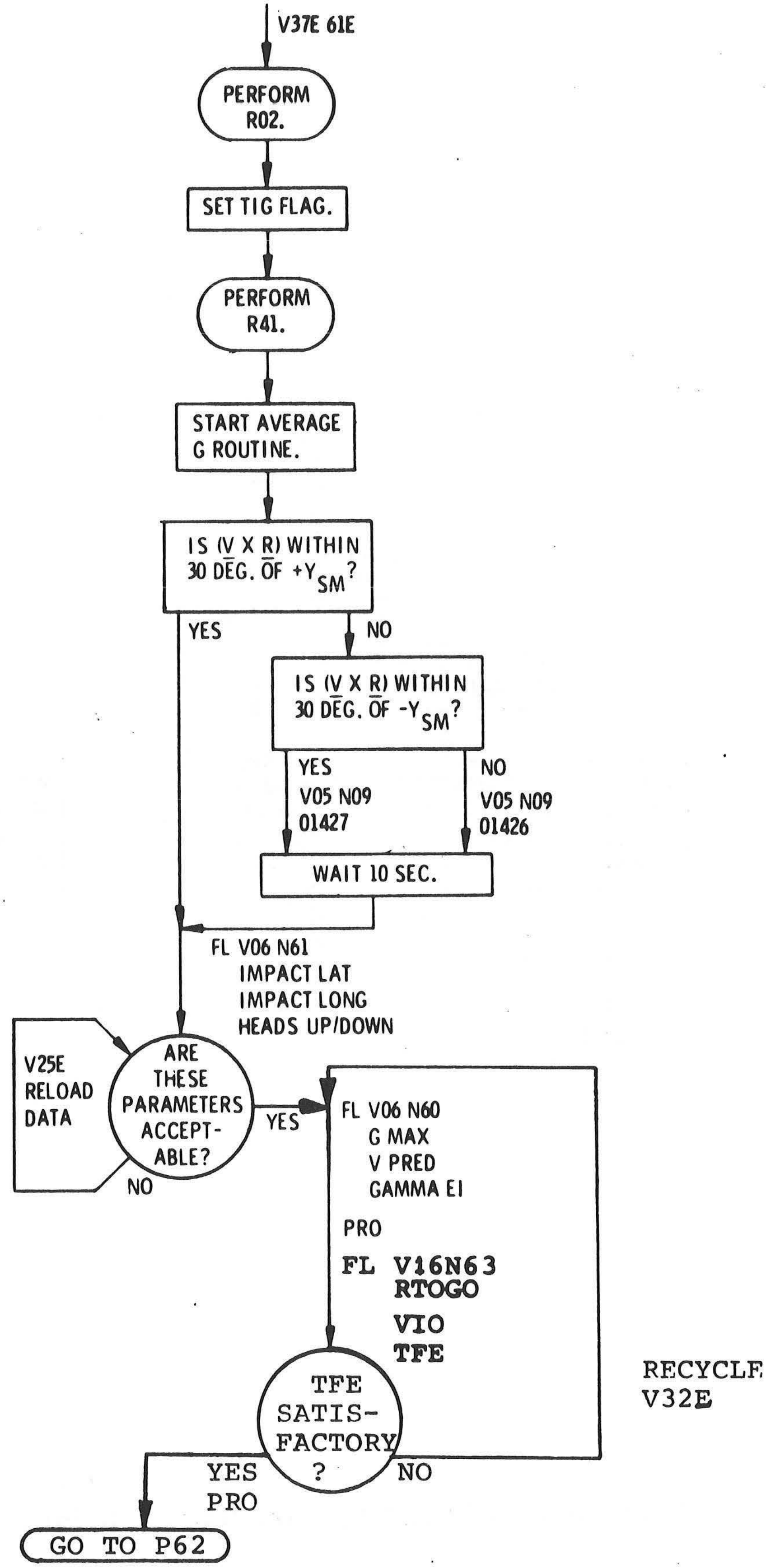


Fig. 5-49. Entry Preparation Program (P61)

predicted velocity, and flight path angle; followed by range to go to preloaded altitude, predicted inertial velocity at that altitude, and time to go until that altitude is reached.

5.2.3.27.2 CM/SM Separation and Preentry Maneuver Program (P62). This program (Fig. 5-50) notifies the crew when the CM/SM separation should be performed and orients the CM for atmospheric entry. The separation is accomplished by manually setting the SEP switches on. Prior to requesting separation, if P61 was bypassed, state vector integration routine (R41) (paragraph 5.2.3.20.1) is performed and average g started. The CMC warns of unsatisfactory or inverted IMU. This is done because program P62 can be entered manually by V37E 62E to bypass P61. After separation, the CMC switches to the entry DAP and displays the impact coordinates for astronaut approval. The CMC computes the CM inertial attitude for entry into the atmosphere and displays the final gimbal angles. It maneuvers the CM until the angle of attack (alpha) is less than 45 degrees and then automatically enters P63.

5.2.3.27.3 Entry Initialization Program (P63). The entry initialization program (Fig. 5-51) initializes the entry equations, hold the CM at the proper attitude, establishes entry displays (acceleration, inertial velocity, and range to impact point), and monitors for 0.05g. When 0.05g is reached, the entry DAP configuration is changed and program P64 is automatically entered. If P64 is not entered at 0.05g, the remainder of the entry is controlled manually.

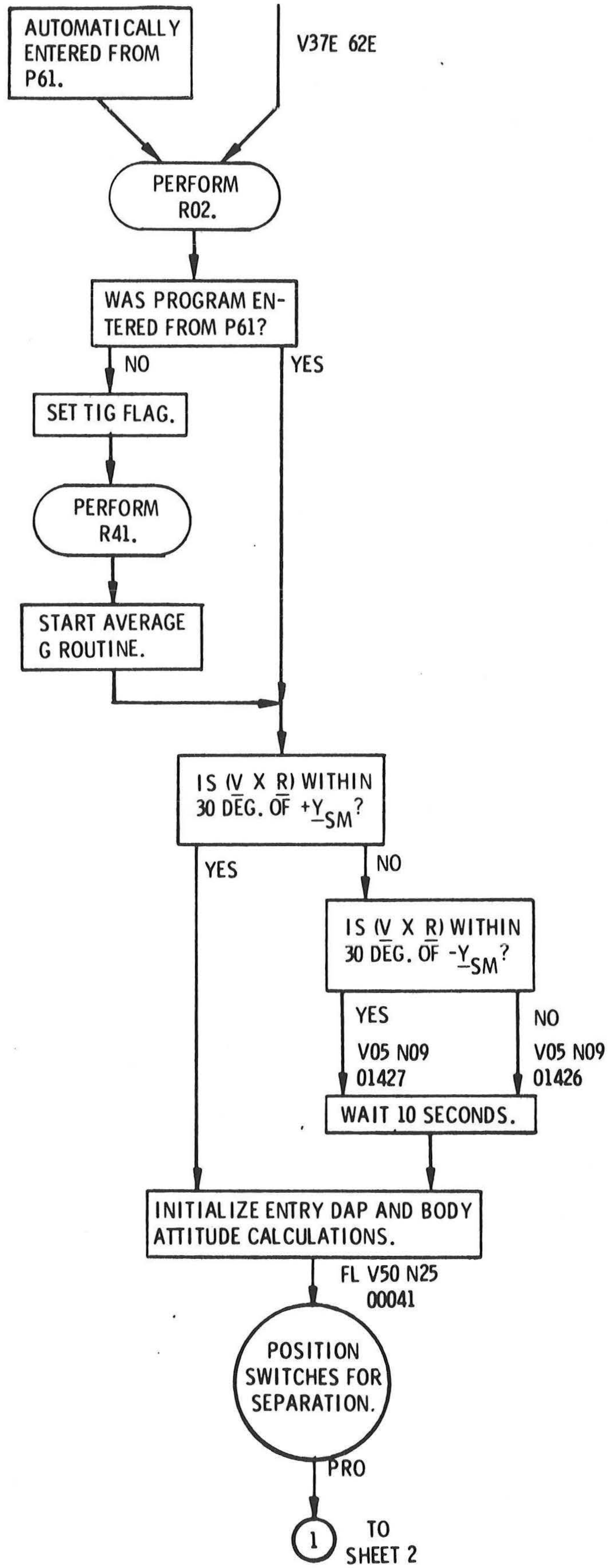


Fig. 5-50. CM/SM Separation and Preentry Maneuver Program (P62) (Sheet 1 of 2)

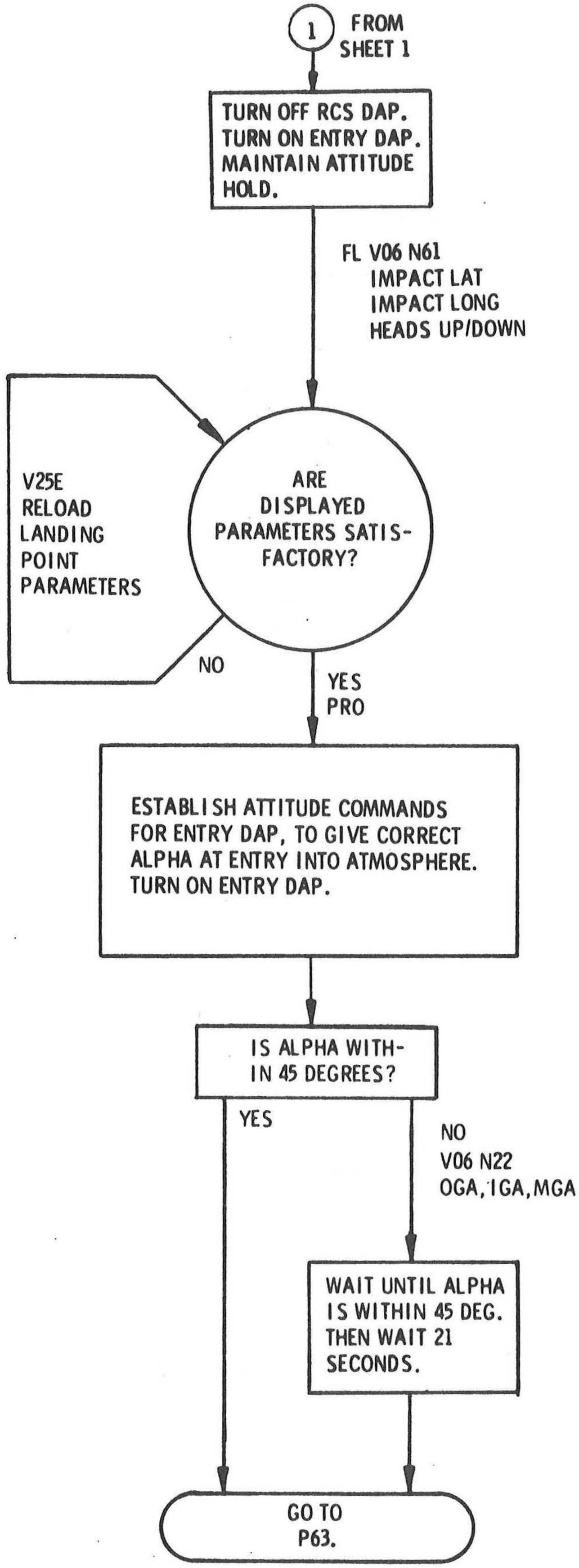


Fig. 5-50. CM/SM Separation and Preentry Maneuver Program (P62)
(Sheet 2 of 2)

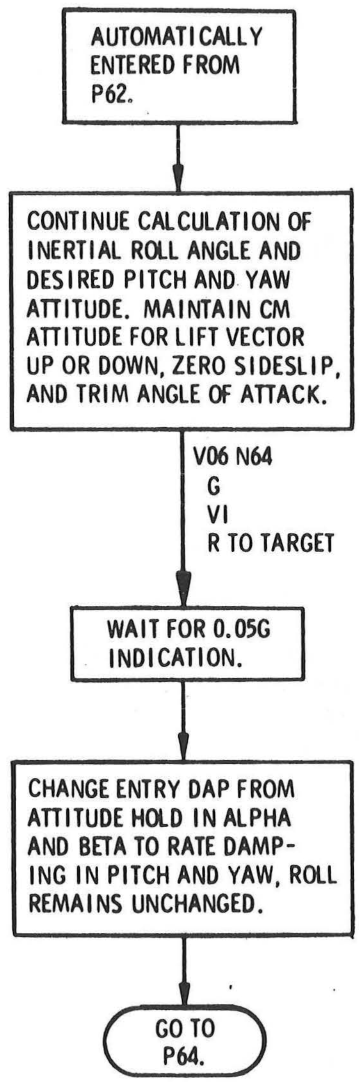


Fig. 5-51. Entry Initialization Program (P63)

5.2.3.27.4 Post 0.05g Program (P64). The post 0.05g program (Fig. 5-52) starts the entry guidance, establishes the SCS 0.05g mode, and displays commanded bank angle (beta), inertial velocity, and drag acceleration. At the start of this program, the commander must set the 0.05G-ENTRY switch on and then monitor the DSKY. If velocity is 27,000 feet per second or greater at the first 0.05g point, program P65 is entered. If the velocity is less than 27,000 feet per second, at about 0.2g, program P67 is entered.

5.2.3.27.5 Up Control Program (P65). The up control program (Fig. 5-53) steers the CM to a controlled skip-out condition and monitors for exit (drag acceleration less than a prescribed value). It displays commanded bank angle (beta), drag acceleration, and skip-out velocity; followed by beta, inertial velocity, and drag acceleration. When drag acceleration falls below exit threshold, program P66 is entered. When rate of change of range is negative and velocity is sufficiently low, P67 is entered.

This program is not used on earth orbit missions.

5.2.3.27.6 Ballistic Program (P66). The ballistic program (Fig. 5-54) maintains the CM attitude for atmospheric reentry during ballistic (skip-out) phase of the entry and monitors drag acceleration for entering final phase of entry. It establishes entry DAP attitude commands for proper angle of attack and calculates and displays required final gimbal angles. When drag acceleration reaches about 0.2g, the entry final phase program P67 is entered.

5.2.3.27.7 Entry Final Phase Program (P67). The entry final phase program (Fig. 5-55) continues entry guidance until termination of steering (when CM velocity with respect to earth decreases to 1000 feet per second). One entering this program, commanded bank angle and cross range and down range errors are displayed, followed by a display of range to splash point and

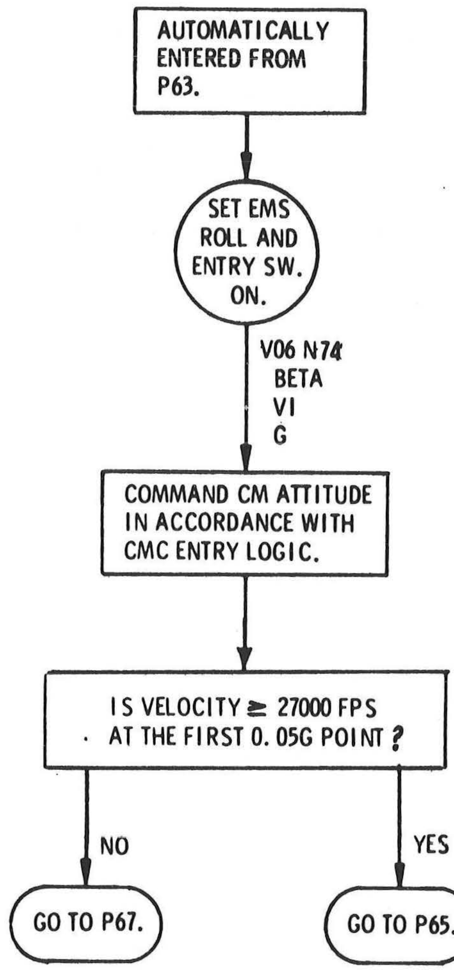


Fig. 5-52. Post 0.05G Program (P64)

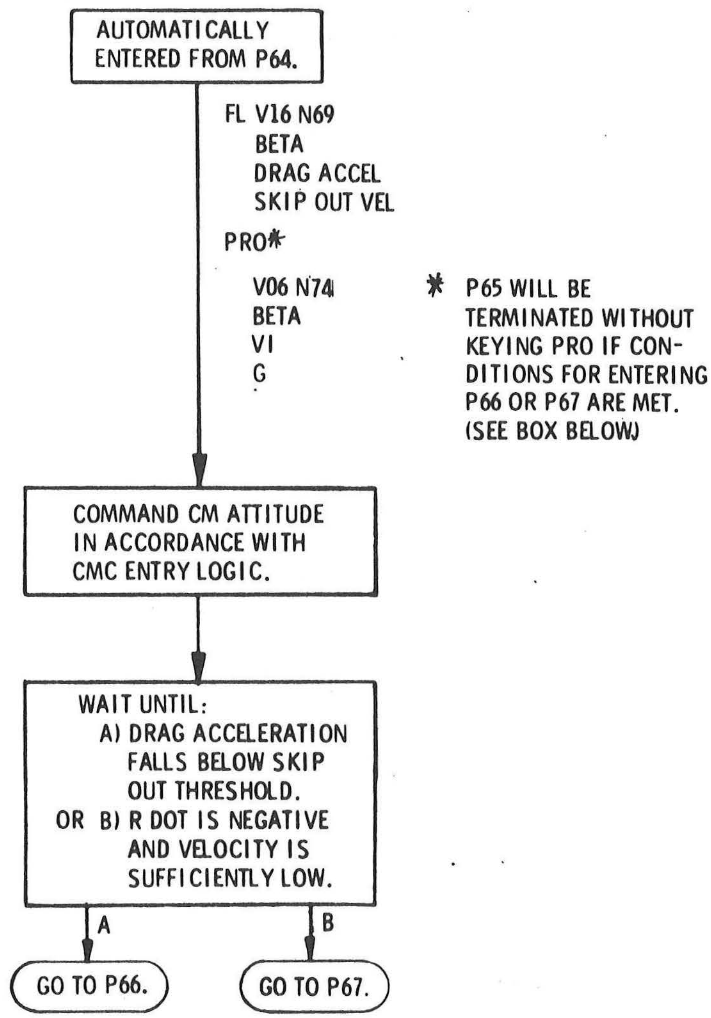


Fig. 5-53. Up Control Program (P65)

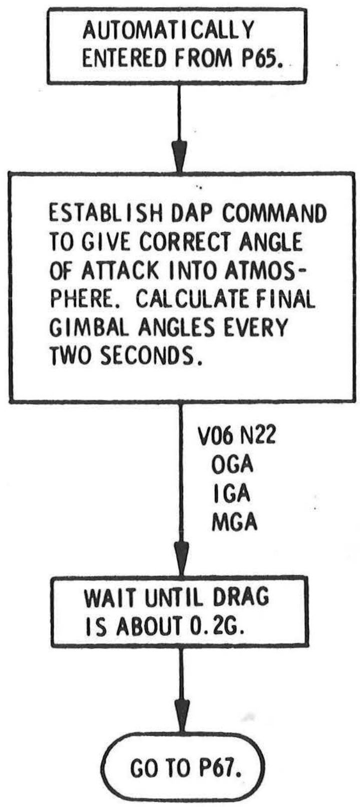


Fig. 5-54. Ballistic Program (P66)

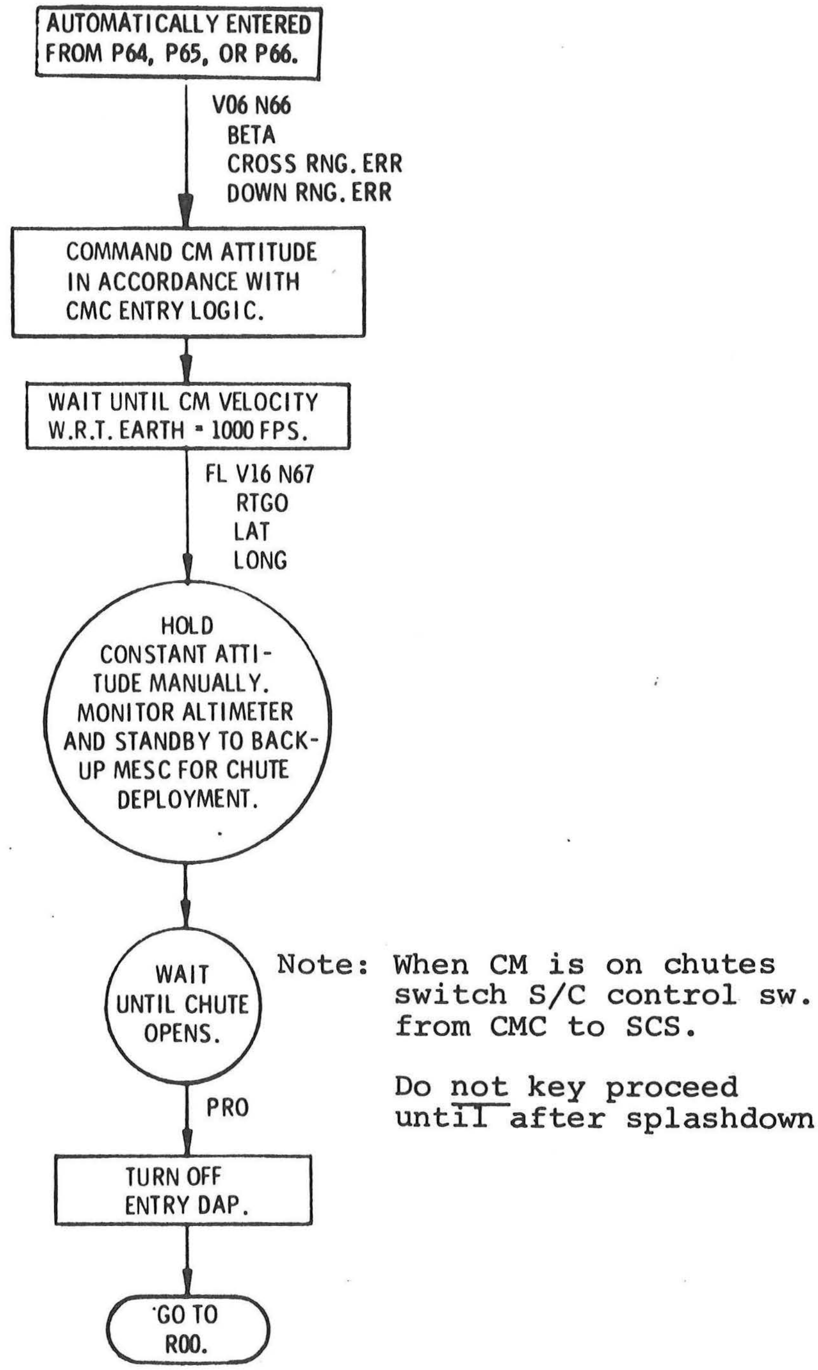


Fig. 5-55. Entry Final Phase Program (P67)

present CM latitude and longitude. The crew monitors the altimeter and stands by to deploy the chutes (at 65,000 feet) in case the MESC does not. When chutes are open, the CMC idling program is selected.

5.2.3.28 LM Targeting Programs (P72, P73, P74, P75, P77, P78, and P79)

Programs P72, P73, P74, P75, P77, P78, and P79 (Figs. 5-55A, 5-55B, 5-56, 5-57, 5-59, 5-60, and 5-61) are equivalent in most respects to programs P32, P33, P34, P35, P17, P38, and P39 (paragraphs 5.2.3.14A, 5.2.3.14B, 5.2.3.15, 5.2.3.16, 5.2.3.7, 5.2.3.18, and 5.2.3.19) respectively. The difference is that in the P70's the CMC calculates the parameters for a LM maneuver. Consequently, the active vehicle flag is set to LM and additional time is required for transmitting the calculated parameters to the LM by voice link.

5.2.3.29 Target Delta V Program (P76)

The target delta V program (Fig. 5-58) is used to notify the CMC that the LM has changed its orbital parameters by performing a thrusting maneuver, and to supply the CMC with the LM delta V to enable updating the LM state vector in the CMC. If P20 is in process, rendezvous marking should be stopped and this program performed before the LM thrusting maneuver. Marking should not be restarted until after the LM maneuver and LM state vector update.

5.2.3.30 Final Automatic Request Terminate Routine (R00)

This routine (Fig. 5-62) provides an exit for most programs and provides an option to select any desired program. The flash of V37 is a request to select a new program. Upon keying in the new program, routine R00 turns off the TVC DAP, engine on command, and average g calculation. The selected program is entered, if it is not P00 or P20.

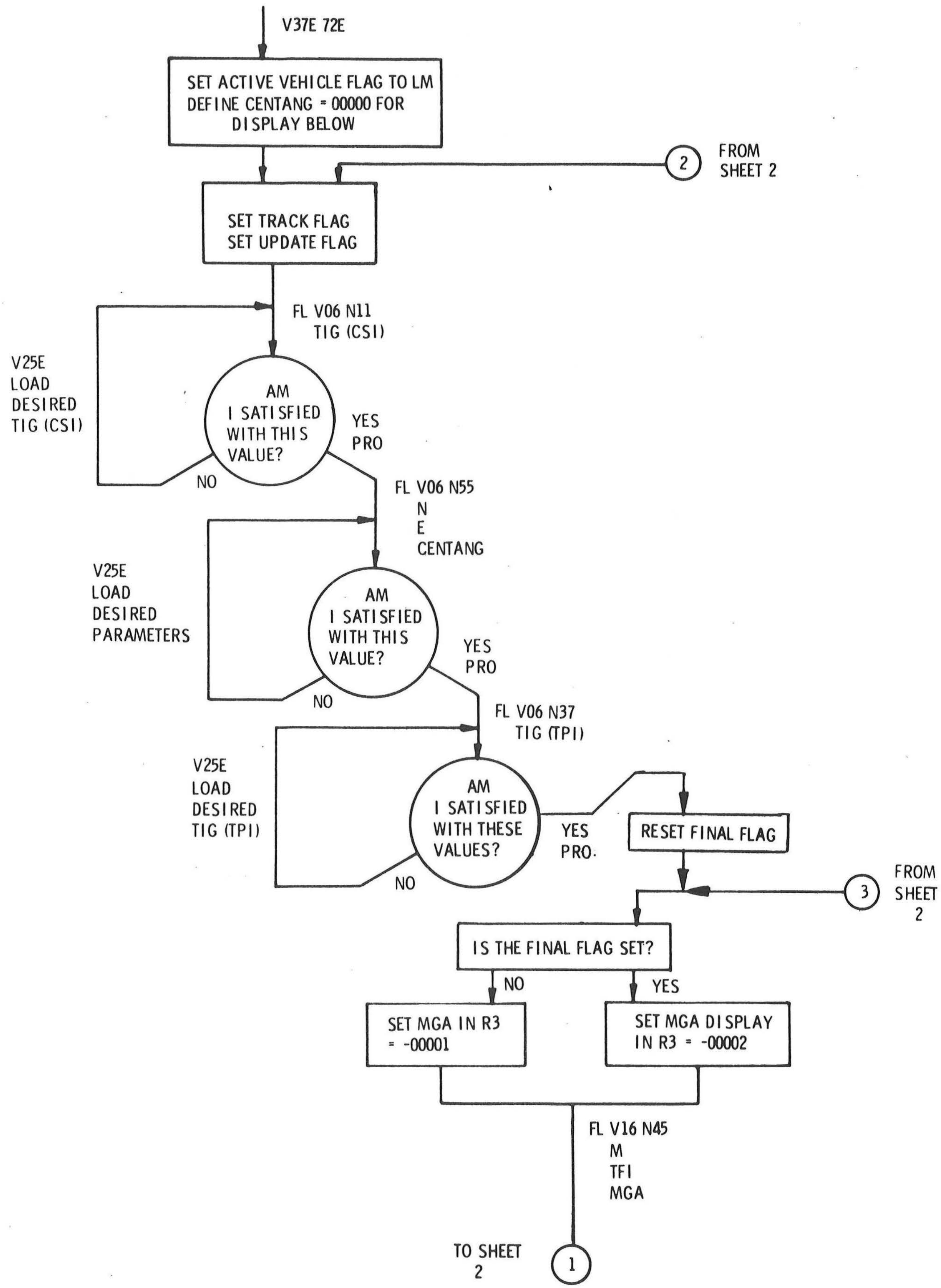


Fig. 5-55A. LM Co-Eliptic Sequence Initiation (CSI) Program (P-72) (Sheet 1 of 2)

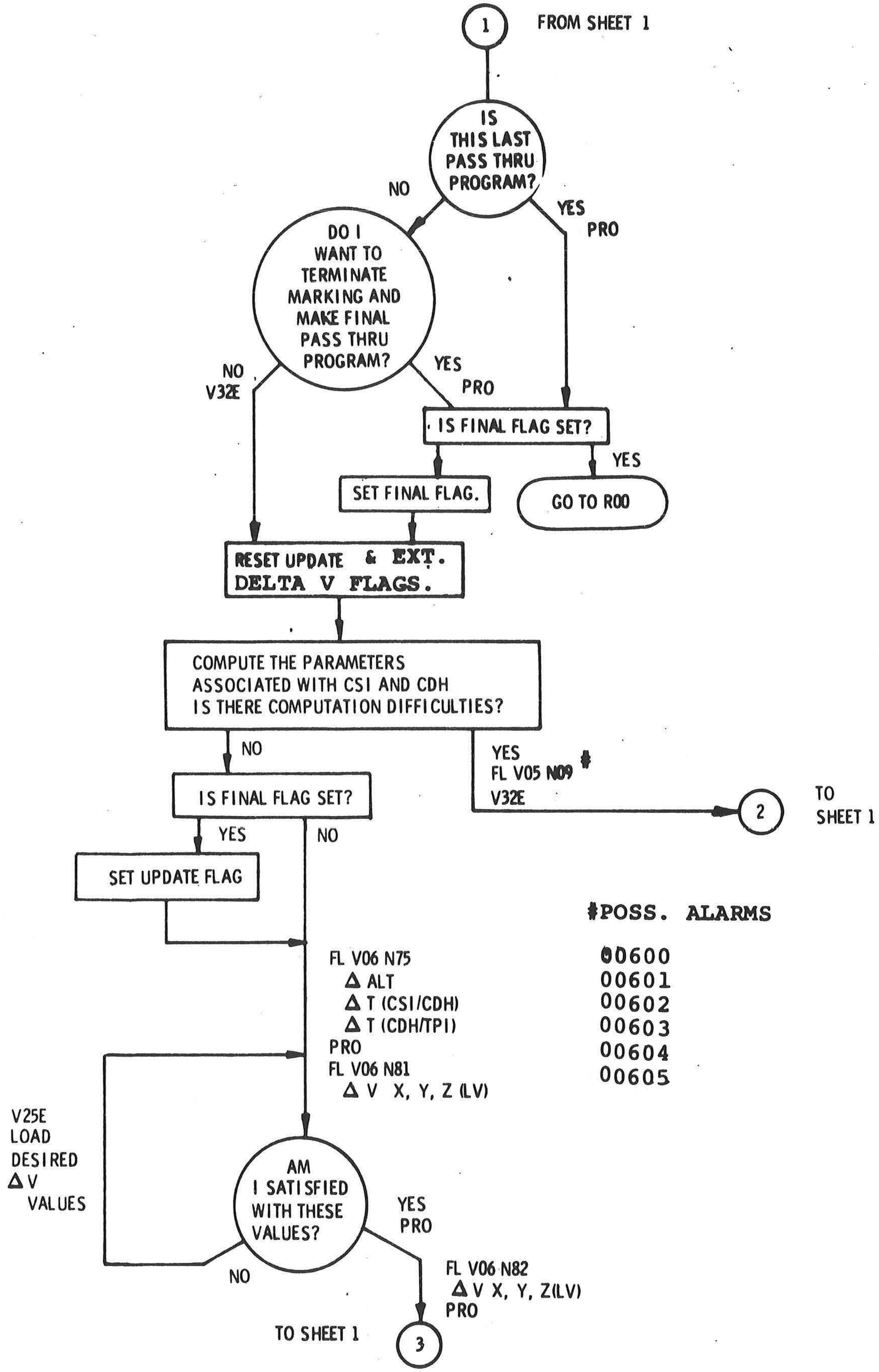


Fig. 55A. LM Co-Eliptic Sequence Initiation (CSI) Program (P72) (Sheet 2 of 2)

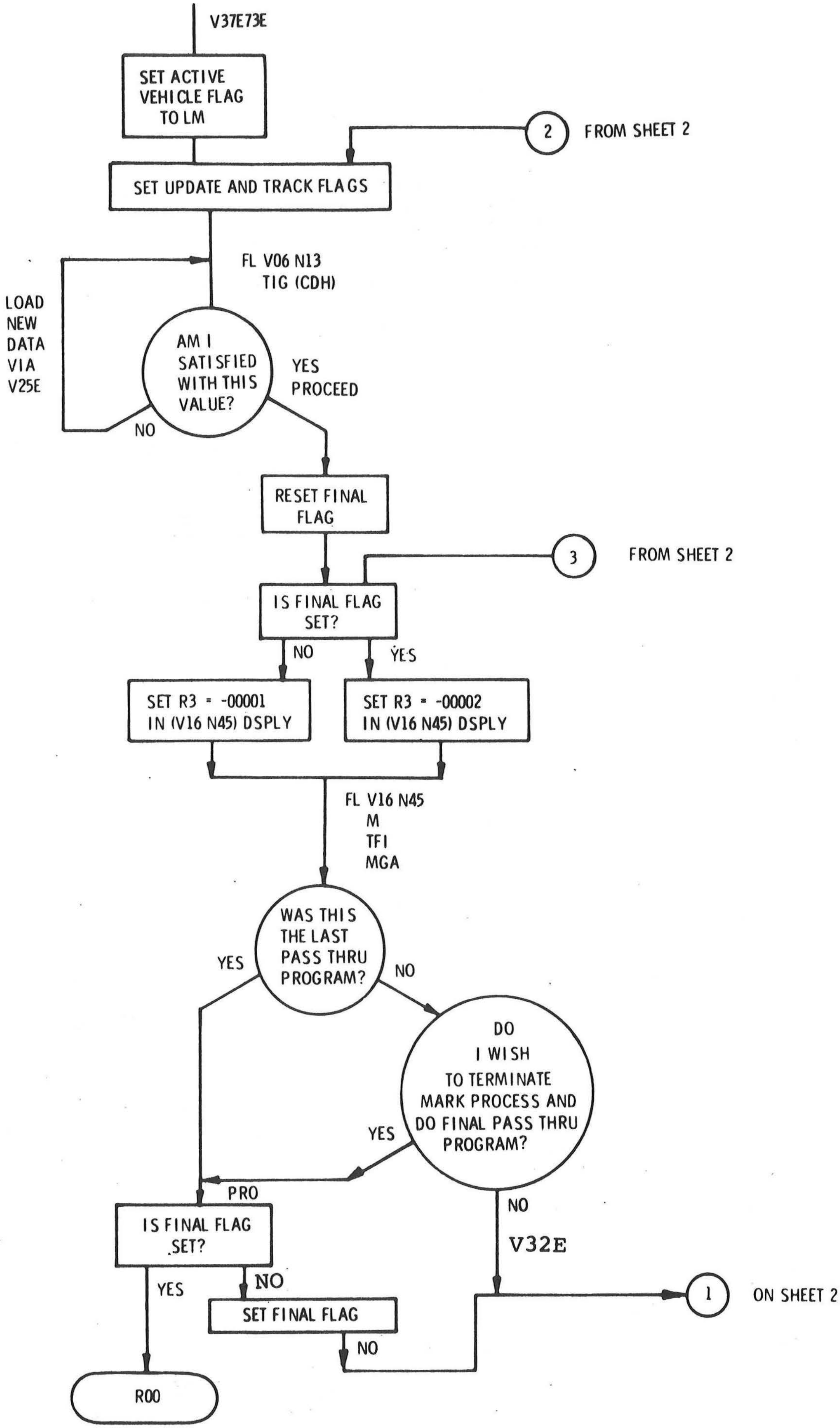


Fig. 5-55B. LM Constant Delta Altitude (CDH) Targetting Program (P73) (Sheet 1 of 2)

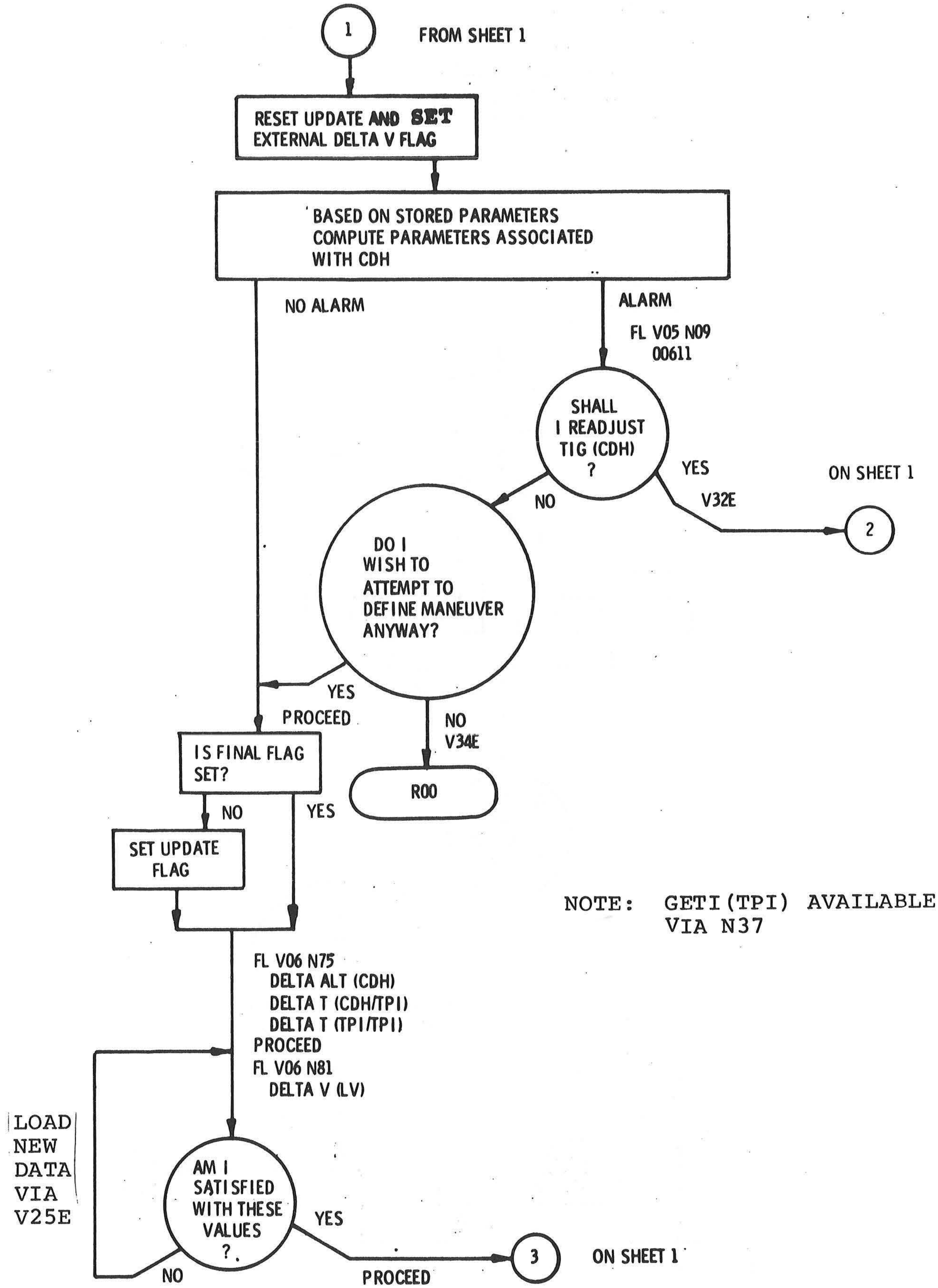


Fig. 5-55B. LM Constant Delta Altitude (CDH) Targetting Program (P73) (Sheet 2 of 2)

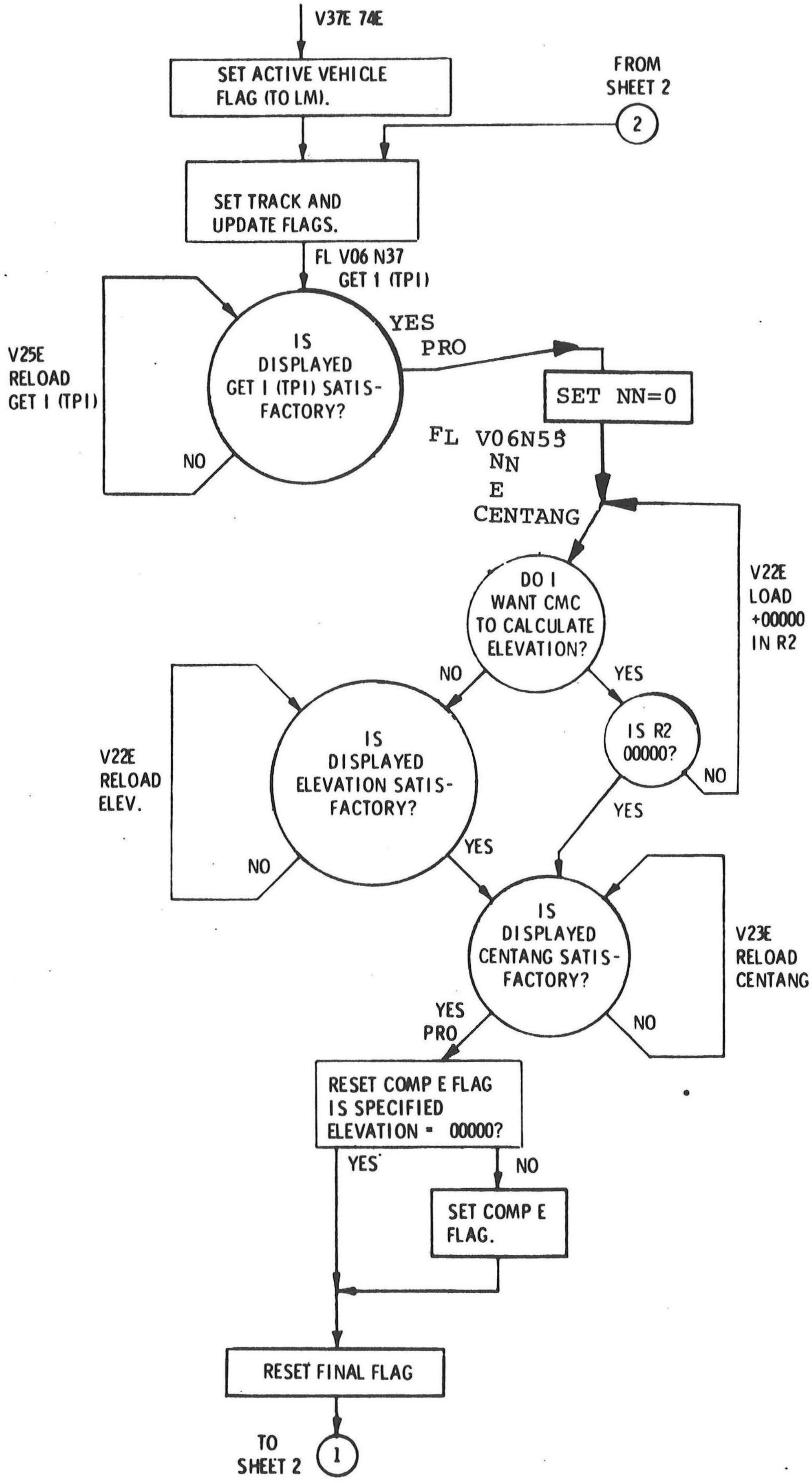


Fig. 5-56. LM Transfer Phase Initiation Program (P74) (Sheet 1 of 3)

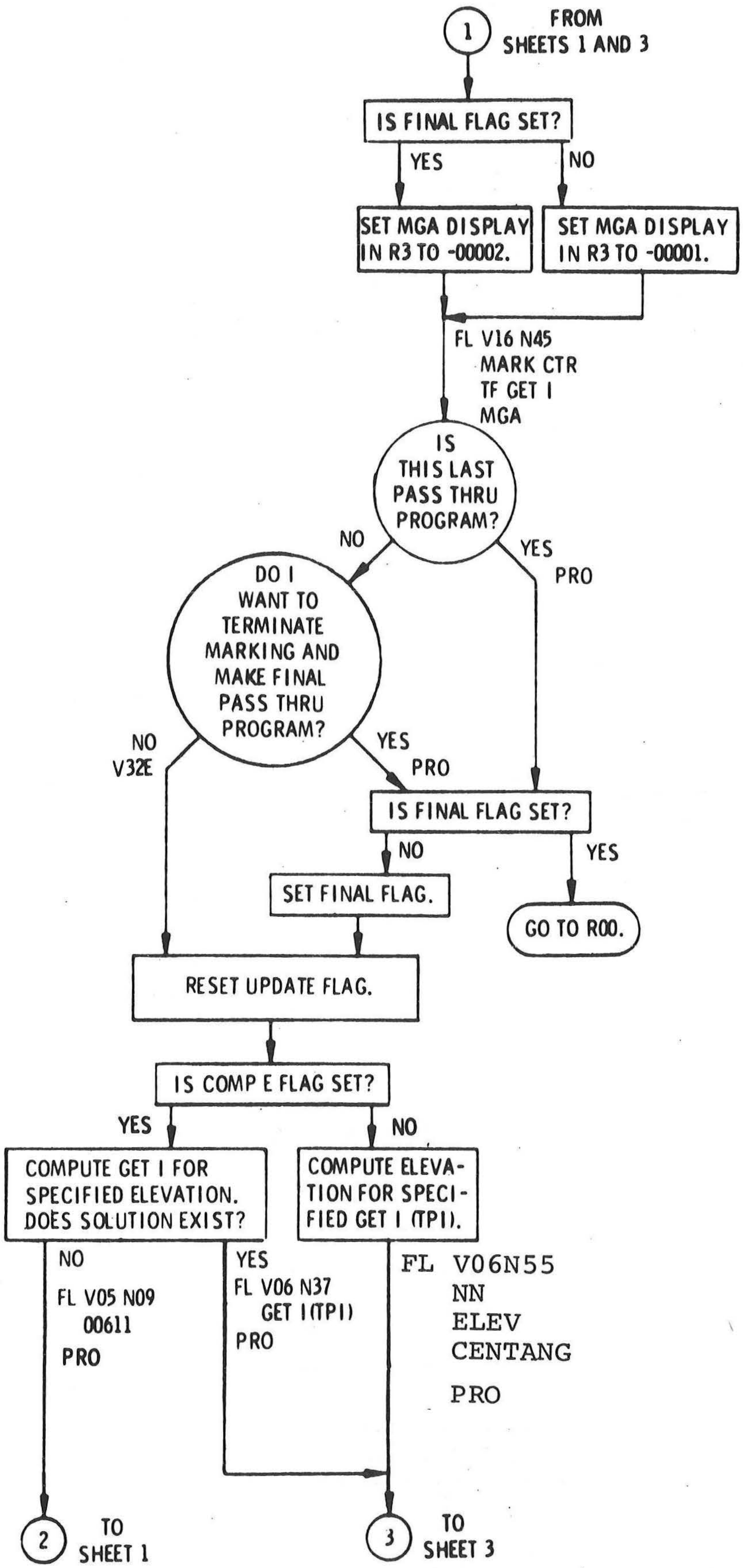


Fig. 5-56. LM Transfer Phase Initiation Program (P74) (Sheet 2 of 3)

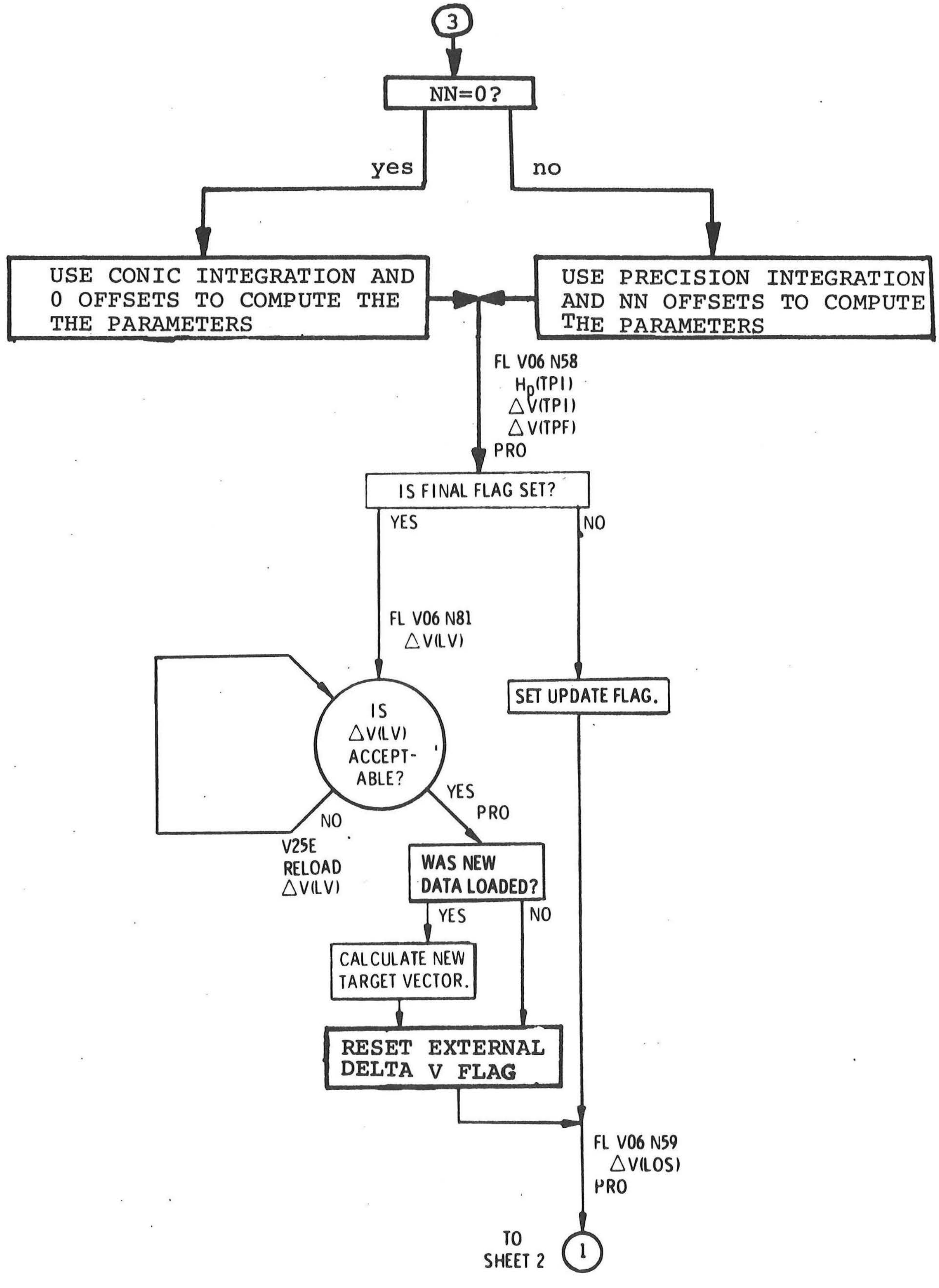


Fig. 5-56. LM Transfer Phase Initiation Program (P74) (Sheet 3 of 3)

Page 5-158 deleted.

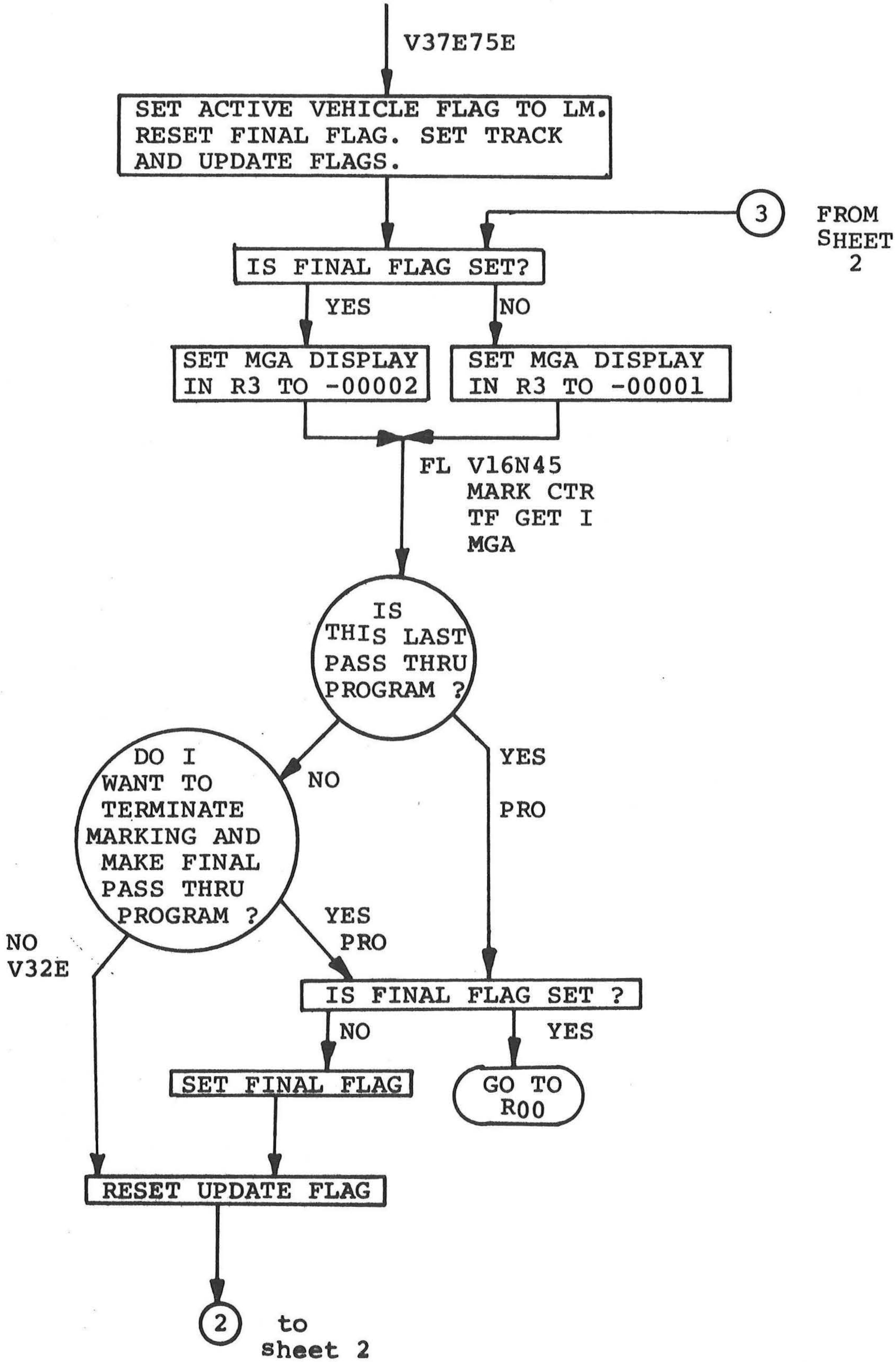


Fig. 5-57. LM Transfer Phase Midcourse Program(P75) (Sheet 1 of 2)

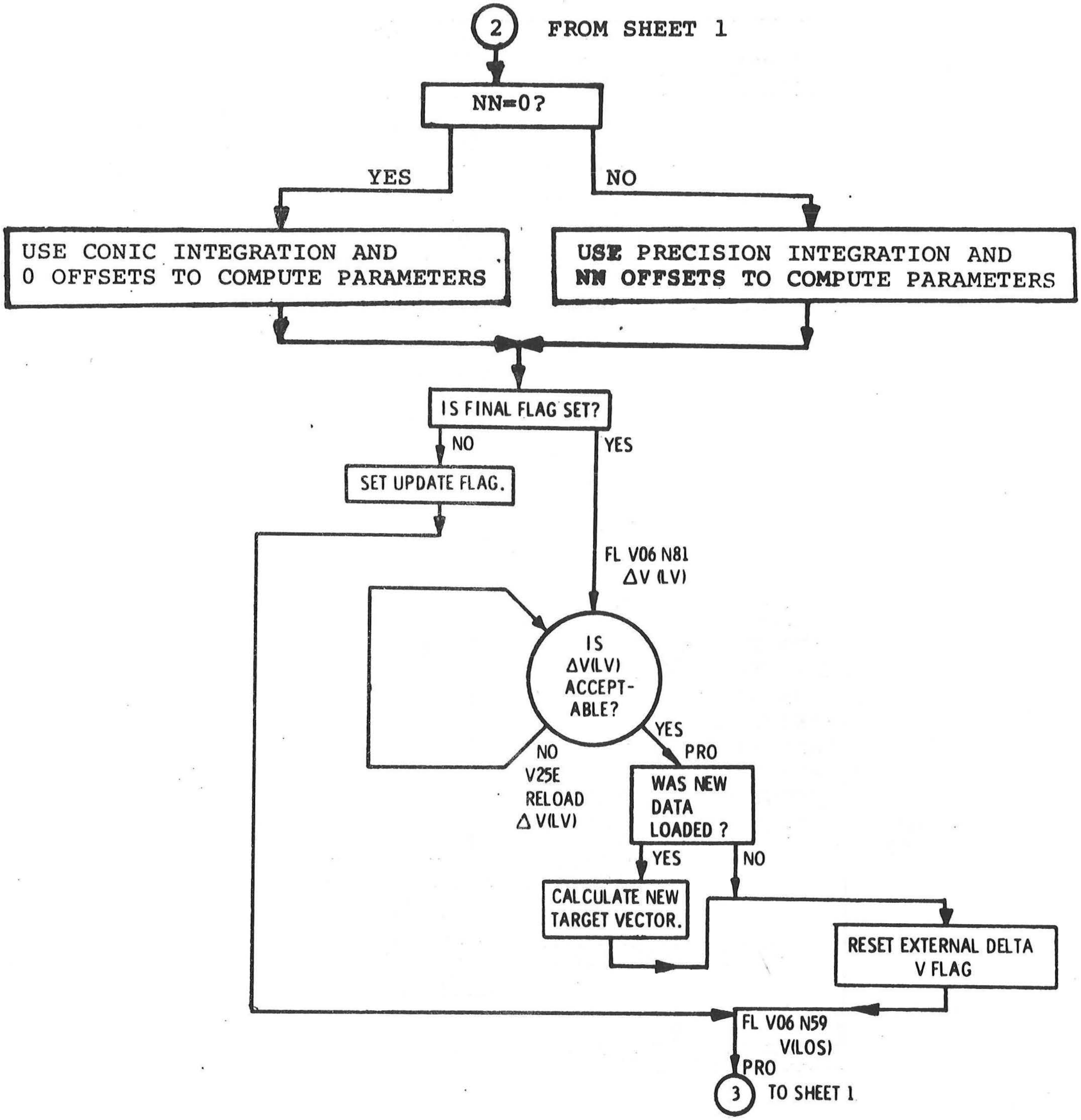


Fig. 5-57. LM Transfer Phase Midcourse Program (P75) (Sheet 2 of 2)

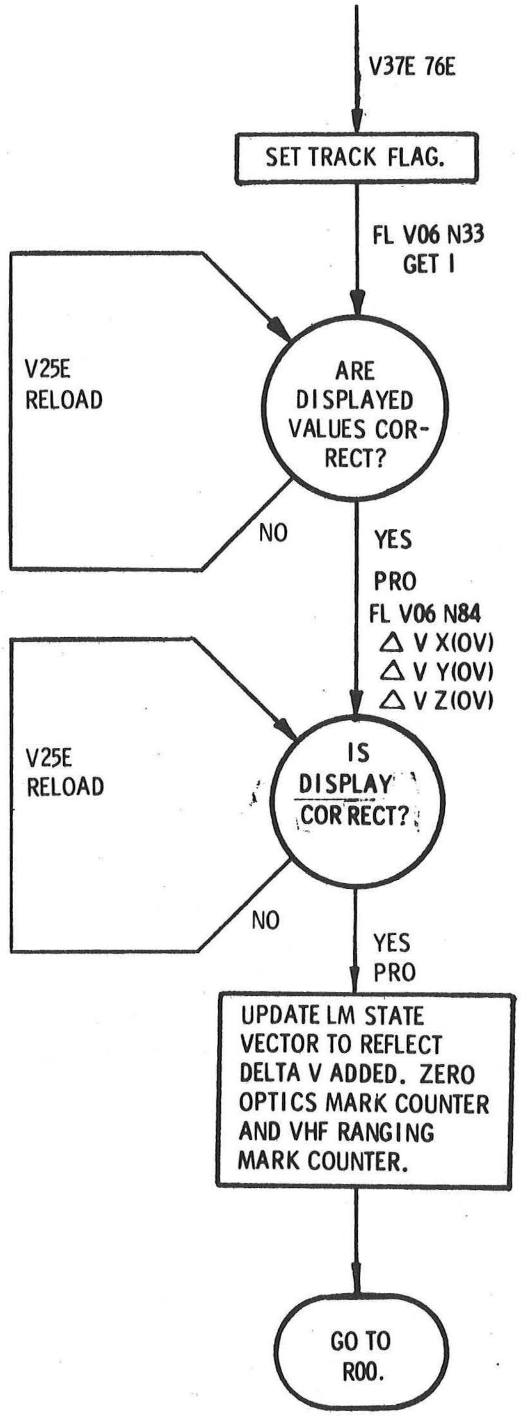


Fig. 5-58. Target Delta V Program (P76)

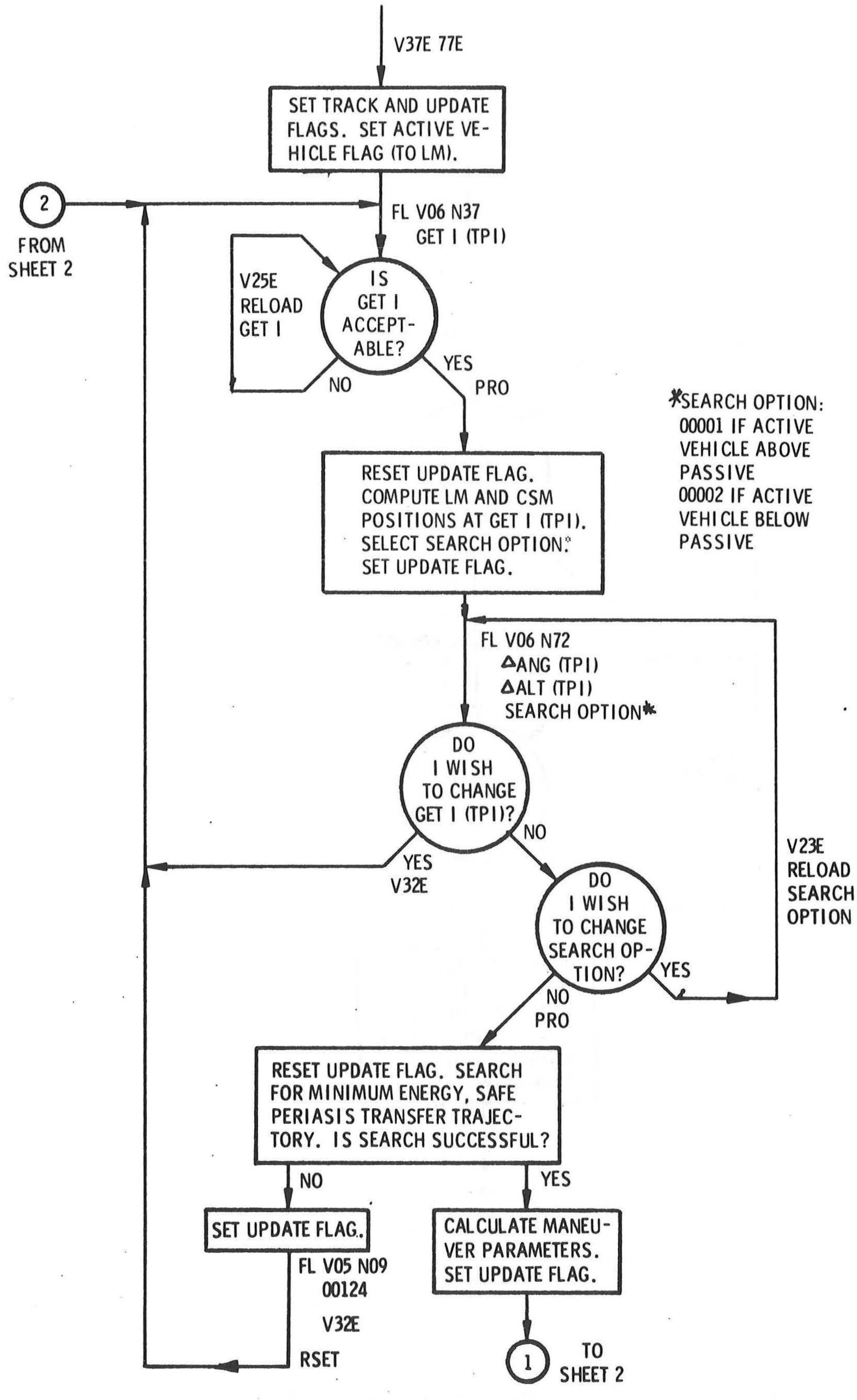


Fig. 5-59. LM TPI Search Program (P77) (Sheet 1 of 2)

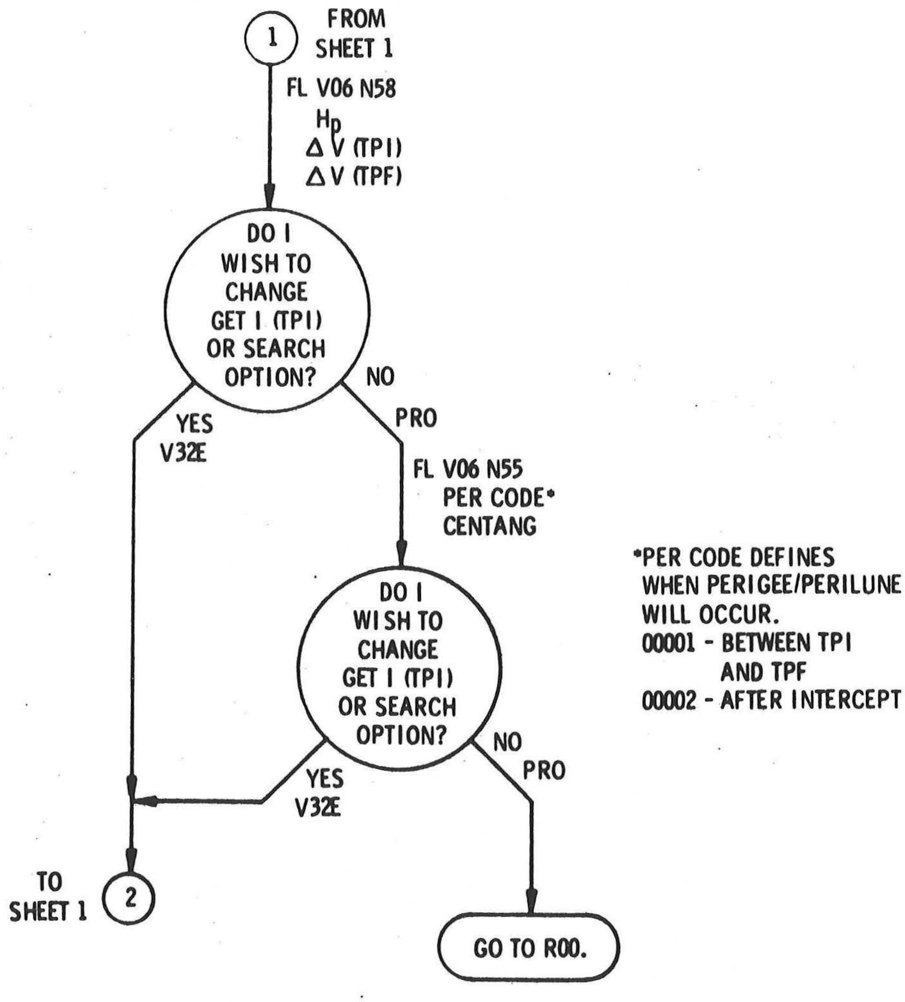


Fig. 5-59. LM TPI Search Program (P77) (Sheet 2 of 2)

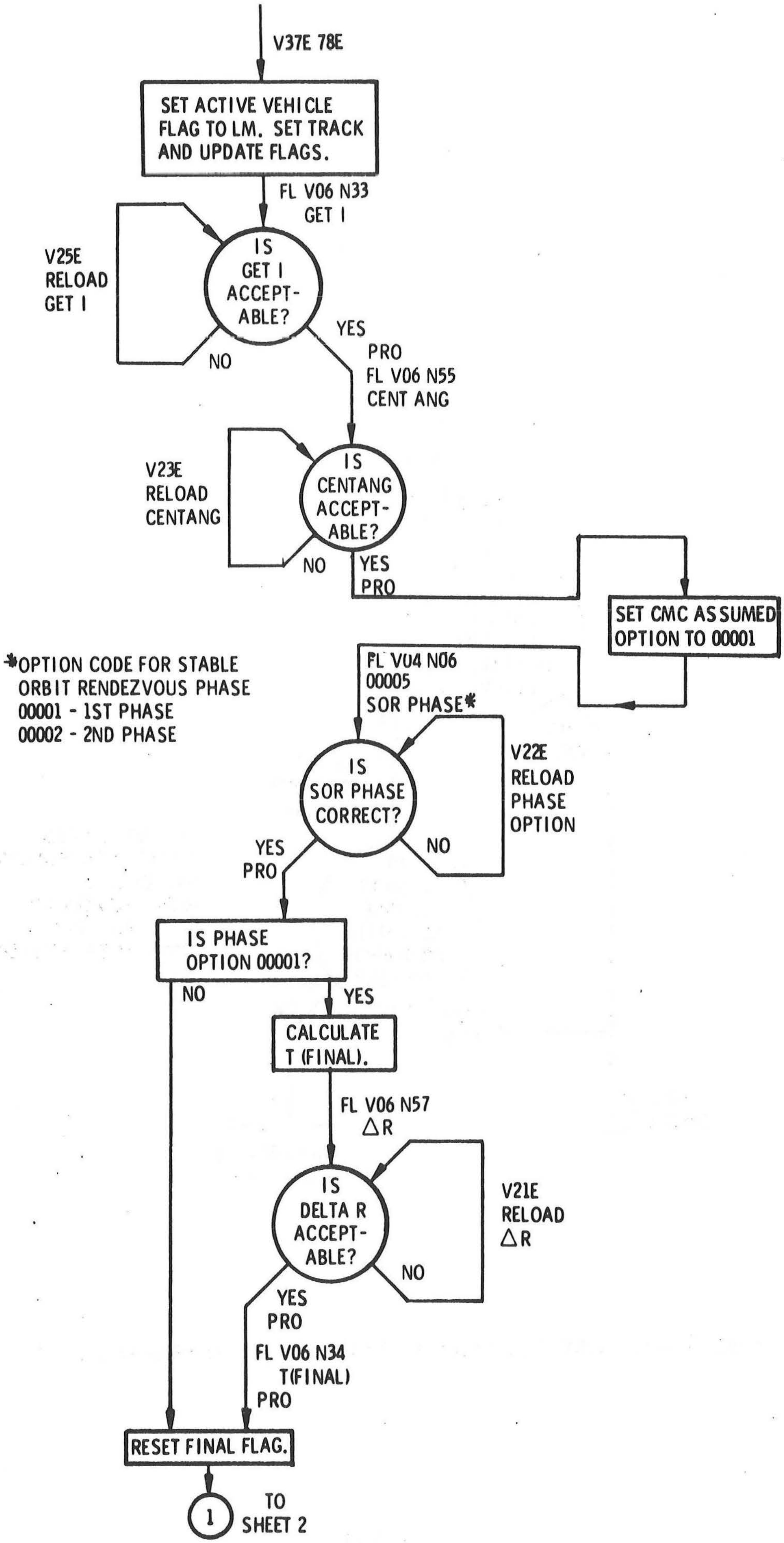


Fig. 5-60. LM Stable Orbit Rendezvous Program (P78) (Sheet 1 of 3)

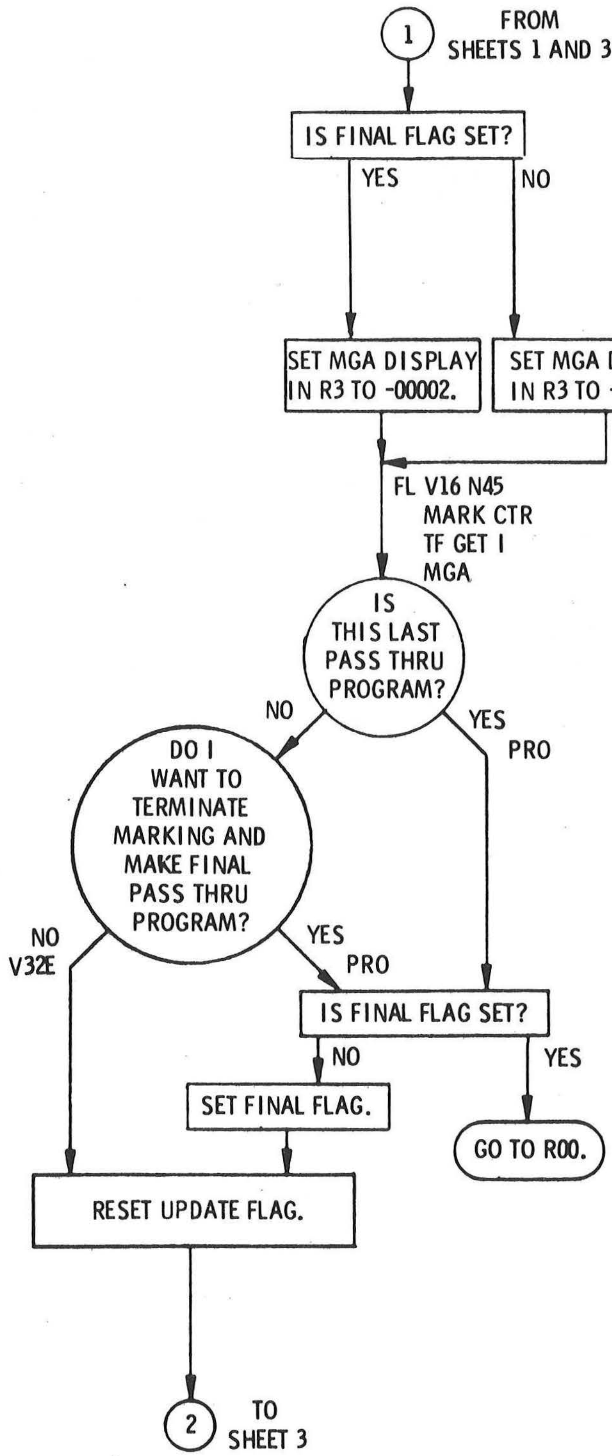


Fig. 5-60. LM Stable Orbit Rendezvous Program (P78) (Sheet 2 of 3)

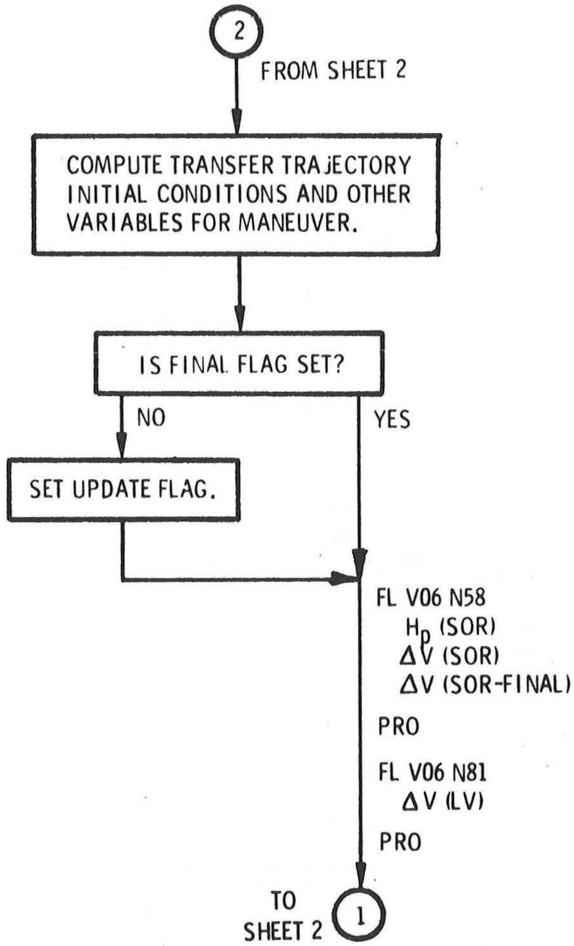


Fig. 5-60. LM Stable Orbit Rendezvous Program (P78) (Sheet 3 of 3)

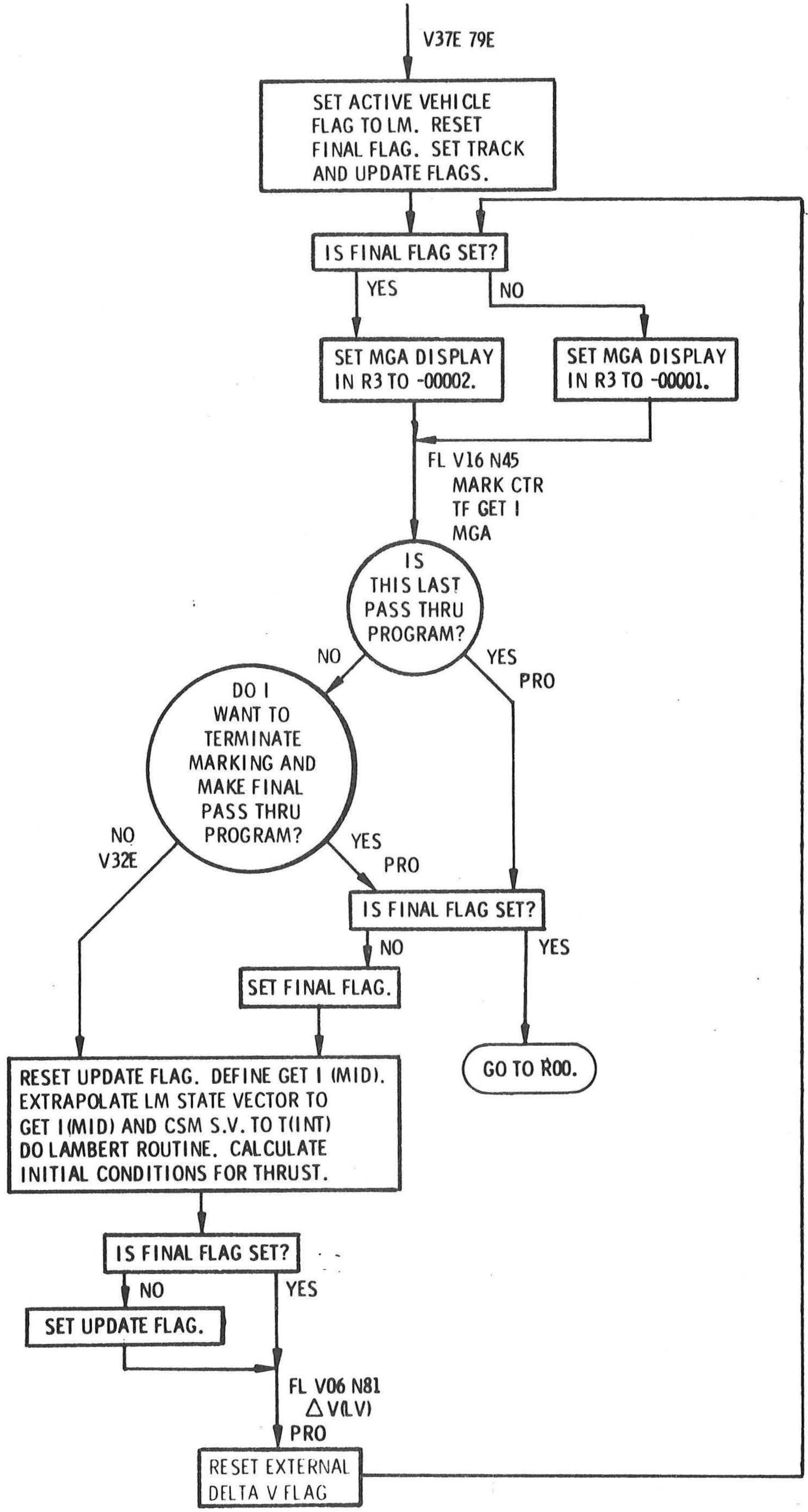


Fig. 5-61. LM Stable Orbit Midcourse Program (P79)

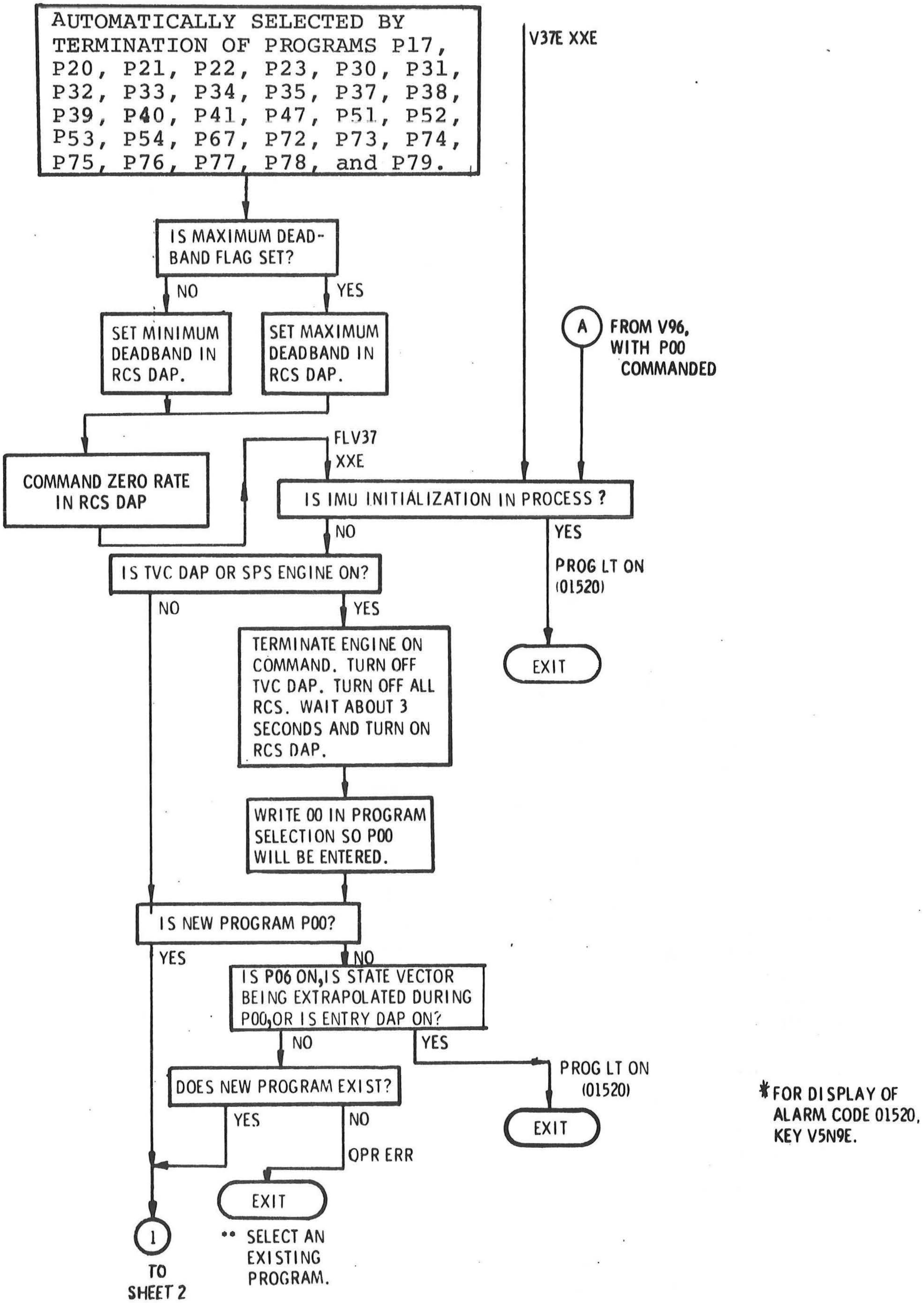


Fig. 5-62. Final Automatic Request Terminate Routine (R00) (Sheet 1 of 2)

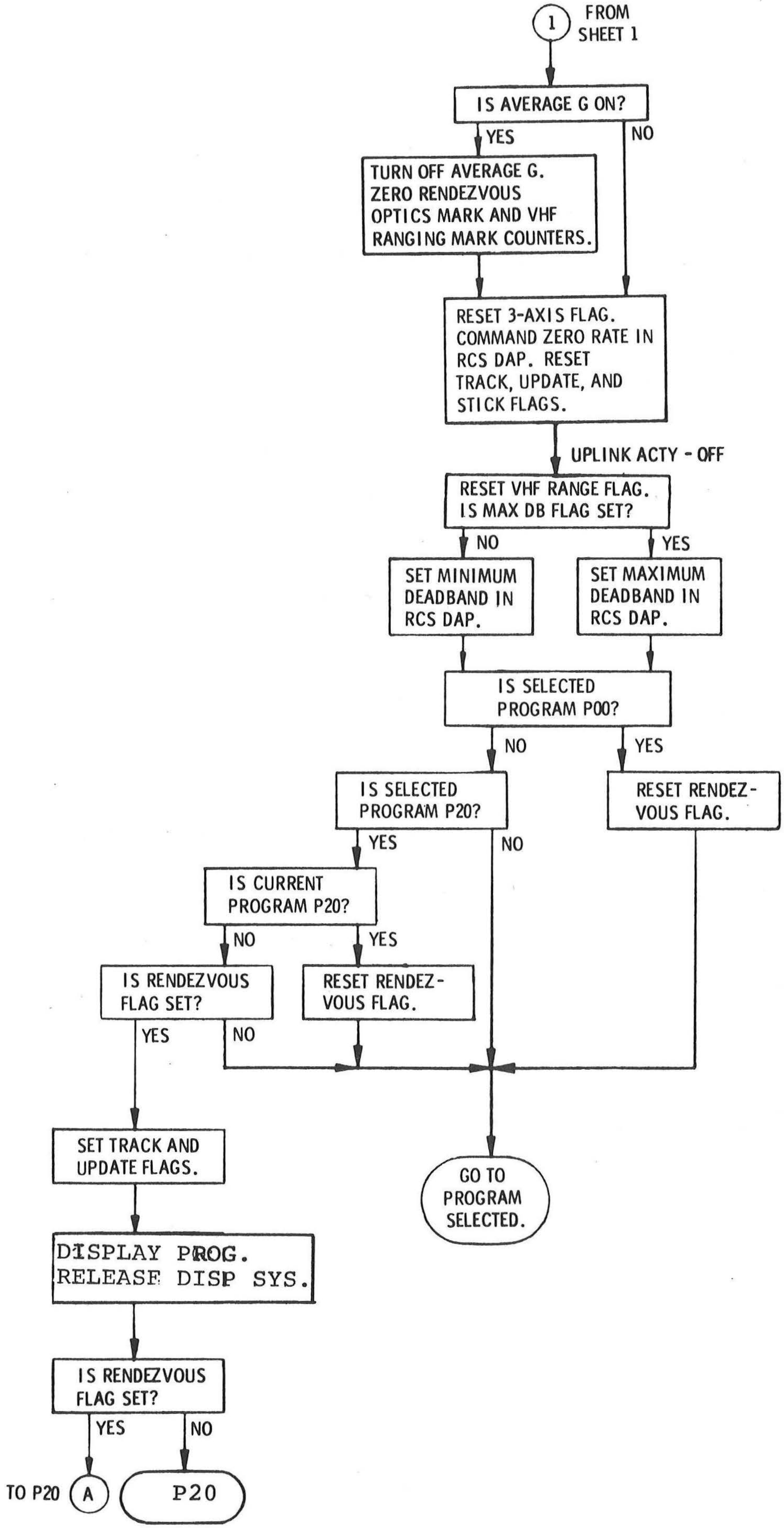


Fig. 5-62. Final Automatic Request Terminate Routine (R00) (Sheet 2 of 2)

If P20 is selected and is already in process or if P00 is selected, the rendezvous flag is reset and the selected program is entered. If P20 is selected and not running, conditions are initialized for entry into P20 depending on the state of the rendezvous flag.

5.2.3.31 IMU Status Check Routine (R02)

The IMU status check routine (Fig. 5-63) is called by programs which need the IMU for performance. R02 checks if the IMU is turned on and if its orientation is known by checking the IMU operate bit and the IMU orientation known (REFSMMAT) flag. If either is not set, the PROG indicator is lighted. The alarm code is displayed by keying V5N 9E. If the IMU is not on, the alarm code is 00210. If the IMU is on, but the orientation is not known, the alarm code is 00220.

5.2.3.32 DAP Data Load Routine (R03)

The DAP data load routine (Fig. 5-64) is called by keying in V48E. This routine is called prior to performing a GNCS controlled thrusting maneuver. The DAP configuration is loaded and stored mass and propulsion parameters are loaded and/or verified. After loading, a V46E entry activates the appropriate DAP.

5.2.3.33 S-Band Antenna Routine (R05)

The S-band antenna routine (Fig. 5-65) computes and displays the two S-band antenna gimbal angles required to point the S-band antenna at the center of the earth. This routine is entered by V64E.

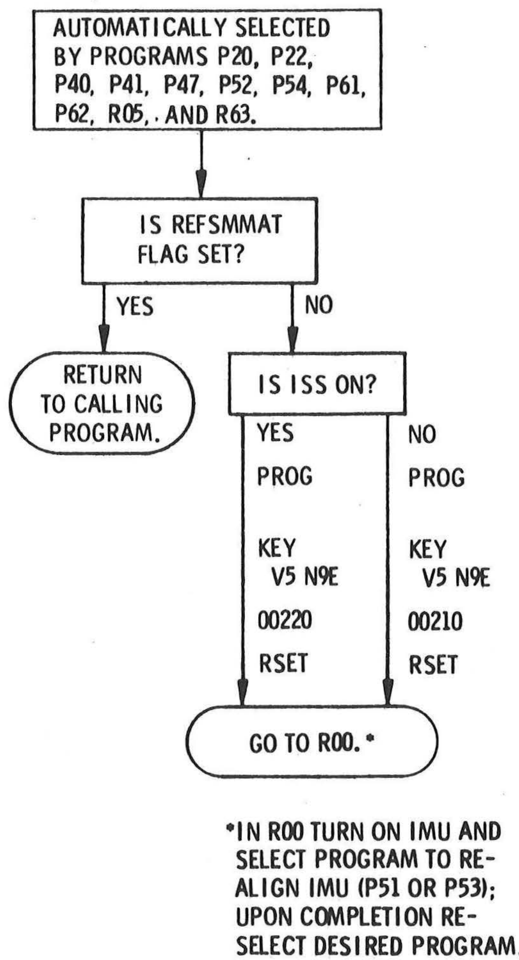


Fig. 5-63. IMU Status Check Routine (R02)

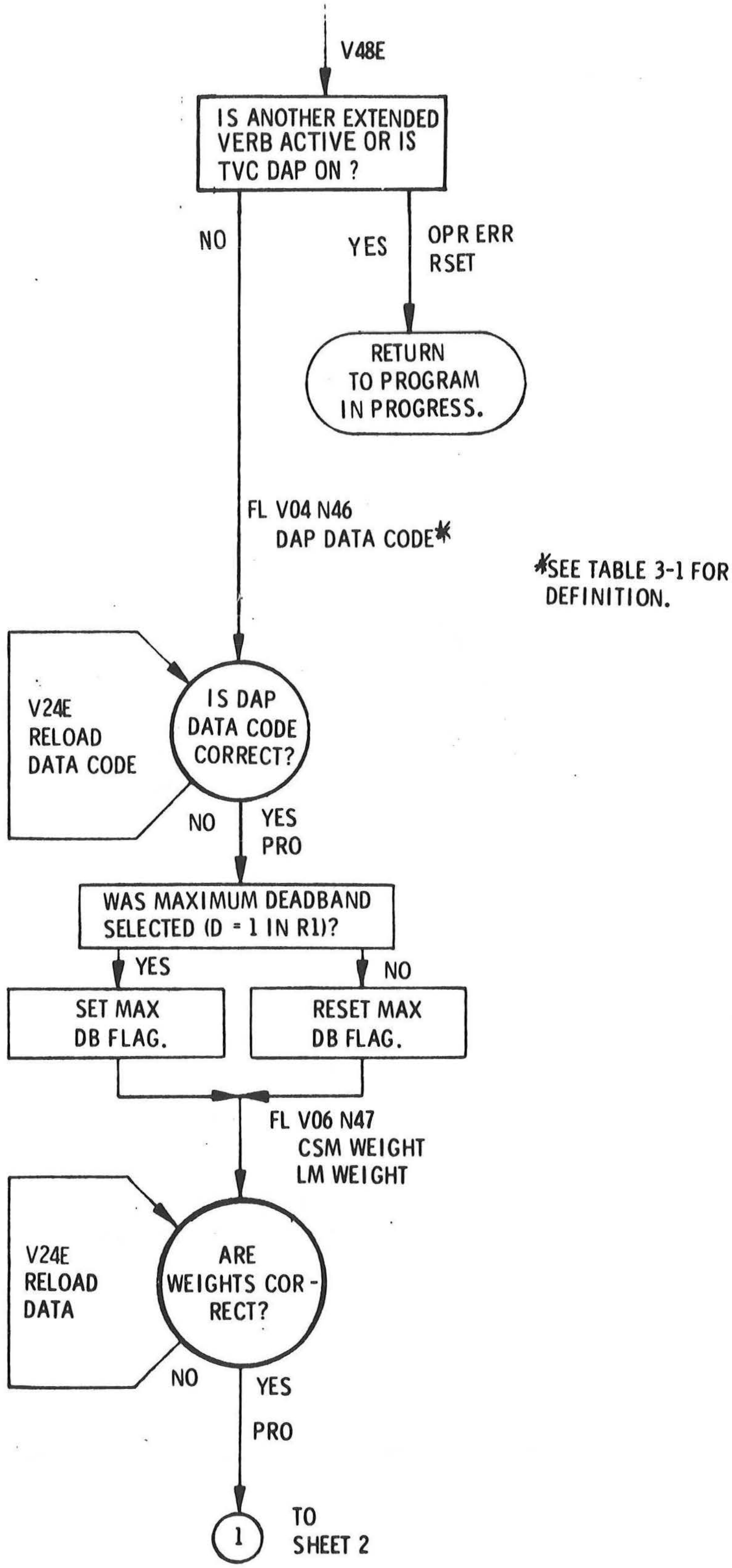


Fig. 5-64. DAP Data Load Routine (R03) (Sheet 1 of 2)

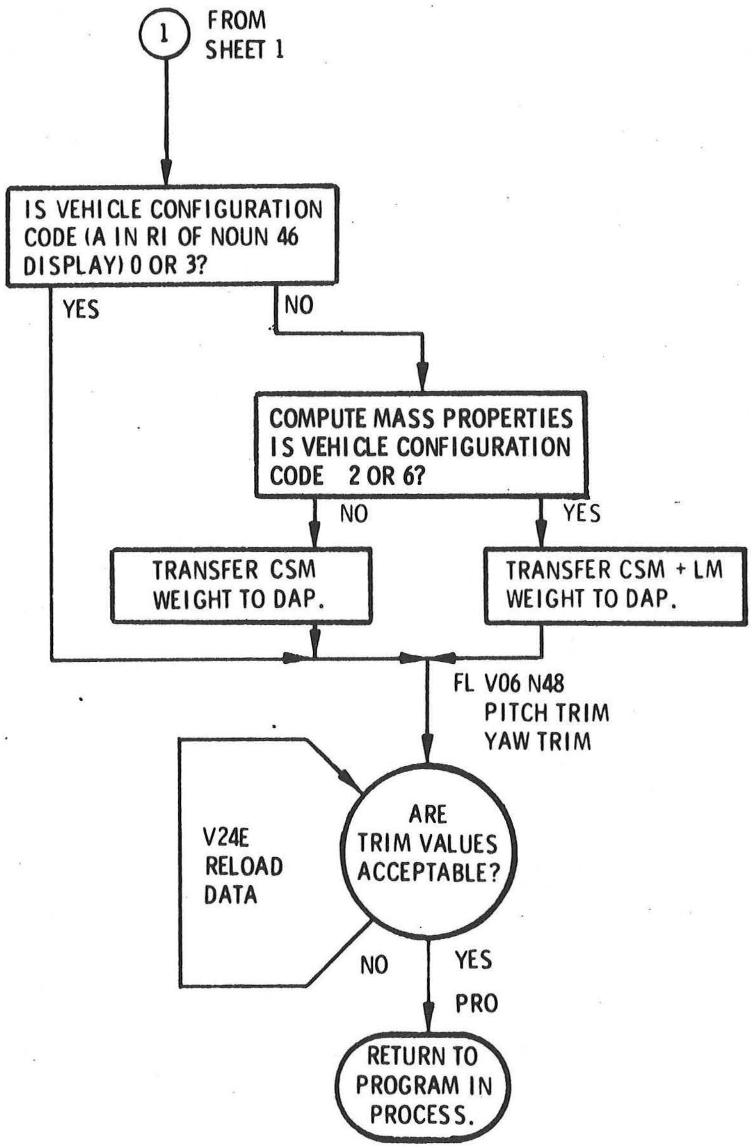


Fig. 5-64. DAP Data Load Routine (R03) (Sheet 2 of 2)

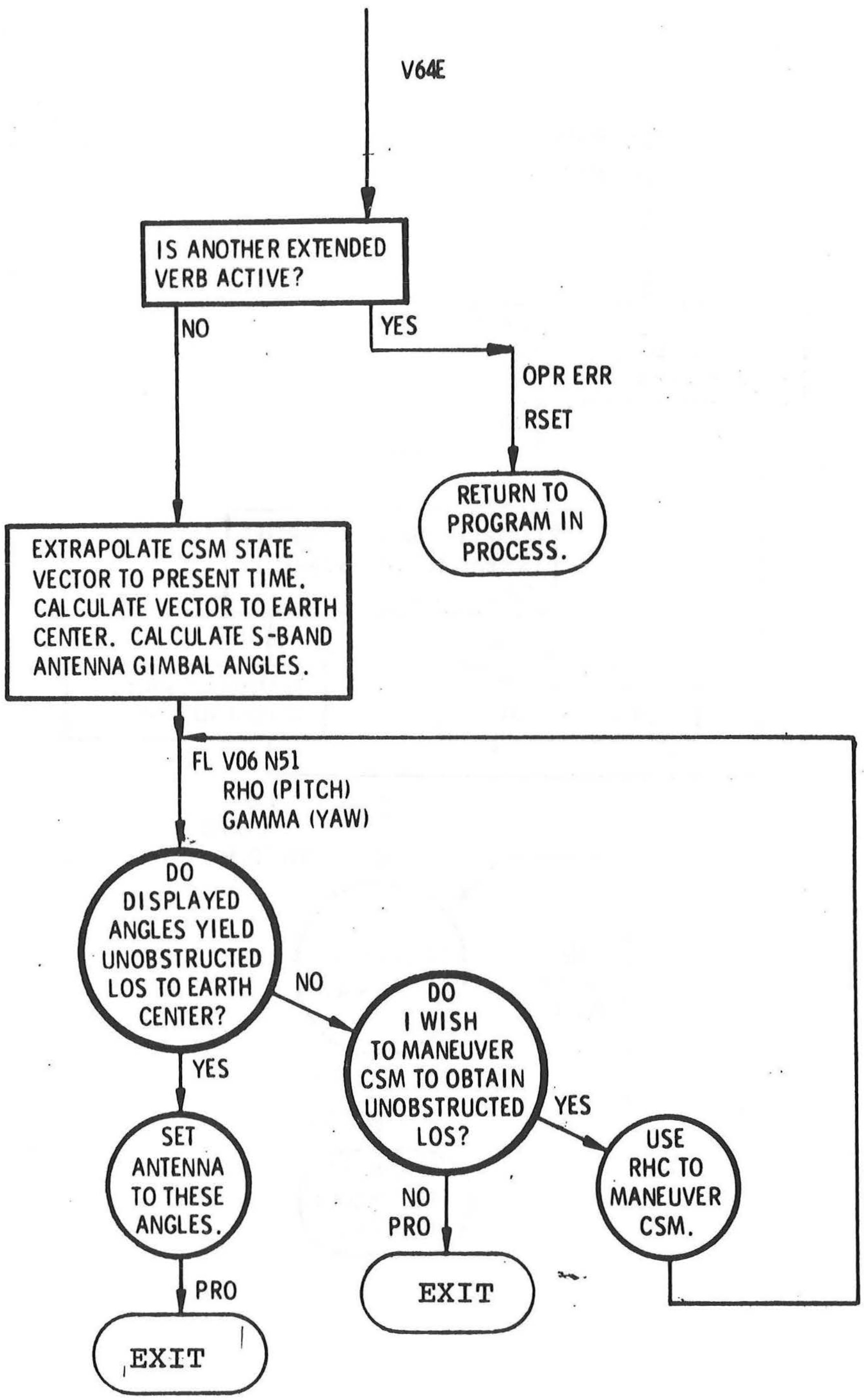


Fig. 5-65. S-Band Antenna Routine (R05)

5.2.3.34 CMC/LGC Clock Synchronization Routine (R33)

This routine (Fig. 5-66) is used to synchronize the CMC and LGC clocks. This is done by keying V06 N65 (computer clock time) in both vehicles and performing a countdown to press ENTR in the two vehicles simultaneously. The difference in displayed clock time constitutes one data point. The process is repeated for as many data points as deemed necessary and the average difference is recorded as the CMC/LGC clock difference.

5.2.3.35 Rendezvous Out of Plane Routine (R36)

This routine (Fig. 5-67) is used to display the rendezvous out of plane parameters calculated by the CMC or the LGC. This routine is entered by astronaut option by keying V90E. It calculates and displays distance along the Y axis to the LM or the CSM, the rate of change of this distance, and the angle between the CSM or LM orbital plane and the LOS to the LM or CSM. The Y axis is defined along the cross product of the CSM or LM velocity vector and the geocentric (selenocentric in moon orbit) radius vector.

5.2.3.36 Crew Defined Maneuver Routine (R62)

This routine (Fig. 5-68) provides the crew with the capability to specify a final vehicle attitude, by loading gimbal angles, for use by a GNCS controlled attitude maneuver. The maneuver is performed by routine R60. Routine R62 is entered by DSKY entry of V49E and can only be commanded from the CMC idling program (P00).

5.2.3.37 Rendezvous Final Attitude Routine (R63)

This routine (Fig. 5-69) calculates the final gimbal angles required to point the CSM +X axis at the LM and the final gimbal angles required to point the preferred tracking axis at the LM. The crew has the option of selecting which set of final gimbal axes to be displayed. This routine also calls the attitude maneuver routine (R 60) to maneuver to the selected calculated orientation.

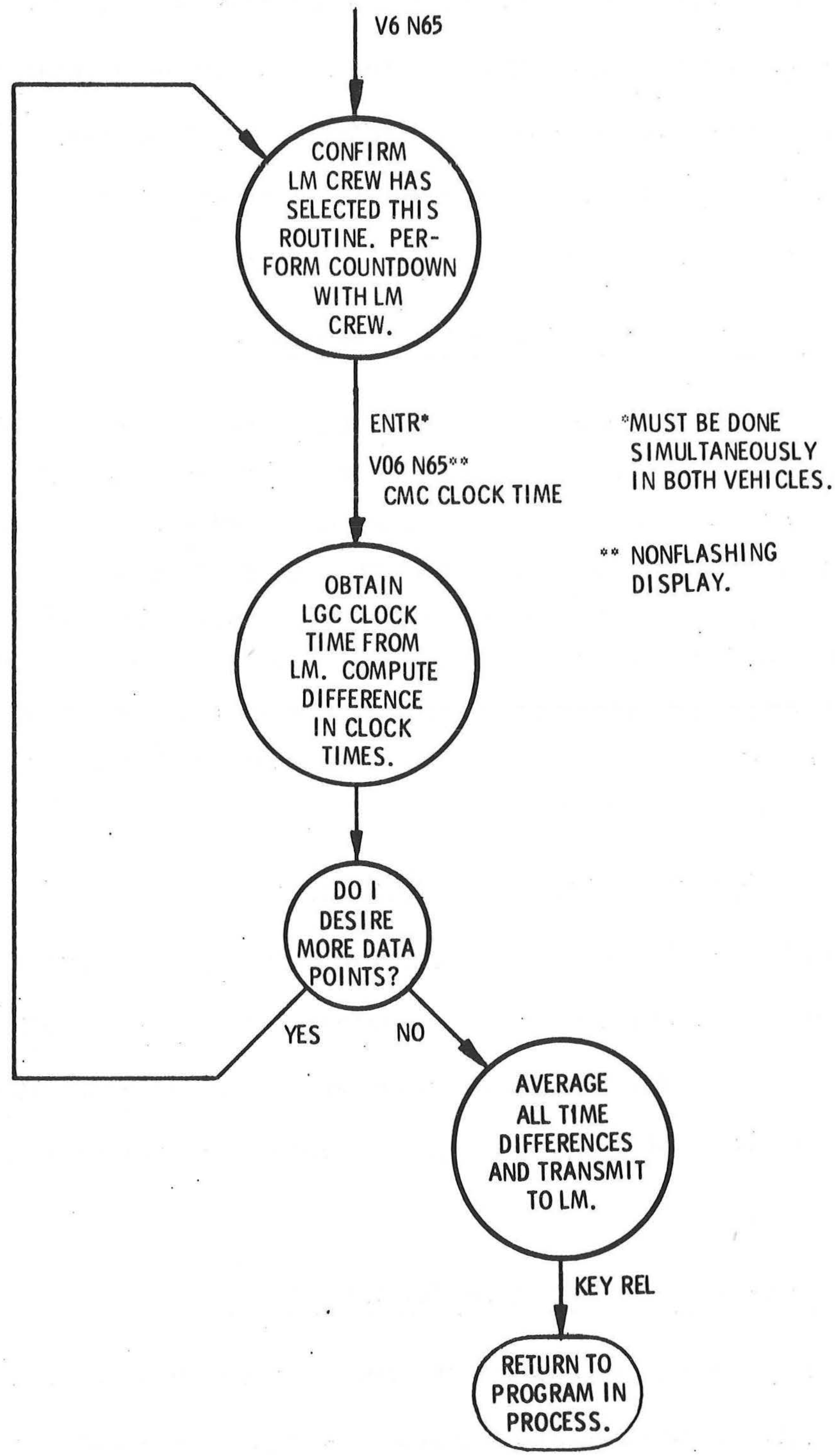


Fig. 5-66. CMC/LGC Clock Synchronization Routine (R33)

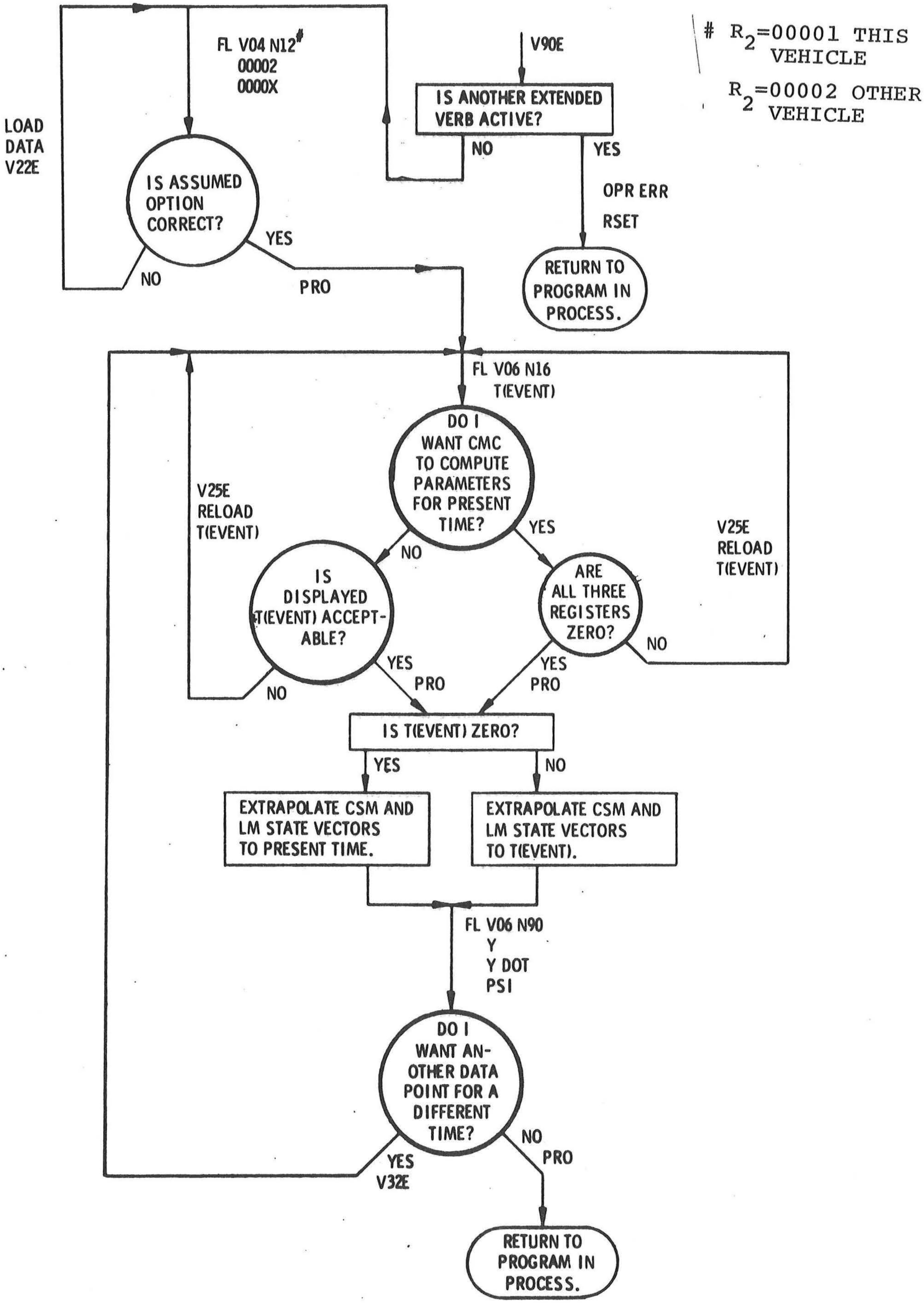


Fig. 5-67. Rendezvous Out-of-Plane Display Routine (R36)

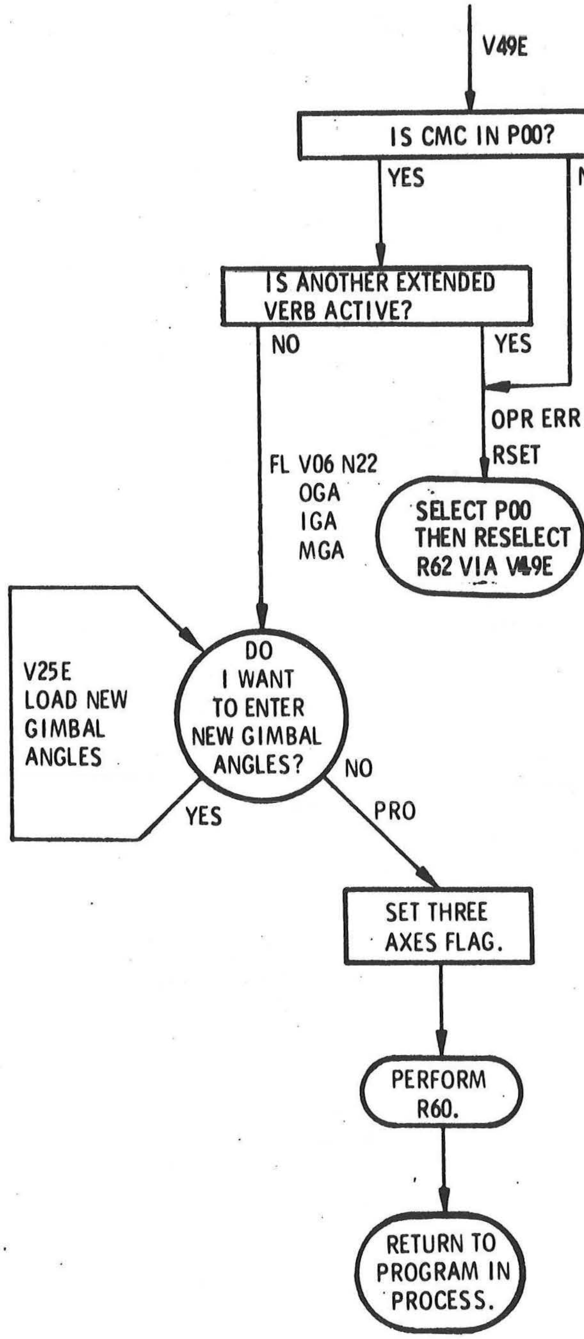


Fig. 5-68. Crew Defined Maneuver Routine (R62)

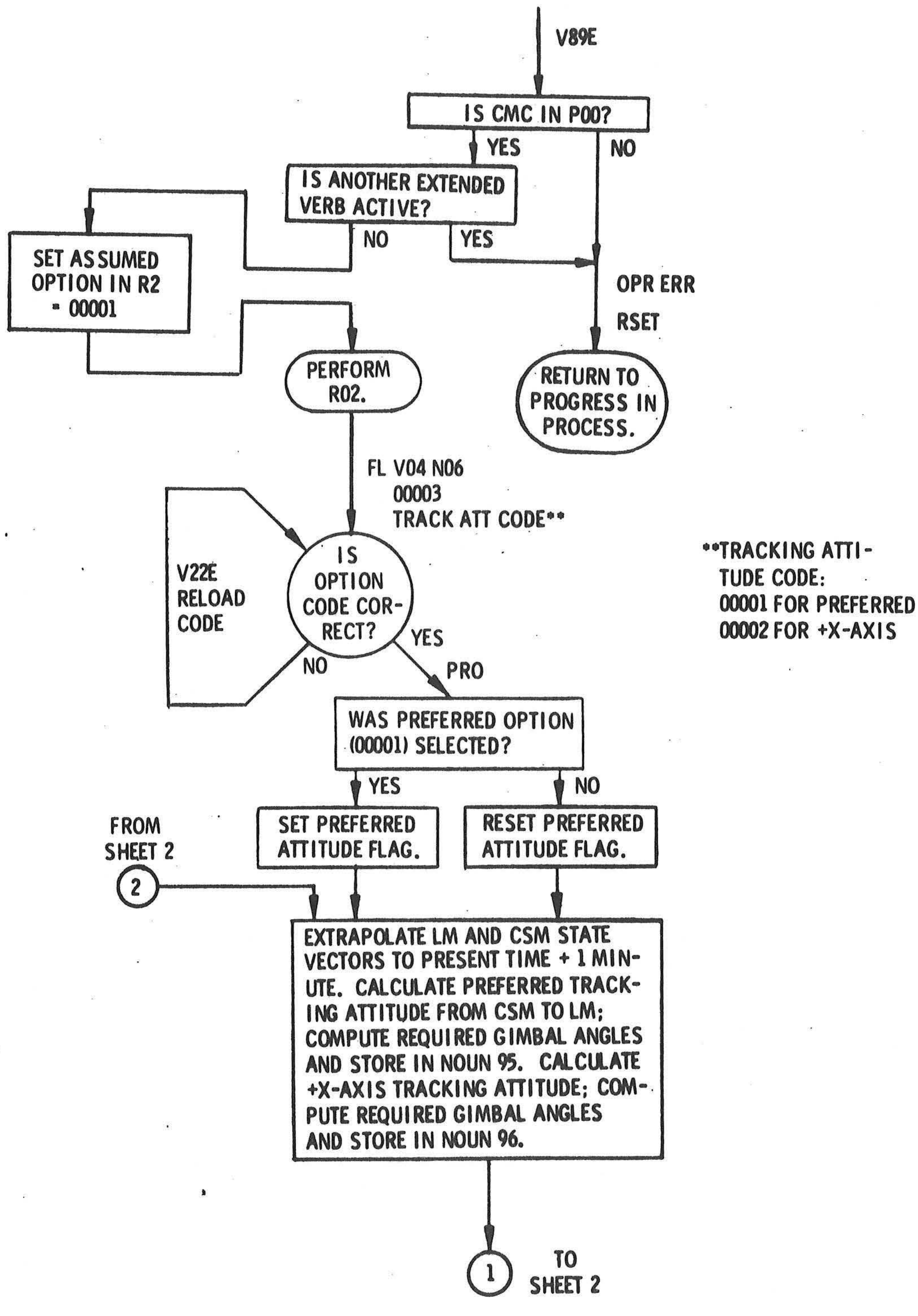


Fig. 5-69. Rendezvous Final Attitude Routine (R63) (Sheet 1 of 2)

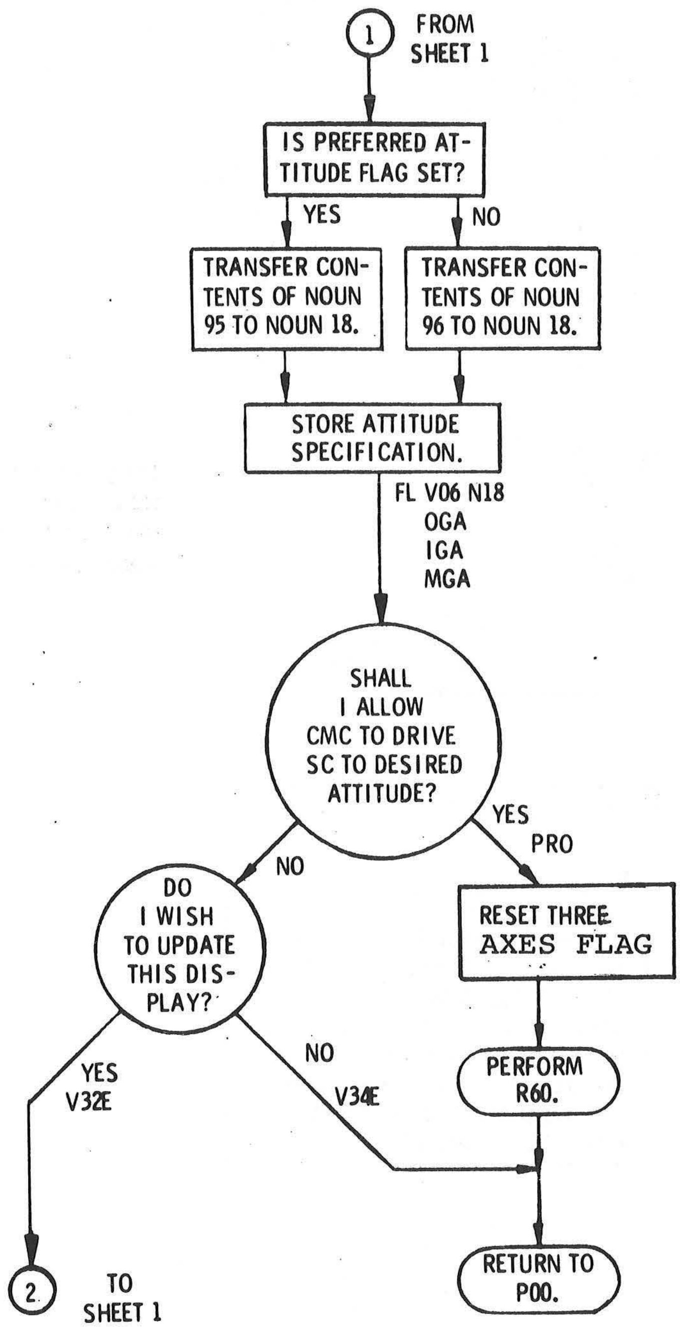


Fig. 5-69. Rendezvous Final Attitude Routine (R63) (Sheet 2 of 2)

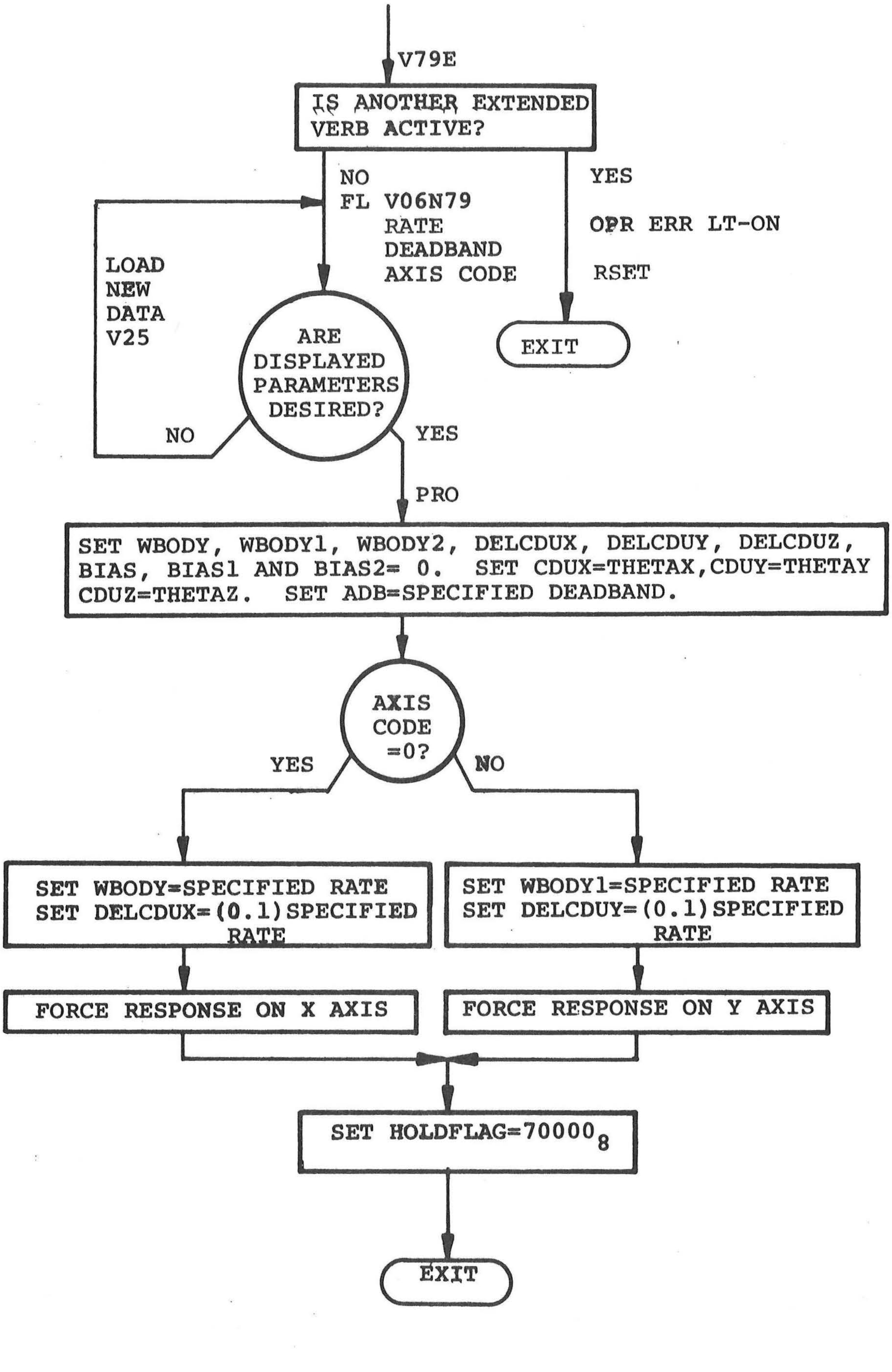


Fig. 5-69A BARBEQUE MODE ROUTINE (R64) SHEET 1 OF 1

5.2.3.37A Barbeque Mode Routine (R64)

The Barbeque Mode Routine (Fig. 5-80A) provides the crew the capability of having the DAP maintain a controlled rate about the X or Y control axis. Once N79 is configured as desired, PRO on FL V06N79 will:

1) change the DAP deadband to that specified by component two of N79.

2) A. if PTC(X axis roll) option is selected, generate a commanded rate about the vehicle X axis equal to that specified in component one of N79.

   B. if ORBRATE(Y axis) option is selected, generate a commanded rate about the Y RCS control axis equal to that specified in component one of N79.

The maneuvering commands will be communicated to the DAP only if the S/C CONT switch is in CMC and the CMC MODE switch is in AUTO. The physical response to PRO on FL V06N79 will be an immediate forced roll or forced pitch (dependent on specified axis) which will reduce the difference between commanded rate and actual rate by about 80%.

The mode of operation established by R64 can be altered in various ways as indicated in Table 5-5.

	Zero Commanded Rate	Return to Deadband Specified By R03	Zero Dap Attitude Error
V46E or S/C Cont Sw Cycled CMC-SCS-CMC	✓	✓	✓
CMC Sw to Hold or Rotation Hand Control Activity	✓		✓
V37EXXE	✓	✓	
KALCMANU	●		✓

● KALCMANU generates new commanded rates.

Table 5-5 BARBEQUE MODE (R64) ALTERATIONS

5.2.3.38 Nonroutine Extended Verbs

A number of extended verbs are provided to call up CMC tasks which are not classified as routines. They provide the CMC with extra capabilities not used in normal operations. Most of them can not be used while another extended verb (including callable routines) is active.

5.2.3.38.1 Fresh Start Extended Verb (V36). This verb (Fig. 5-70) provides the crew with the capability of commanding a CMC fresh start. This can be done at any time the CMC is on. However, if it is commanded during state vector integration, the state vector may be invalidated. REFSMMAT is not disturbed. An IMU orientation determination program (P51 or P53) must be performed to reestablish the REFSMMAT flag. A fresh start may also be forced during a restart by simultaneously pressing the RSET and MARK REJECT pushbuttons. A fresh start should not be commanded unnecessarily.

5.2.3.38.2 ICDU-Zero Extended Verb (V40N20). This verb (Fig. 5-71) is used to synchronize the ICDU counters to the CDU counters in the CMC. It also switches the IMU from the coarse align to the fine align mode. It cannot be entered when the IMU is in coarse align mode with a gimbal lock or during IMU initialization. It is primarily intended for ground use. For in-flight alignment the IMU alignment programs P51 through P54 should be used.

5.2.3.38.3 Coarse Align ISS Extended Verb (V41N20). This verb-noun (Fig. 5-72) is used to align the IMU to an orientation specified by the operator. It can be used to align the gimbals to zero when in coarse align mode with a gimbal lock (when V40 cannot be used). The operator loads the gimbal angles desired. The IMU is then aligned accordingly. This verb can only be used when no other extended verb is active and cannot be used during IMU initialization.

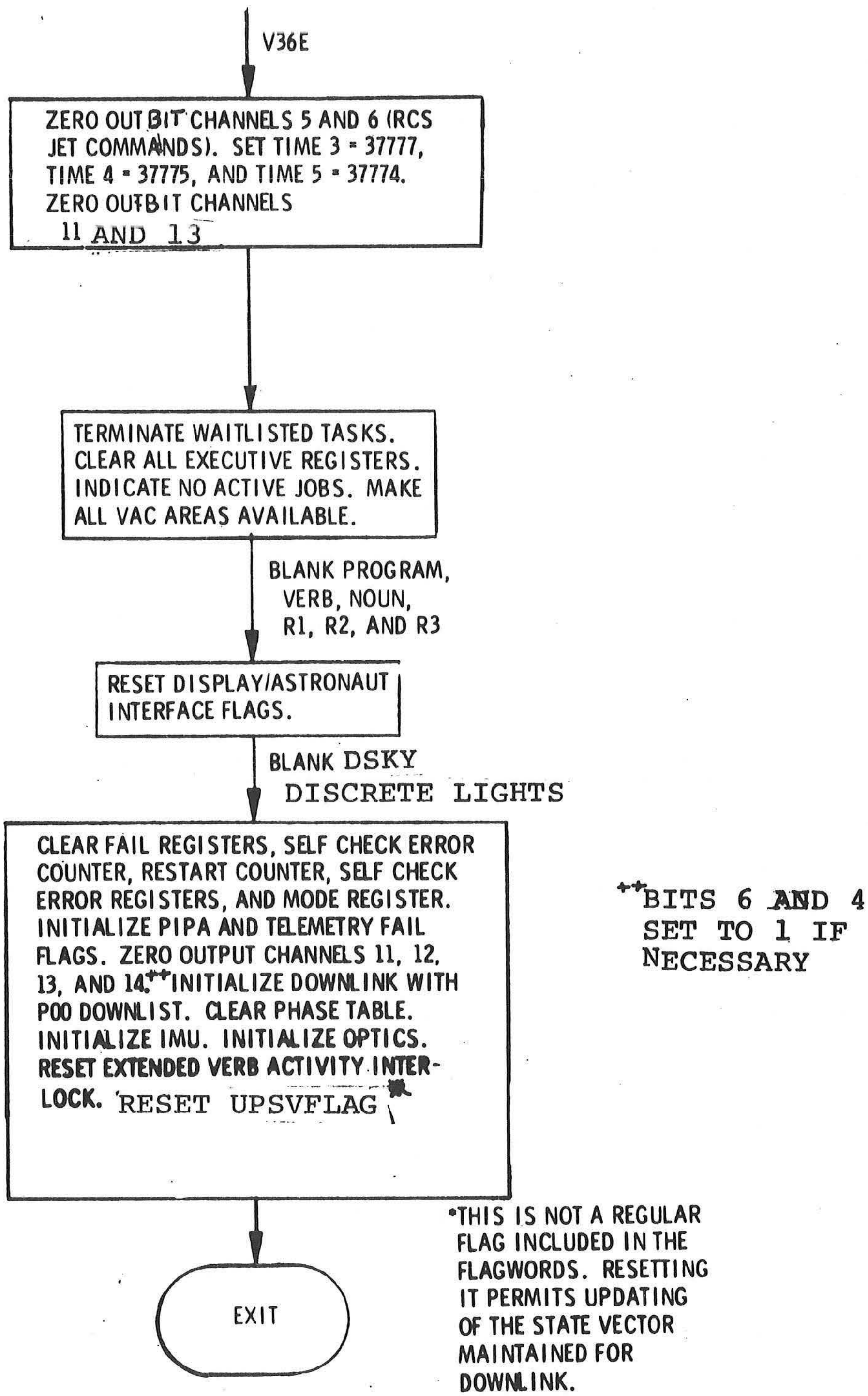


Fig. 5-70. Fresh Start Extended Verb (V36)

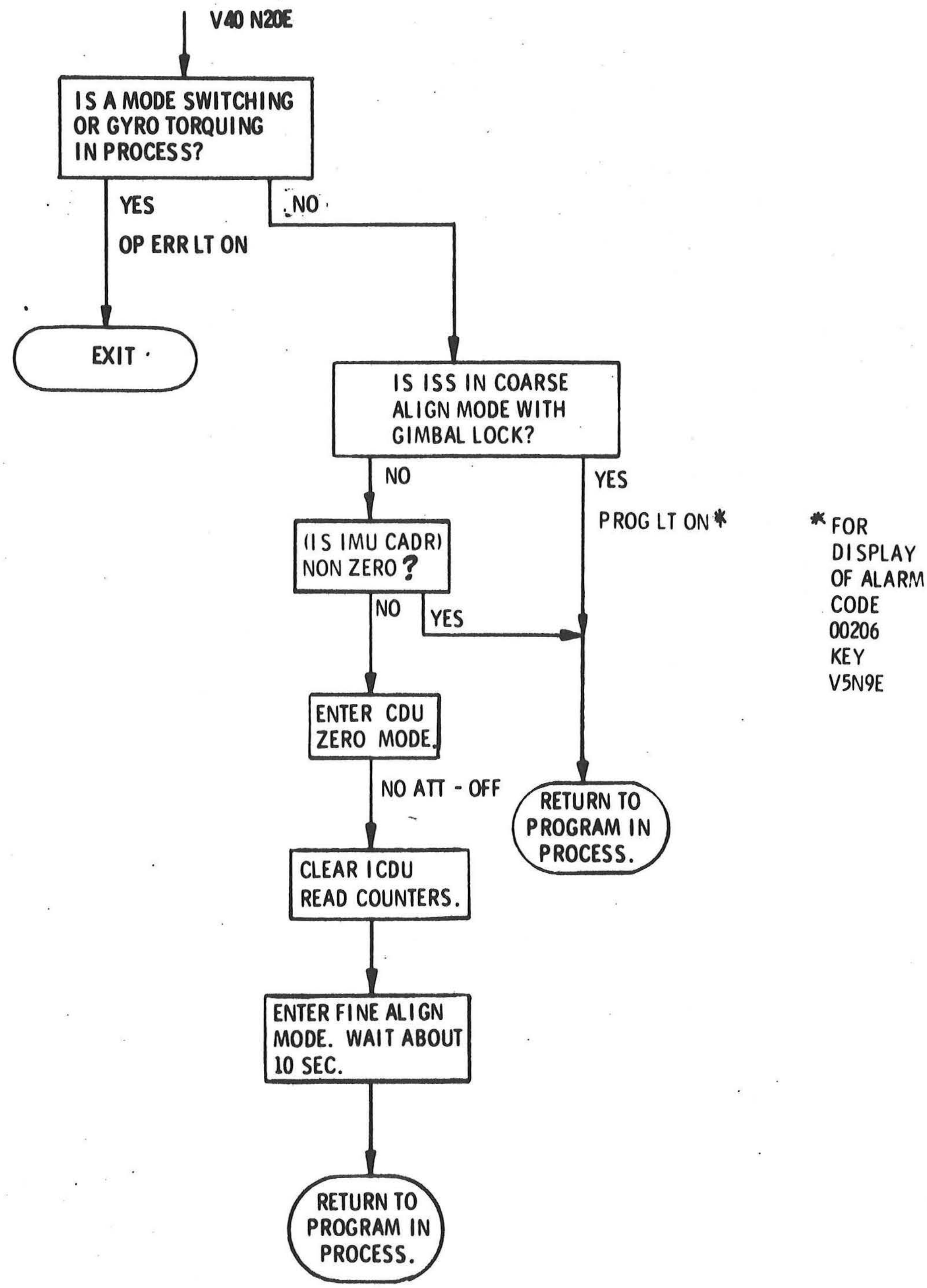


Fig. 5-71. ICDU - Zero Extended Verb (V40 N20)

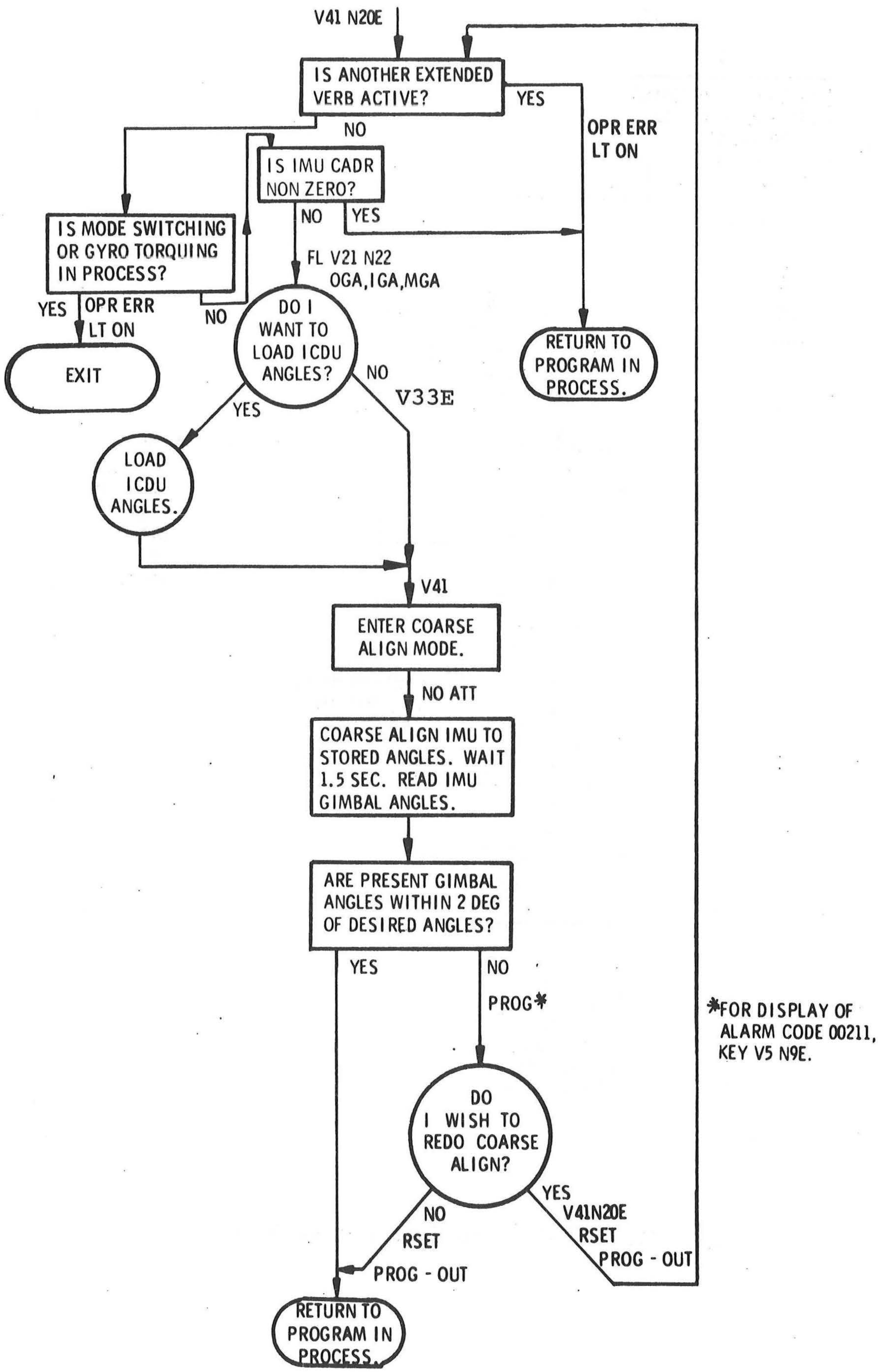


Fig. 5-72. Coarse Align ISS Extended Verb (V41 N20)

5.2.3.38.4 Coarse Align OSS Extended Verb (V41 N91). This verb-noun (Fig. 5-73) is used to drive the optics to a position selected by the operator. The OSS must be on and in the CMC mode. The operator loads the desired shaft and trunnion angles and the optics are driven to the specified angles. This verb can only be used when no other extended verb is active.

5.2.3.38.5 Fine Align Extended Verb (V42). This verb (Fig. 5-74) is used to fine align the IMU platform and to switch from coarse align to fine align mode. The operator loads the desired delta gyro angles through which the gyros are to be torqued, when V21 N93 flashes. If any of the desired angles are greater than 99.999 degrees (the capacity of the register) the angles must be loaded into the double-precision gyro torquing registers directly by V21 N2 entry with address 02757. This method of loading is only for ground use; in flight, all angles must be less than 100 degrees. After loading the data in the first address, a N15E can be used to increment the address automatically after each data load, since the addresses are in numerical sequence. This loading must be done before selecting V42. In this case the operator merely proceeds (PRO) on the V21 N93 flash. After the delta gyros are loaded, the IMU is fine aligned. This verb cannot be used if another extended verb is active or the IMU is being initialized.

5.2.3.38.6 Load IMU Attitude Error Needles Extended Verb (V43). This verb (Fig. 5-75) is used to load astronaut specified angles into the FDAI error needles. The operator loads the angles desired and these are displayed on the FDAI error needles. The maximum angle that can be loaded is 16.88 degrees; any angle greater than that is interpreted as 16.88 degrees. This verb can only be entered from P00. It cannot be entered if another extended verb is active, except prior to liftoff.

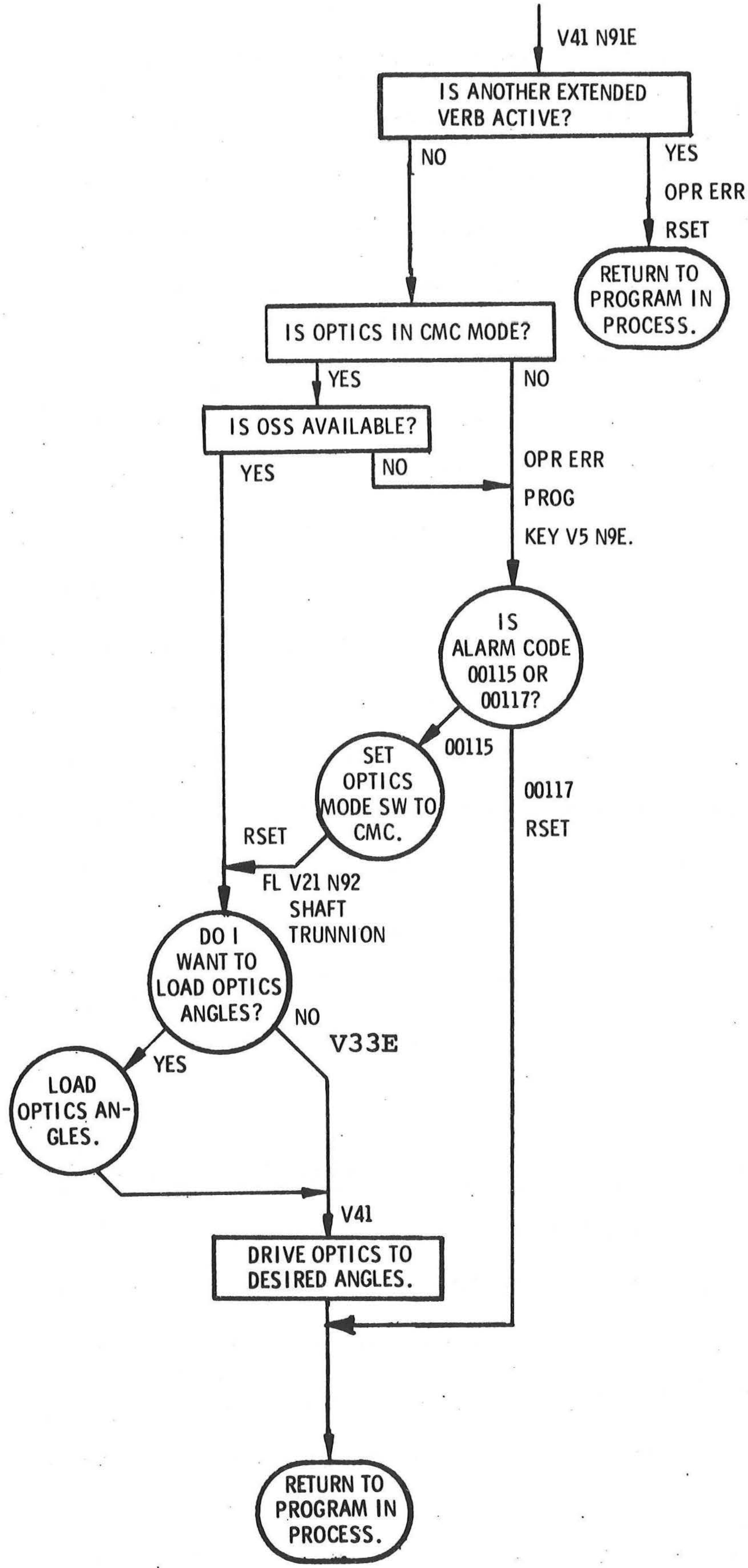


Fig. 5-73. Coarse Align OSS Extended Verb (V41 N91)

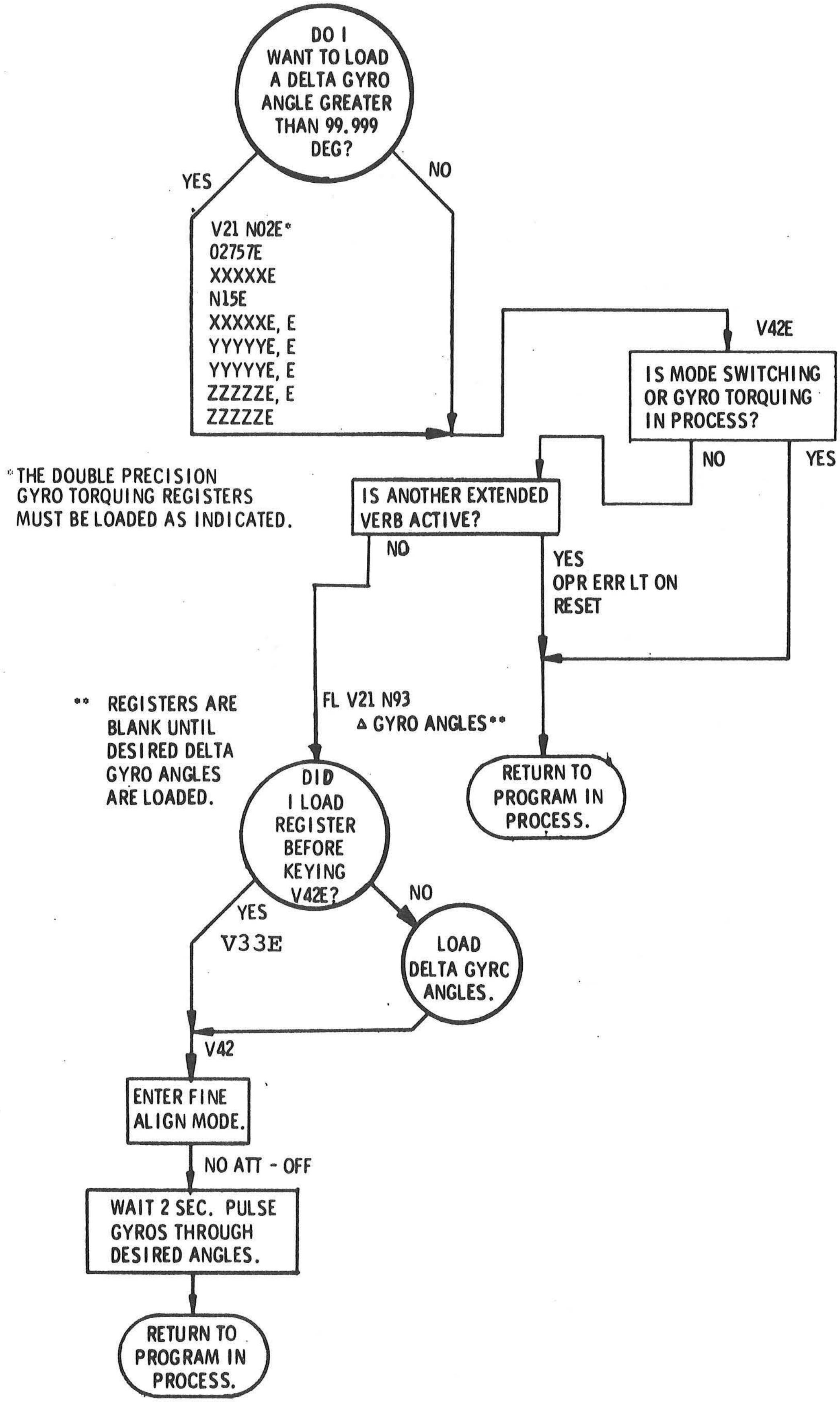


Fig. 5-74. Fine Align Extended Verb (V42)

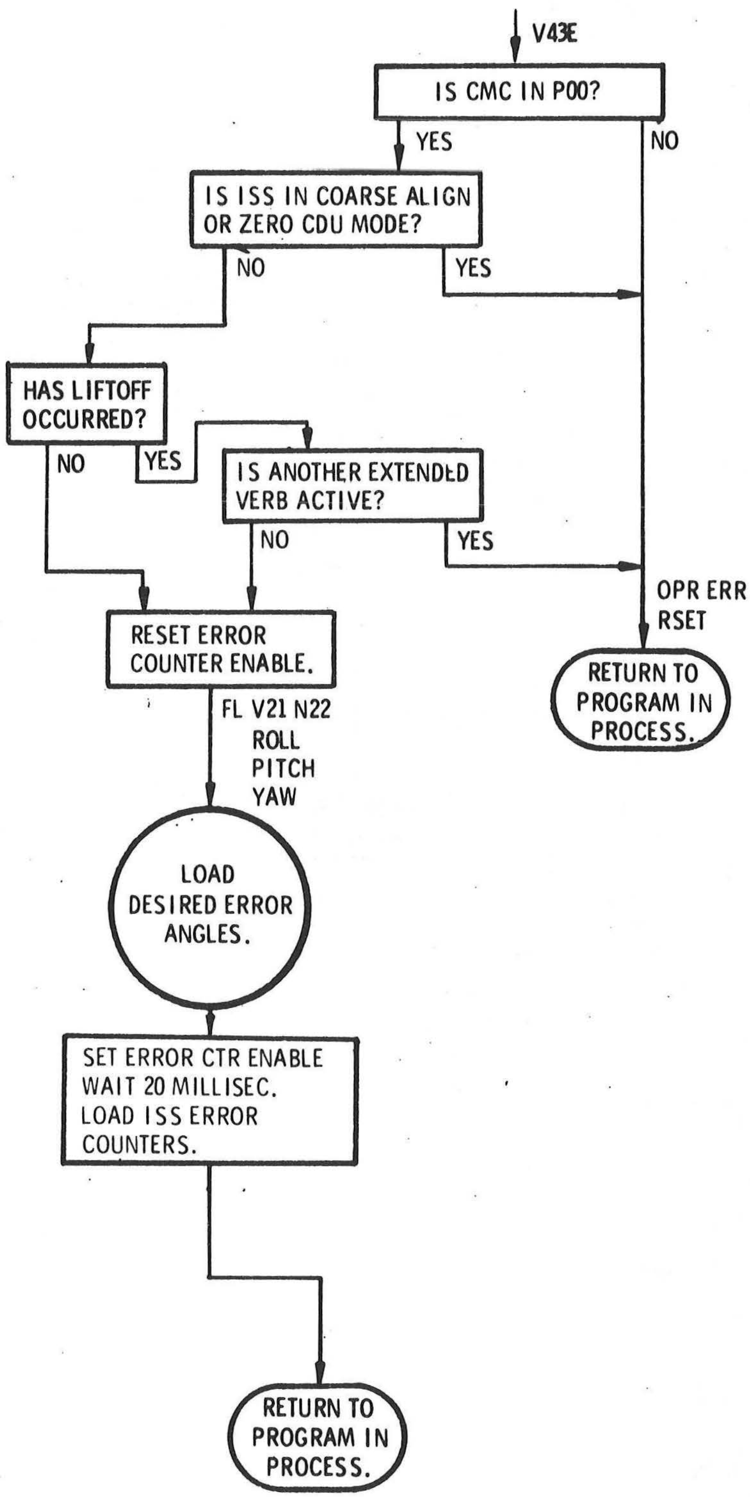


Fig. 5-75. Load IMU Attitude Error Needles Extended Verb (V43).

5.2.3.38.7 Set and Reset Surface Flag Extended Verbs (V44 and V45). These verbs (Figs. 5-76 and 5-77) are used to set and reset the surface flag. When set, this flag indicates that the LM is on the lunar surface.

5.2.3.38.8 Establish G & C Control Extended Verb (V46). This verb (Fig. 5-78) is used to activate the DAP. Prior to performing this verb, DAP data load routine (R03) should be performed to establish or verify the proper DAP configuration. The V46 entry then activates the appropriate DAP.

5.2.3.38.9 Move Other Vehicle State Vector To This Vehicle State Vector Extended Verb (V47). This verb (Fig. 5-79) is used to transfer the LM state vector data into the CSM state vector. This process is useful when the LM and CSM are in close proximity, the LM state vector is more current, and it is not feasible to update the CSM state vector from the ground or take navigation measurements.

5.2.3.38.10 Increment CMC Time Extended Verb (V55). This verb (Fig. 5-80) provides the crew with the capability to change the CMC clock time. This routine serves as a backup method to program P27 for updating the CMC clock time.

5.2.3.38.11 Terminate Tracking Extended Verb (V56). This verb (Fig. 5-81) is used to terminate rendezvous tracking (P20) and resets the rendezvous, update, and track flags.

5.2.3.38.12 Reset Stick Flag Extended Verb (V58). This verb (Fig. 5-82) is used to reset the stick flag after use of the rotational hand controller to enable automatic attitude maneuvering during rendezvous navigation (P20). The stick flag is set by moving the RHC out of detent and must be reset before the attitude maneuver routine R60 can be called by the tracking attitude routine R61.

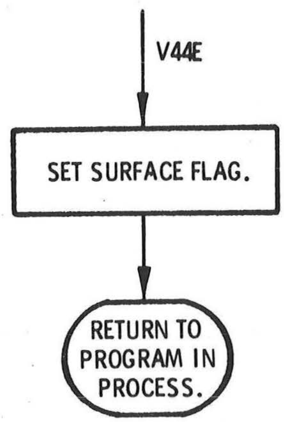


Fig. 5-76. Set Surface Flag Extended Verb (V44)

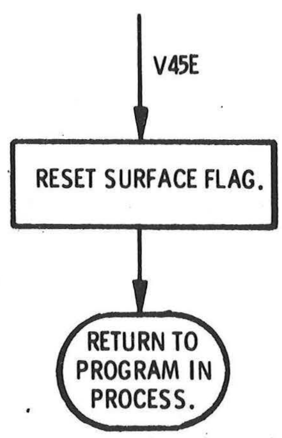


Fig. 5-77. Reset Surface Flag Extended Verb (V45)

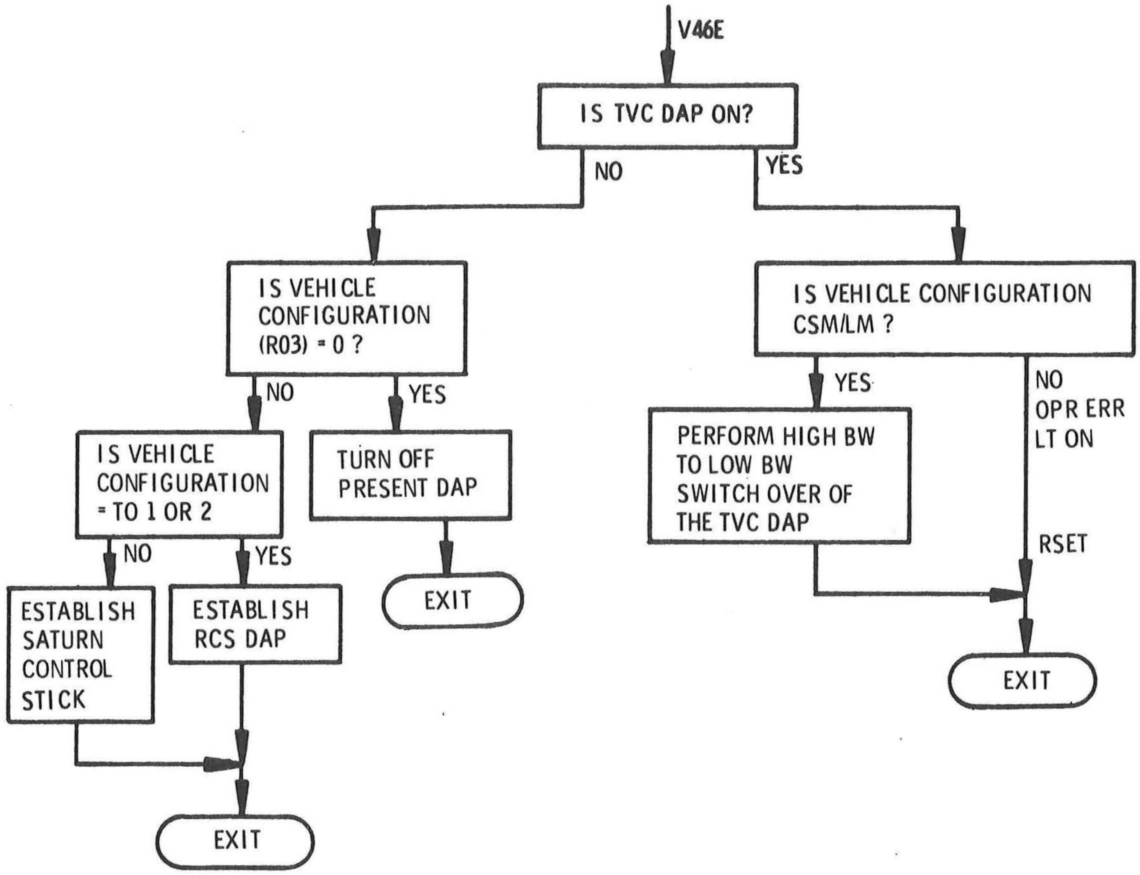


Fig. 5-78. Establish G&C Control Extended Verb (V46)

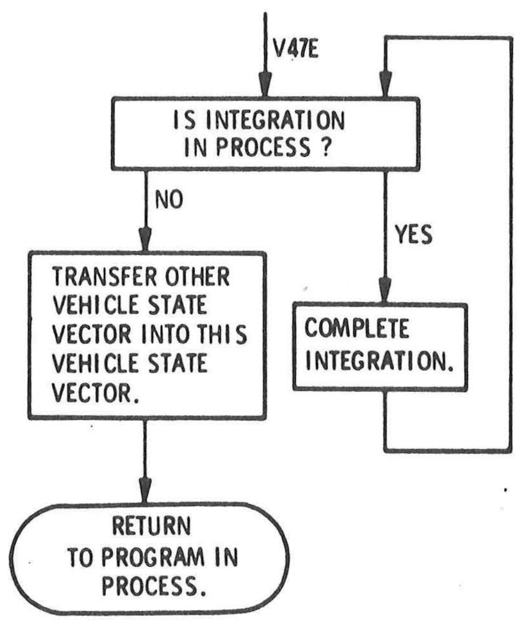


Fig. 5-79. Move Other Vehicle State Vector To This Vehicle State Vector Extended Verb (V47)

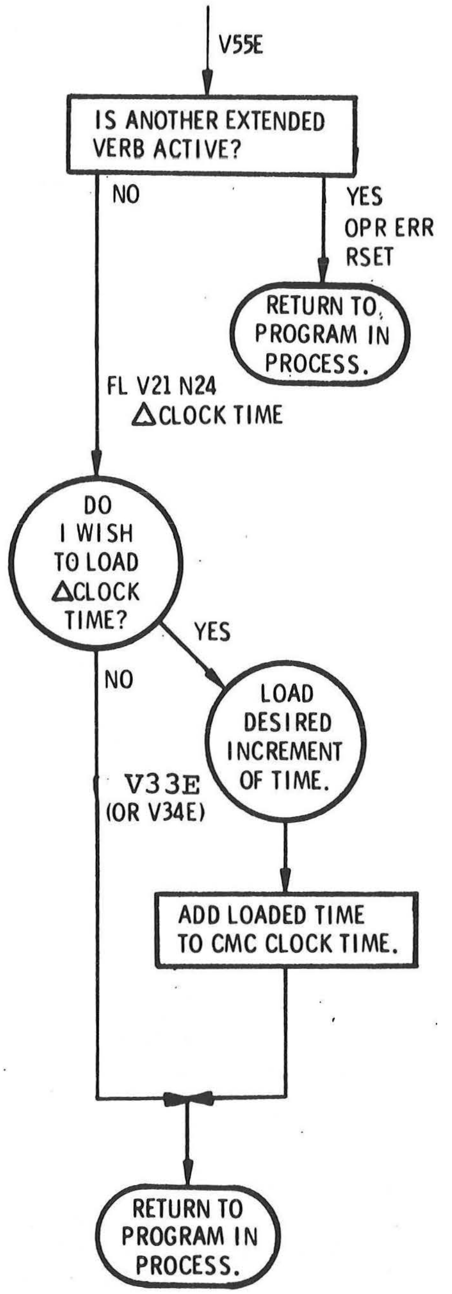


Fig. 5-80. Increment CMC Time Extended Verb (V55)

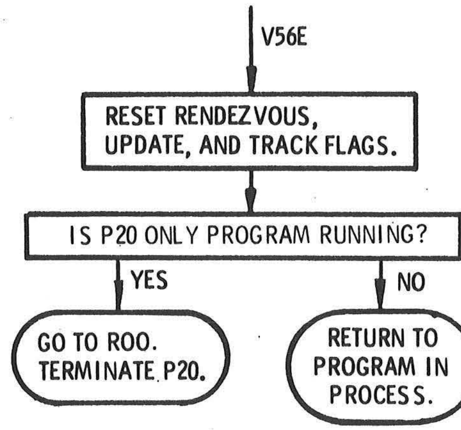


Fig. 5-81. Terminate Tracking Extended Verb (V56)

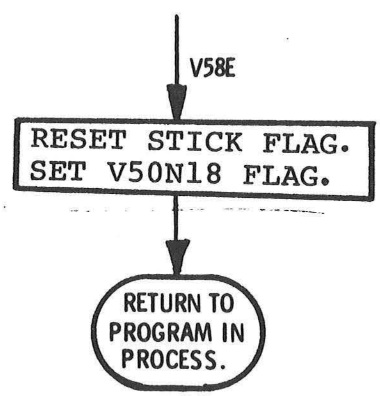


Fig. 5-82. Reset Stick Flag Extended Verb (V58)

5.2.3.38.13 Set Noun 17 Equal to Noun 20 Extended Verb (V60). This verb (Fig. 5-83) sets the astronaut selected gimbal angles equal to the present gimbal angles. It can be used to input the DAP.

5.2.3.38.14 Display DAP Attitude Error Extended Verb (V61). This verb (Fig. 5-84) is used during RCS maneuvers to display on the FDAI error needles the difference between the present ICDU angles and the DAP commanded angles.

5.2.3.38.15 Display Total Attitude Error Extended Verb (V62). This verb (Fig. 5-85) is used during RCS maneuvers to display on the FDAI error needles the difference between the current gimbal angles (noun 20) and the desired final gimbal angles (noun 22).

5.2.3.38.16 Display Total Astronaut Attitude Error Extended Verb (V63). This verb (Fig. 5-86) is used during RCS maneuvers to display on the FDAI error needles the total attitude error between the astronaut-selected gimbal angles (noun 17) and the current gimbal angles (noun 20).

5.2.3.38.17 Move This Vehicle State Vector To Other Vehicle State Vector Extended Verb (V66). This verb (Fig. 5-87) is used in the same manner as V47, except that the CSM state vector data is transferred to the LM state vector.

5.2.3.38.18 W-Matrix RMS Error Display Extended Verb (V67). This verb (Fig. 5-88) is used to display W-matrix information and to reinitialize the W-matrix if warranted by the display. It displays the RMS value of the position and velocity errors, and a code which indicates which process (rendezvous, orbital, or cislunar) will be initialized if the astronaut desires to change the display.

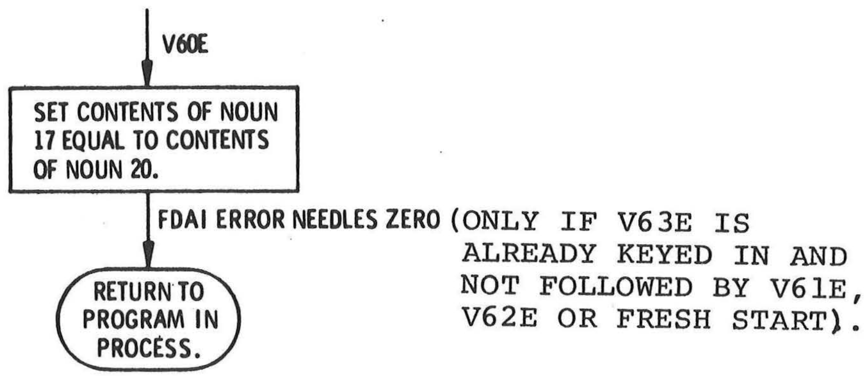


Fig. 5-83. Set Noun 17 Equal to Noun 20 Extended Verb (V60)

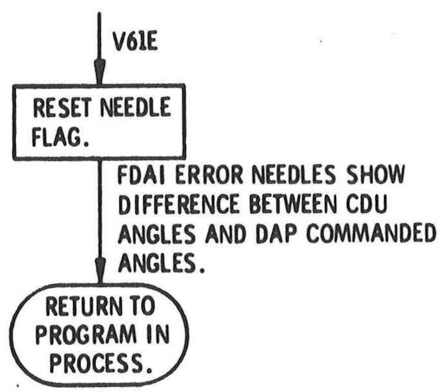


Fig. 5-84. Display DAP Attitude Error Extended Verb (V61)

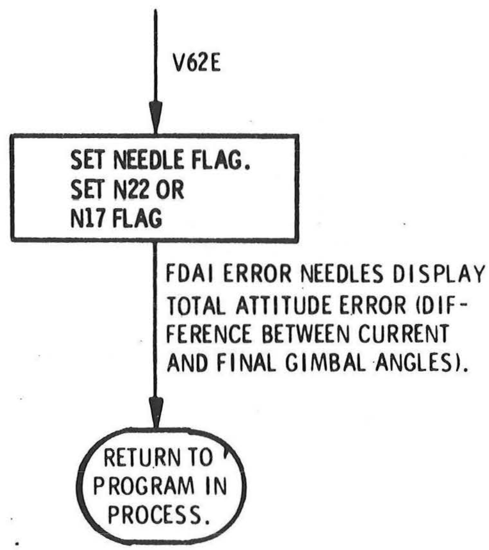


Fig. 5-85. Display Total Attitude Error Extended Verb (V62)

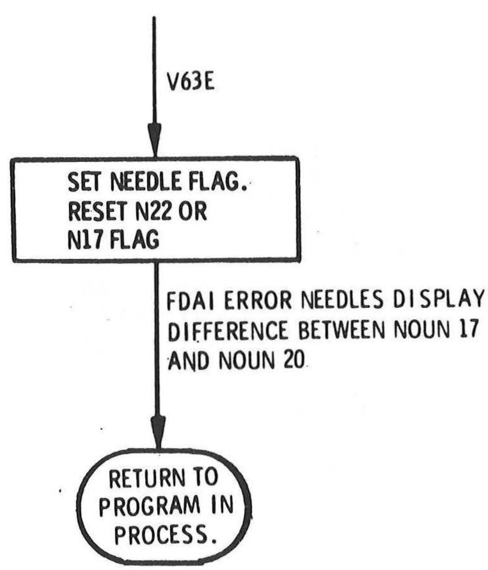


Fig. 5-86. Display Total Astronaut Attitude Error Extended Verb (V63)

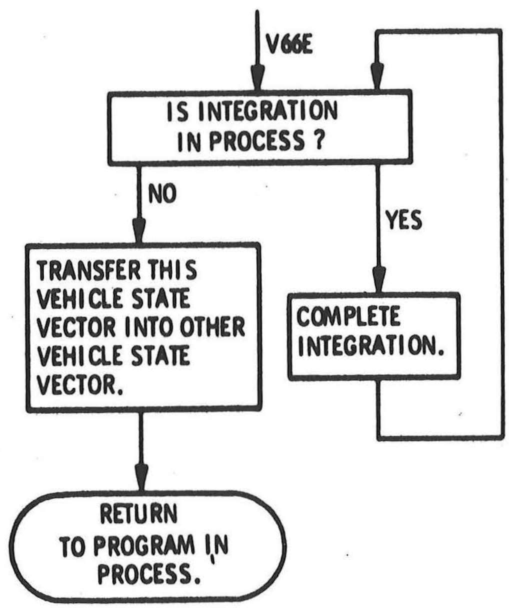


Fig. 5-87. Move This Vehicle State Vector To Other Vehicle State Vector Extended Verb (V66)

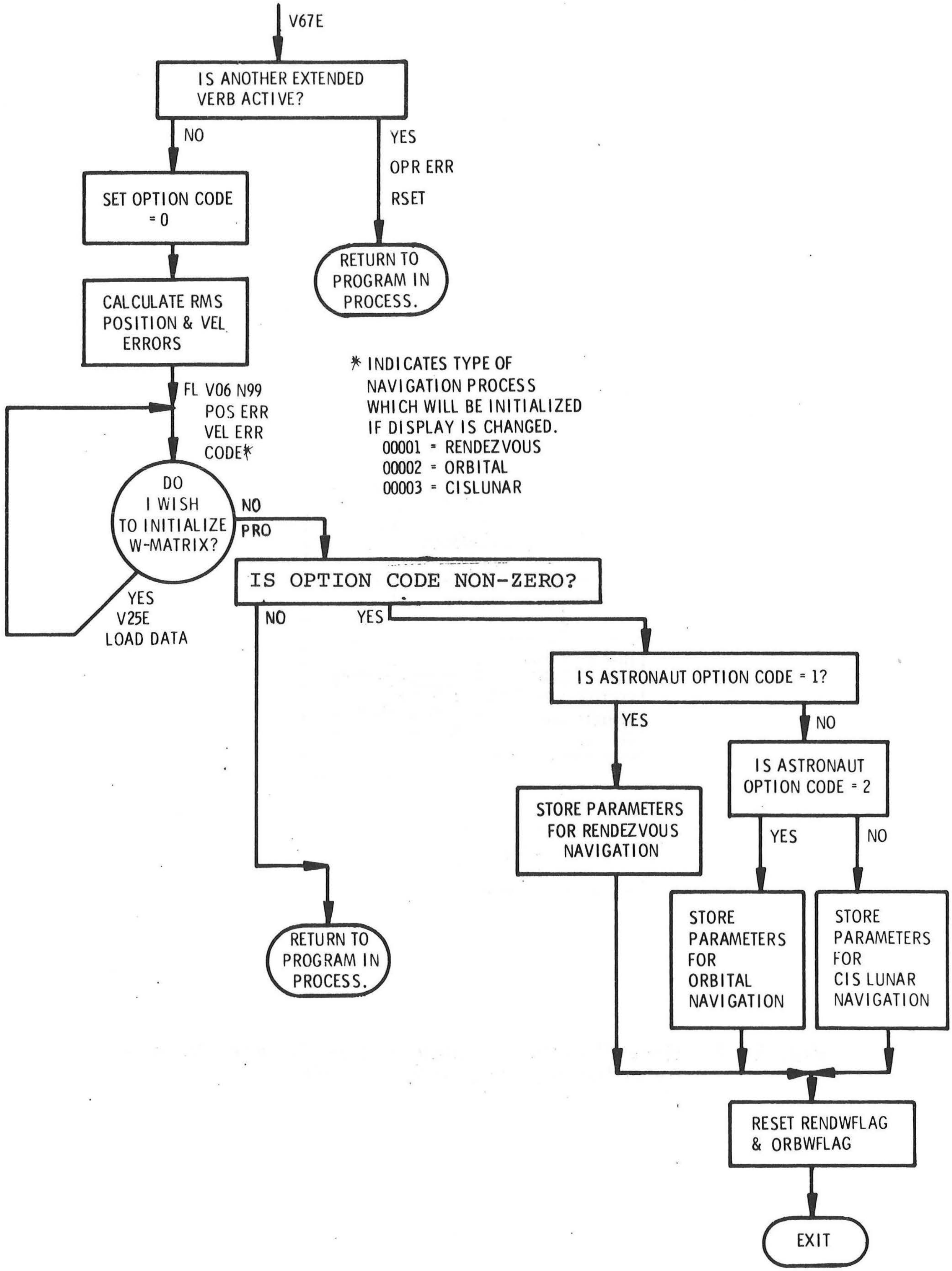


Fig. 5-88. W-Matrix RMS Error Display Extended Verb (V67)

5.2.3.38.19 CSM Stroke Test On Extended Verb (V68). This verb (Fig. 5-89) is used to perform the SPS stroke test. It can be used only during CMC TVC. The stroke test introduces pulses into the SPS engine control pitch axis to produce bending for spacecraft test purposes.

5.2.3.38.20 Restart Extended Verb (V69). This verb (Fig. 5-90) is used to force a CMC restart. The V69E does not directly command a restart but forces the CMC into a transfer control trap which in turn causes a restart.

5.2.3.38.21 Initialize Erasable Dump Via Downlink Extended Verb (V74). This verb (Fig. 5-91) starts the downlink of all eight banks of erasable memory. The erasable dump via downlink permits the banks to be downlinked two complete times. Obviously, all other downlink activity is inhibited during the verb. Once the process is started, it can only be terminated by running to completion, by keying V69E for a restart, or by keying a fresh start (V36E). The last is not recommended since it also invalidates the stored state vector.

5.2.3.38.21A Set Liftoff Flag Extended Verb (V75). The purpose of this extended verb (Fig. 5-91A) is to permit the astronaut to manually set bit 5 of FLAGWRD5 if the lift off discrete has not been received, during P02, from the SATURN IU and liftoff has occurred.

5.2.3.38.22 Set and Reset Preferred Attitude Flag Extended Verbs (V76 and V77). These verbs (Figs. 5-92 and 5-93) are used to set (V76) and reset (V77) the preferred attitude flag which defines the spacecraft attitude to which R61 is to maneuver. If set, the preferred tracking attitude, along the LOS to the LM, is selected. If reset, the +X axis tracking attitude is selected.

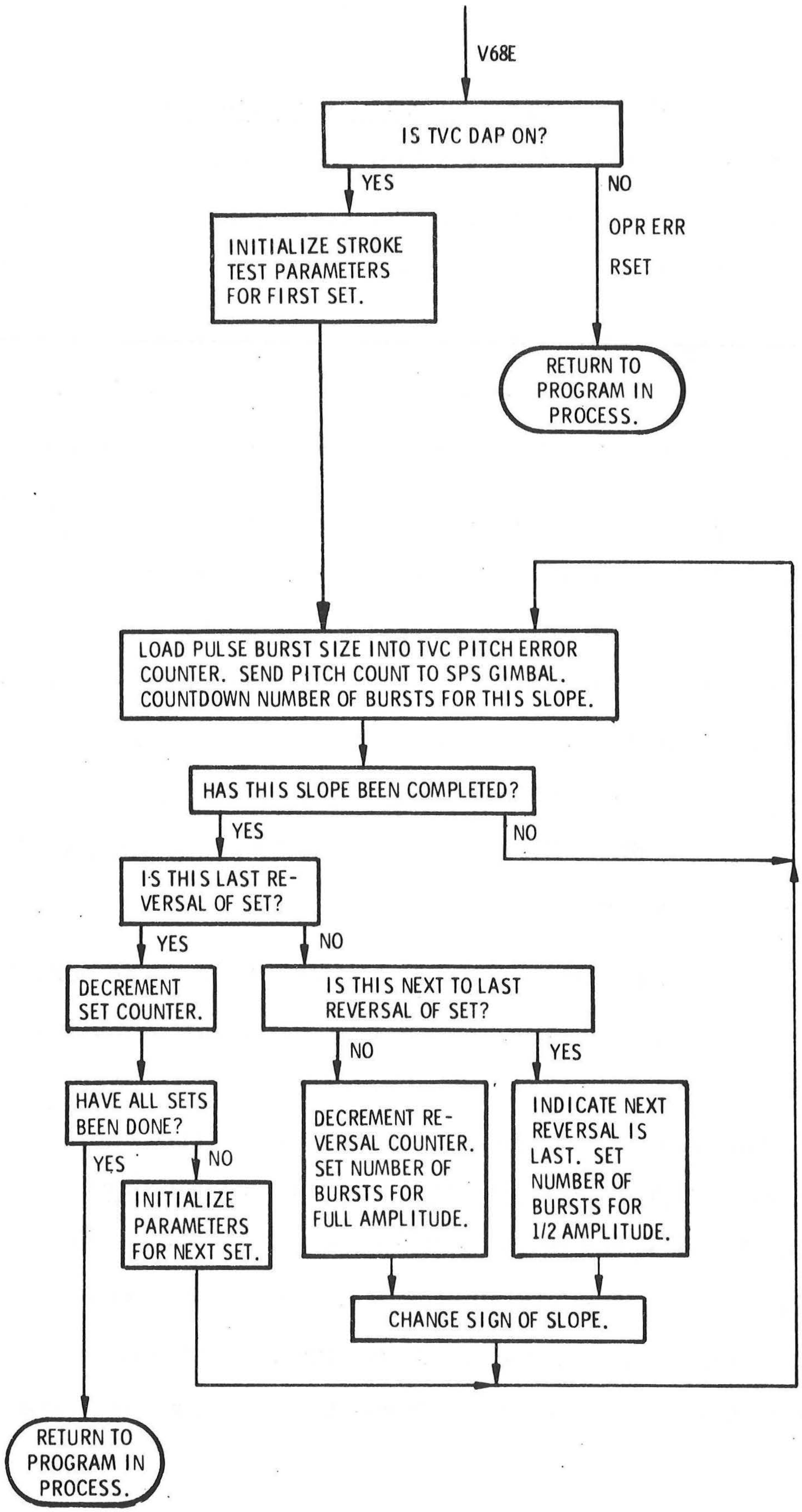


Fig. 5-89. CSM Stroke Test on Extended Verb (V68)

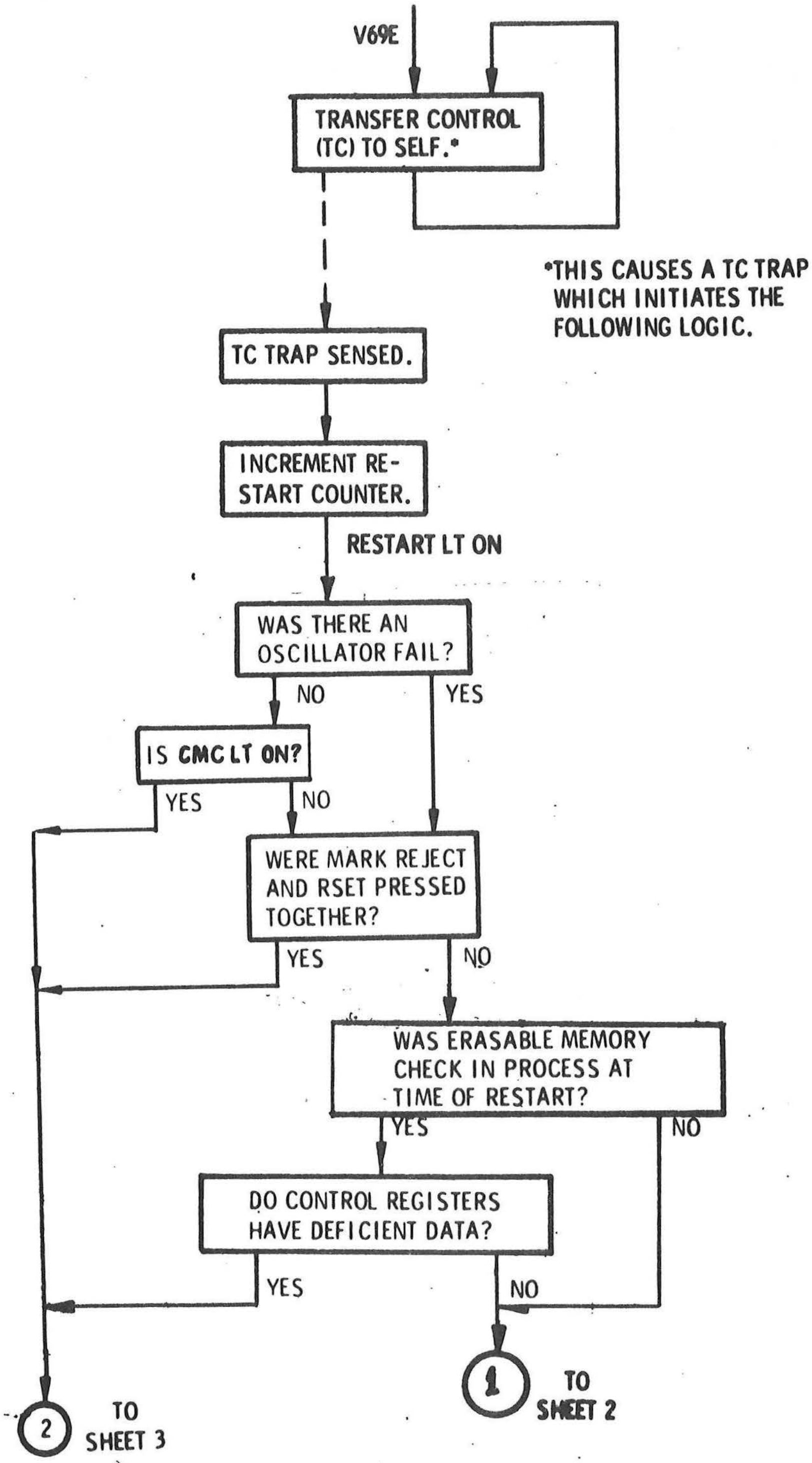


Fig. 5-90. Restart Extended Verb (V69) (Sheet 1 of 3)

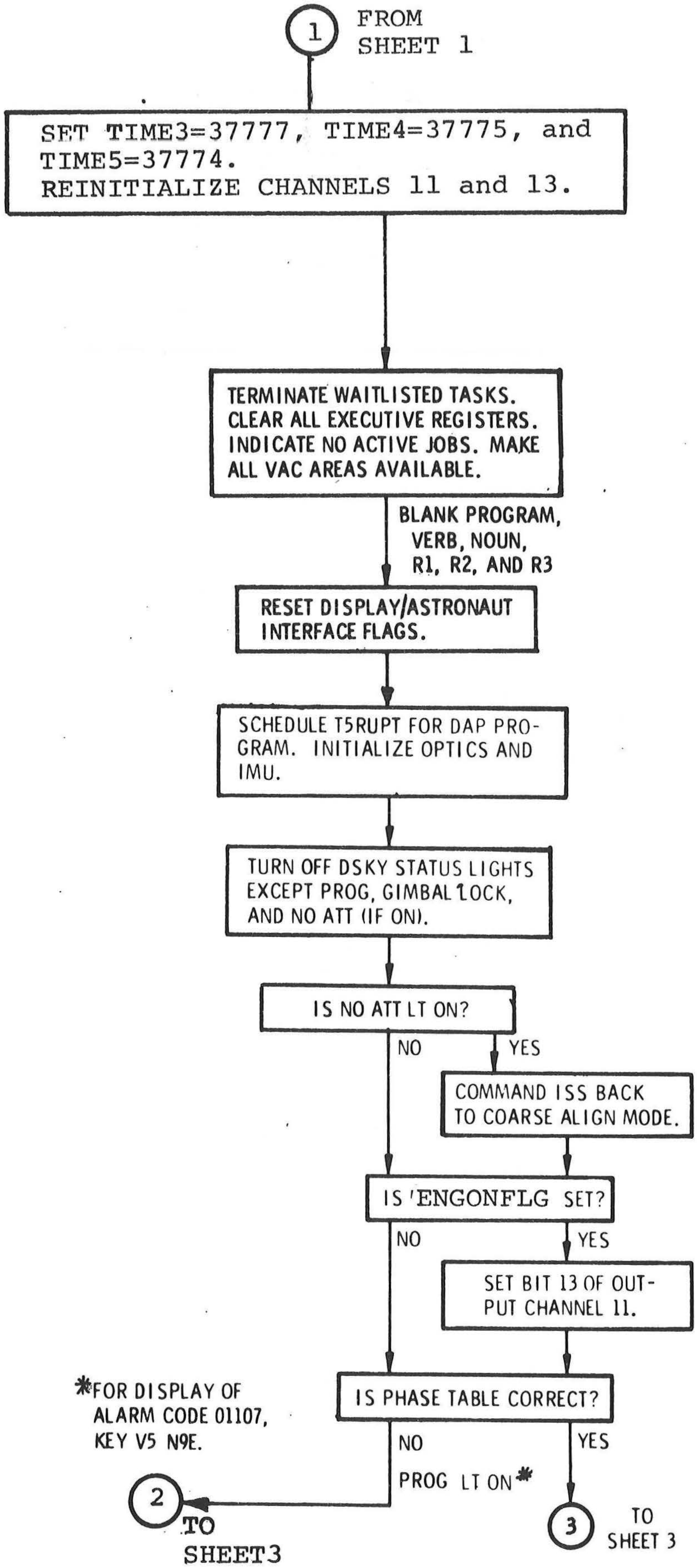


Fig. 5-90. Restart Extended Verb (V69) (Sheet 2 of 3)

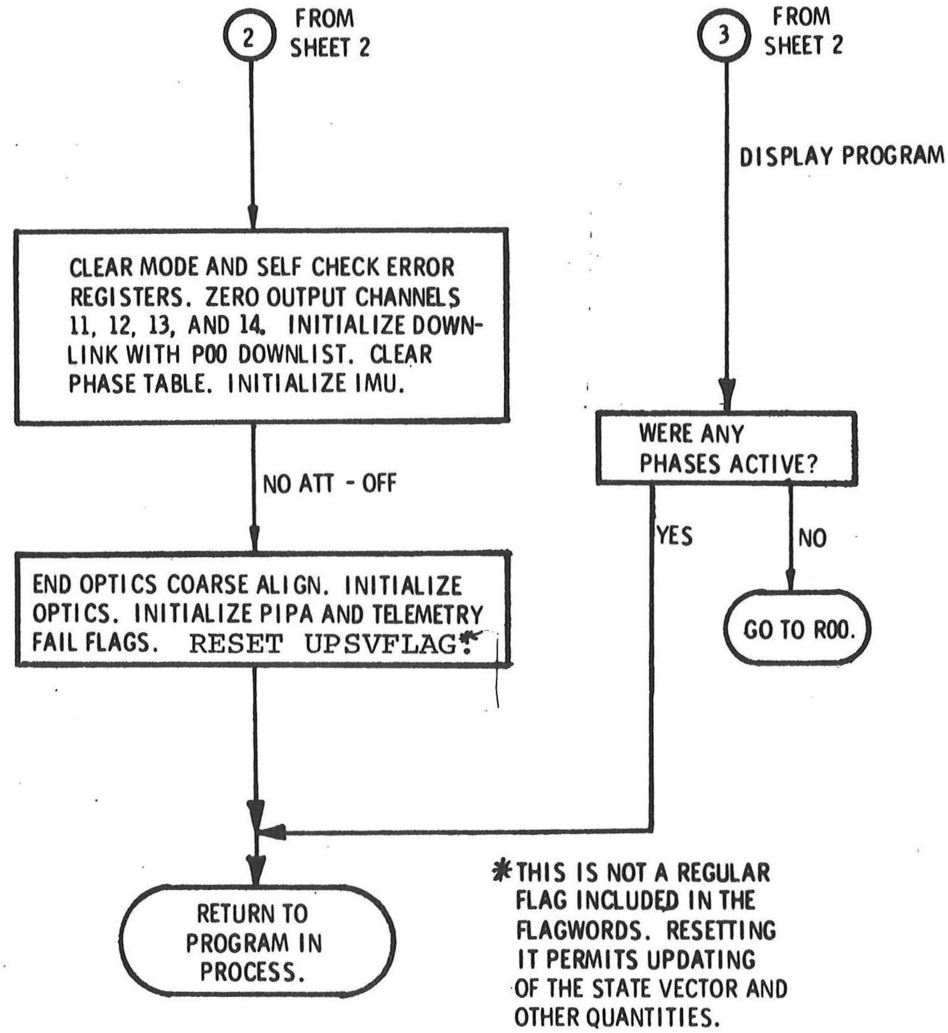


Fig. 5-90. Restart Extended Verb (V69) (Sheet 3 of 3)

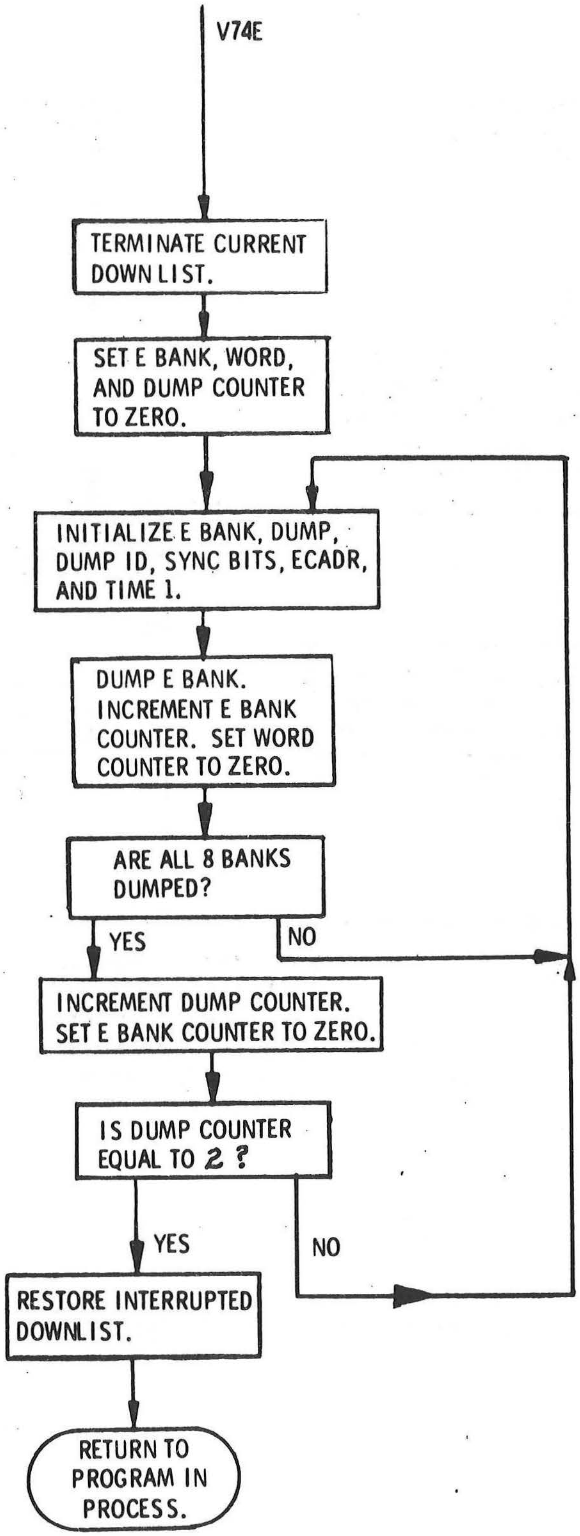


Fig. 5-91. Initialize Erasable Dump Via Downlink Extended Verb (V74)

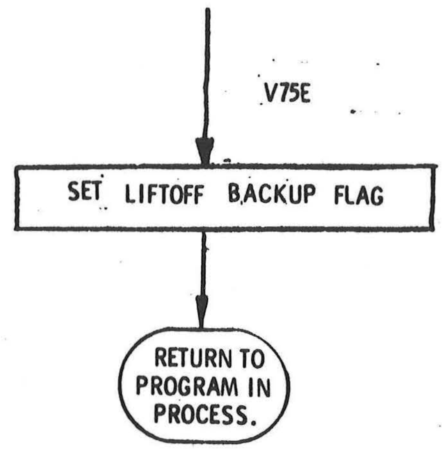


Fig. 5-91A Set Lift Off Flag Extended Verb (V75)

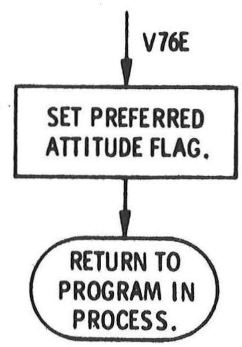


Fig. 5-92 Set Preferred Attitude Flag Extended Verb (V76)

5.2.3.38.22A <u>Change Gyro Compass Launch Azimuth (V78).</u>

The purpose of the Change Gyro Compass Launch Azimuth (figure 5-93A) is to provide the astronaut the ability to monitor and change the X stable member launch azimuth. This extended verb routine may only be called during the Gyro Compassing Program (P02). It is initiated by keying V78E on the DSKY.

5.2.3.38.23 <u>Update State Vector Extended Verbs (V80&V81).</u>

The Purpose of the Update State Vector Verbs (Figures 5-94 and 5-95) is used to choose which vehicle state vector is to be updated by rendezvous data processing. V80 selects the LM state vector and selecting V81 updates the CSM state vector. Keying V80E resets the vehicle update flag; keying V81E sets the vehicle update flag.

5.2.3.38.23A <u>Reject Rendezvous Back Up Sighting Mark (V86).</u>

The purpose of the reject rendezvous back up sighting mark extended verb (Figure 5-95A) is to erase any mark data in position one, in the event of an unsatisfactory sighting mark has been taken during the Rendezvous Back Up Sighting Mark Routine.

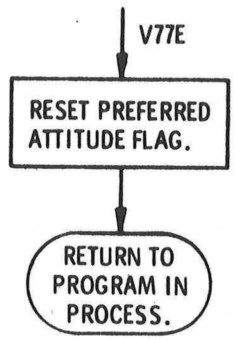


Fig. 5-93 Reset Preferred Attitude Flag Extended Verb (V77)

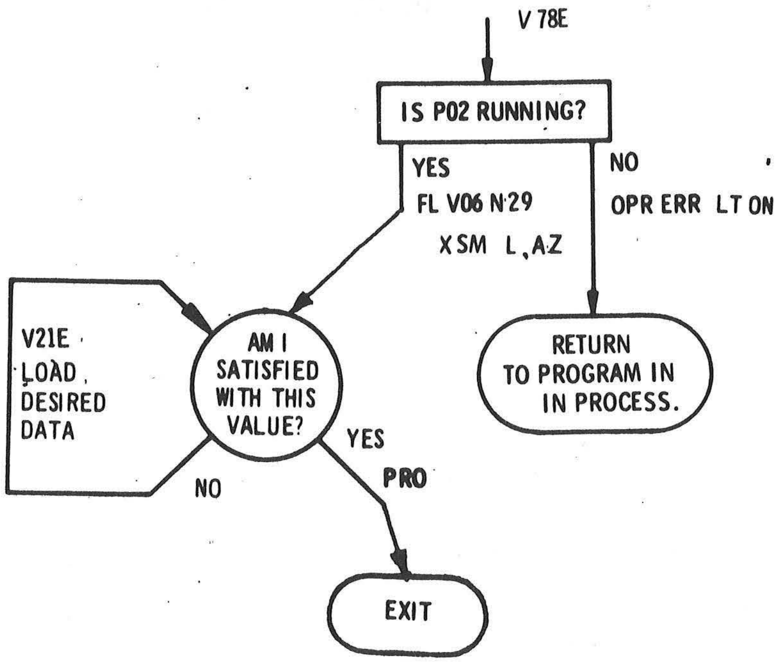


Fig. 5-93A Change Gyro Compass Launch Azimuth (V78)

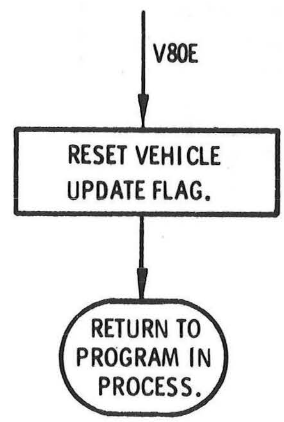


Fig. 5-94. Update LM State Vector Extended Verb (V80)

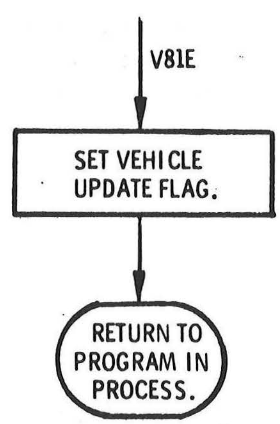


Fig. 5-95. Update CSM State Vector Extended Verb (V81)

5.2.3.38.24 Set and Reset VHF Range Flag Extended Verbs (V87 and V88). These verbs (Figs. 5-96 and 5-97) are used to set (V87) and reset (V88) the VHF range flag; which, when set, allows VHF ranging data to be processed by the rendezvous data processing routine (R22).

5.2.3.38.25 Display Sum of Each Bank Extended Verb (V91). This verb (Fig. 5-98) is used to perform the fixed memory check, SHOW BANKSUM. Refer to paragraph 6.1.3.

5.2.3.38.26 Enable W-Matrix Initialization Extended Verb (V93). This verb (Fig. 5-99) permits the crew to enable W-matrix initialization. It does this by resetting the RENDWFLG and ORBFLAG flags. Reset, these flags indicate that the W-matrix is invalid and must be reinitialized.

5.2.3.38.27 Cislunar Tracking Extended Verb (V94). This verb (Fig. 5-100) is used in program P23, during automatic optics positioning, prior to mark acceptance, to recycle back in the program to have the CMC aid in reacquiring the optics target.

5.2.3.38.28 Suspend State Vector Integration Extended Verb (V96). This verb (Fig. 5-101) allows the crew to suspend integration of the state vector during P00. This capability is very useful if the CMC had been in standby mode for a long period of time. When the CMC is brought back to operate mode, the idling program (P00) will begin integrating the state vector to the present time. Integration over the long shut down period is time consuming and diminished in accuracy. This verb can be used to suspend integration until after a state vector update is received from the ground. Program P00 checks for integration of the state vector about every 10 minutes. This verb suspends integration permanently.

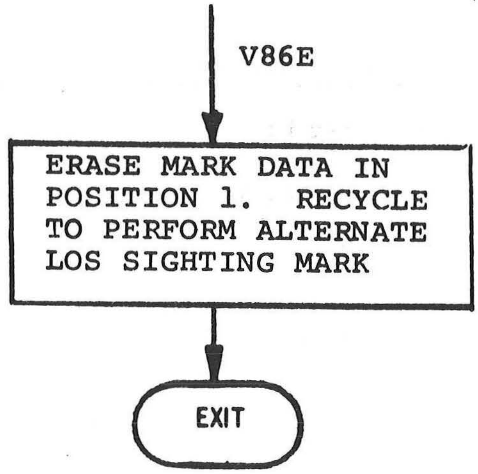


Fig. 5-95A. Reject Rendezvous Backup Sighting Extended Verb (V86)

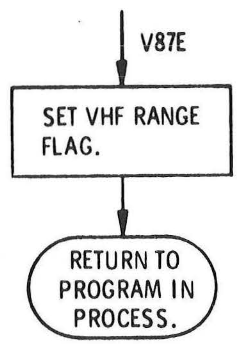


Fig. 5-96. Set VHF Range Flag Extended Verb (V87)

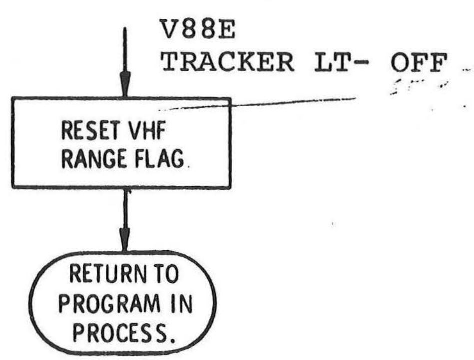


Fig. 5-97. Reset VHF Range Flag Extended Verb (V88)

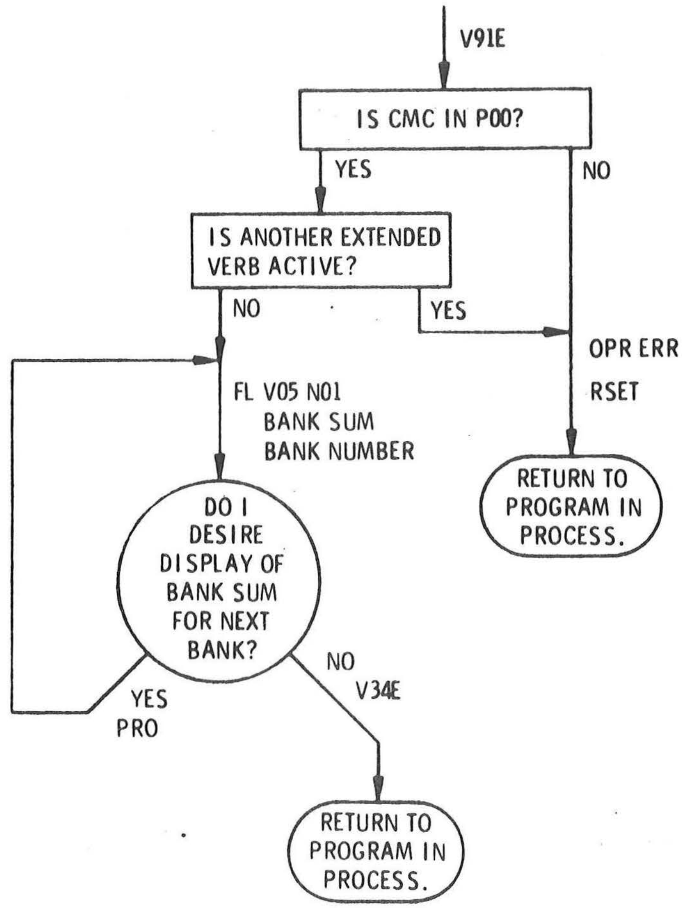


Fig. 5-98. Display Sum of Each Bank Extended Verb (V91)

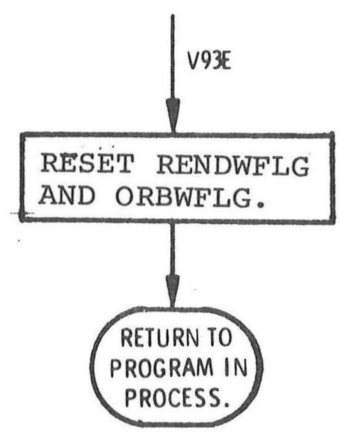


Fig. 5-99. Enable W-Matrix Initialization Extended Verb (V93)

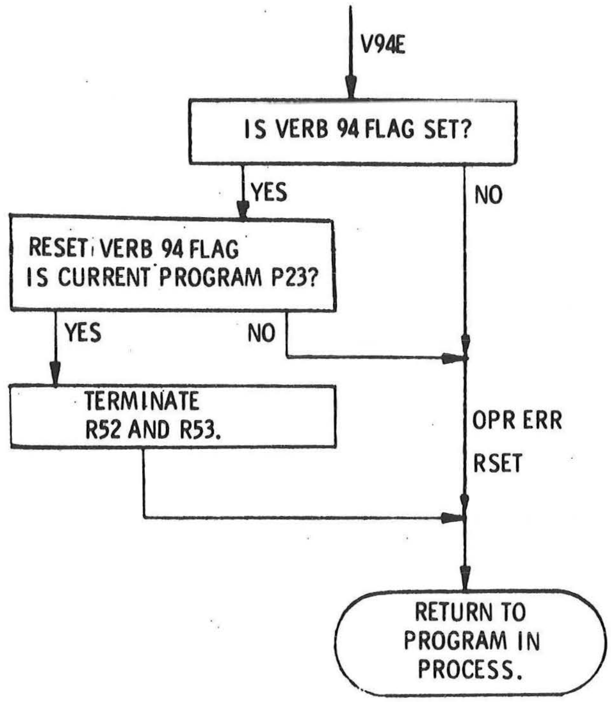


Fig. 5-100. Cislunar Tracking Extended Verb (V94)

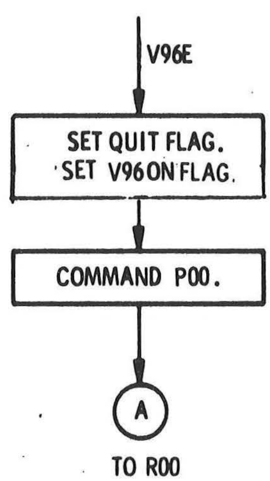


Fig. 5-101. Suspend State Vector Integration Extended Verb (V96)

SECTION VI

FLIGHT OPERATION PROCEDURES

6.1 BACKUP PROCEDURES

The procedures of this section are intended to supplement the normal checklist procedures.

6.1.1 Turn On and Shut Down Procedures

The following procedures are the normal power up and power down procedures for the various GNCS equipment.

6.1.1.1 CMC Power Up Procedure

This procedure assumes the CMC is in the standby mode. The CMC should never be powered down below standby mode, except in extreme emergency.

1. Press PRO button.
   STBY light goes out.
   Program 06 is displayed.
2. Key 00E
   Program display changes to 00.
3. If state vector is to be updated, key V96E to suspend state vector integration.
   Perform CMC update program, P27.
4. Select desired program (key V37E XXE).

6.1.1.2 CMC Power Down Procedure

Perform program P06 (key V37E06E). Do not power down CMC below standby mode. If CMC in standby mode for more than 23 hours use V73 procedure for compensation. The IMU should be shut down prior to CMC power down.

6.1.1.3 IMU Turn On Procedure

This procedure assumes IMU heater power is on. IMU heater power should never be turned off, except in extreme emergency. CMC should be powered up before the IMU; for emergency IMU turn on while CMC is not operating, see paragraph 6.2.2.

1. If STBY light is on, perform CMC power up procedure (paragraph 6.1.1.1).
2. Check that IMU circuit breakers are closed.
3. Set G/N POWER, IMU switch to on (up).
   NO ATT light comes on for 90 seconds.
4. When NO ATT light goes out, wait about 14.24 seconds, then select an IMU alignment program (usually P51).

6.1.1.4 IMU Shut Down Procedure

Set G/N POWER, IMU switch to OFF.
Do not remove IMU heater power, except in extreme emergency.

6.1.1.5 Optics Turn On Procedure

The optics should be turned on about fifteen minutes prior to use to provide a warmup period.

1. Check that OPTICS circuit breakers are closed.
2. Set G/N POWER, OPTICS switch to on (up).
3. After warmup, set G/N PWR switch to AC1 or AC2, for reticle power.
4. If ICDU zeroing is desired, set OPTICS, ZERO switch to ZERO.

Optics are now ready for use.

6.1.1.6 Optics Turn Off Procedure

1. Set OPTICS, ZERO switch to ZERO.

2. Set G/N PWR switch to OFF.

3. Set G/N POWER, OPTICS switch to OFF.

6.1.1.7 RR Transponder Turn On Procedure

The rendezvous radar transponder heater power should be turned on 30 minutes before use of the transponder.

1. Check that RNDZ XPNDR FLT BUS circuit breaker is closed.

2. Set RNDZ XPNDR PWR switch to HEATER.

3. Wait 1000 sec, then set RNDZ XPNDR PWR switch to on (up). If self test only is to be performed forget 1000 sec warmup.

4. Perform transponder self test (paragraph 6.1.7), if not previously done.

6.1.1.8 RR Transponder Shut Down Procedure

1. If the RR is to be used within two hours, set RNDZ XPNDR PWR switch to HEATER until RR is to be used.

2. If the RR is not to be used within two hours, set RNDZ XPNDR PWR switch to OFF until 30 minutes before RR is to be used.

6.1.2 CMC Self Check

The CMC self check consists of two tests which may be commanded individually or together. The latter is recommended for in-flight use. The first test checks the CMC ability to address and read properly into and out of each bit in erasable memory. The second test adds all the cells of each bank of fixed memory and compares the sum to the bank number. They must be the same to pass the test.

During performance of CMC self check it is recommanded that certain erasable addresses be monitored. These include the following:

1363 (ALMCADR) - One greater than the address which contains the instruction to go to the ERRORS routine. It is loaded only when an error is detected.

1365 (ERCOUNT) - Number of errors since last time address was zeroed by self check or fresh start.

1366 (SCOUNT) - Number of times one of the two tests of self check was begun since last time address was zeroed.

1367 (SCOUNT + 1) - Number of times erasable memory was successfully tested in self check since last time address was zeroed.

The following procedure is recommended for in-flight performance of self check:

1. Command P00:

   Key: V37E00E

2. Zero ERCOUNT, SCOUNT, and SCOUNT + 1:

   Key: V25 N1E
   1365E
   ENTR
   ENTR
   ENTR

3. Start monitor of ERCOUNT, SCOUNT, and SCOUNT + 1:

   Key: V15 N1E
   1365E

4. Command self check:

   Key: V21 N27E
   10E

5. Monitor register R2 (SCOUNT):

   Normal indication: 00001 for about 7 seconds
   00002 for about 43 seconds
   00003 or greater (successful self check, go to step 7)

   Abnormal indication: PROG light comes on.
   R2 stops before 00003.
   (Go to step 6)

6. Record results:

   Record R1 (ERCOUNT), R2 (SCOUNT), and R3 (SCOUNT + 1)

   Key: V5 N9E
   Verify alarm code 01102

   Key: V5 N8E
   Record R1 (ALMCADR)

7. Terminate self check:

   Key: V21 N27E
   0E

   If PROG light is on, key RSET.

8. Use following table for diagnosis of failure.

Recorded SCOUNT	Action to take	Probable trouble
00001	1. Key: V1 N1E 1374E 2. Record R1 (SKEEP 4) 3. Key: ENTR 1377E 4. Record R1 (SKEEP 7) 5. Transmit ALMCADR, SKEEP 4, and SKEEP 7 to MSFN 6. Terminate use of CMC	Erasable memory problem. Don't use CMC.
00002	Perform SHOW BANK-SUM (para. 6.1.3). Transmit bank number of failed bank to MSFN.	Fixed memory trouble. CMC not useable.

6.1.3 Fixed Memory Check (SHOW BANKSUM)

SHOW BANKSUM is a CMC routine which checks all the cells in each fixed memory bank. The test adds all the cells for each bank and displays the sum in R1. The bank number is displayed in R2. These magnitudes must be equal for a successful test. If they are not, the bank has an error in it.

Perform SHOW BANKSUM as follows:

1. Check first bank:
   Key: V91E
   Monitor: Flashing V05 N01
   R1 - Sum of cells in bank
   R2 - Bank number
2. If magnitude of R1 and R2 are the same, check next bank
   Key: PRO
3. Repeat step 2 for each succeeding bank until the last bank (43) has been checked.
4. If R1 and R2 differ for any bank, record bank number and transmit to MSFN. Terminate use of CMC after completion of test, until further notice by MSFN.
5. To terminate SHOW BANKSUM:
   Key: V34E

6.1.4 Erasable Memory Verification and Update

The contents of any erasable memory address may be checked. This is useful in determining the condition of flags or the value of pertinent parameters.

Any address may be checked as follows:

1. Key: V1 N1E
   XXXXE, where XXXX is address desired
2. Monitor R1 for contents of address.

The data displayed in R1 is in octal, to determine the state of an individual flag, an octal to binary conversion is necessary. This needn't be done for the entire register, but only for the octal digit that contains the bit in question. Bits 1, 2, and 3 of the channel word appear in digit E (first from the right) of R1; bits 4, 5, and 6...in digit D; bits 7, 8, and 9...digit C; bits 10, 11, and 12...digit B; and bits 13, 14, and 15...digit A. The following is an octal to binary conversion list:

Octal	Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

The contents of erasable memory addresses can be changed; however, great care must be exercised to prevent destroying valid data by keying an incorrect address. Update erasable memory as follows:

1. Command P00:
   Key: V37E00E
2. Start update:
   Key: V21 N1E
3. Load address:
   Key: XXXXE, where XXXX is address to be loaded
4. Load data:
   Key: XXXXXE, where XXXXX is data to be loaded in octal.
5. If more than one nonsequential address is to be loaded, repeat steps 3 and 4, with an extra ENTR after each data load, until all addresses are loaded.

6. If a number of sequential addresses are to be loaded, after the first data load.
   Key V15E
   and repeat step 4, with an extra ENTR after each data load, until all addresses are loaded.

After loading data, verify data word as follows:

1. Start data display:

   Key: V1 N1E

2. Load address:

   Key: XXXXE, where XXXX is address of data to be verified.

3. Verify data word in R1.

4. If the data in a number of sequential addresses are to be verified,
   Key: N15E
   Verify second data word in R1
   Key: ENTR
   Verify third data word in R1
   Key: ENTR
   Continue process until all data words are verified.

6.1.5 PIPA Bias Check

The PIPA bias can be checked and updated as follows:

1. Set digital event timer (DET) to zero.
2. Obtain SC rates of less than 0.1 degrees per second.
3. Key: V25 N21E
   ENTR
   ENTR
   ENTR/START EVENT TIMER

4. V16 N21E
   XYZ PIPA COUNTS

5. AT T + 10:40 - KEY VERB
   RECORD COUNTS
   (X) R1 _____ (Y) R2 _____ (Z) R3 _____

6. V21 N01E
   LOAD 1452E (CALCULATED X BIAS) E,E,
        1454E (CALCULATED Y BIAS) E,E,
        1456E (CALCULATED Z BIAS) E

6.1.6 Gyro Drift Test

Gyro drift can be determined from the gyro torquing angles. The test requires at least two hours for accurate performance. Attitude changes during the test do not affect the test results. Test procedures are as follows:

1. Perform IMU realign program P52.

2. During gyro torquing routine (R55), record gyro torquing angles (FL V06 N93) and time (to nearest 2 minutes), and command gyro torquing (PRO).
3. After two hours repeat steps 1 and 2.
4. The last recorded torquing angles represent the uncompensated gyro drift in degrees to the nearest 0.001 degree. To convert to MERU, use the following formula:

$$D = \frac{\text{Torquing angle (deg)}}{\text{Time (hours)}} \times 67 \text{ meru}$$

6.1.7 Rr Transponder Self Test

The following procedure is used to test the RR Transponder without a signal from the RR on the LM. The test is done on systems test panel (101) in the LEB.

1. Perform RR transponder turn on procedure(para. 6.1.1.7).
2. Set SYSTEMS TEST selector S1 to XPNDR.
3. Set SYSTEMS TEST selector S2 to A; monitor SYSTEMS TEST METER for 2.1 VDC minimum transmitter power voltage.
4. Place and hold the TRANSPONDER TEST ACTIVATE switch in ON position.
5. Set SYSTEMS TEST selector S2 to B; monitor SYSTEM TEST METER for a positive voltage of 2.75 ±1.75 volts.
6. Set SYSTEMS TEST selector S2 to B or D.
   Release TRANSPONDER TEST ACTIVATE switch to the OFF position.

   If LM RR is operating monitor SYSTEMS TEST meter to determine if RR antenna is pointed at CSM and if CSM or oriented correctly to receive RR signal.

   The transponder system is now ready for use. If RR is to be used within 30 minutes leave transponder controls as they are. If RR is to be used in 30 minutes to two hours, set RNDZ XPNDR PWR switch to HEATER until transponder is to be used. If RR is not to be used within two hours, power down transponder (paragraph 6.1.1.8) until 30 minutes before use.

6.1.8 Flagword Monitor and Change

The status of CMC flags may be monitored by the following procedure. The state of any flag may be changed by this procedure:

1. Monitor desired flagword:

   Key: V11 N1E

   Key: Flagword address (CADR) of desired flagword as follows:

Flagword	Address
0	74E
1	75E
2	76E
3	77E
4	100E
5	101E
6	102E
7	103E
8	104E
9	105E

Continue with rest of this procedure if a flag state change is desired.

2. Store flag change in erasable memory:

   Key: V25 N7E

XXE or XXXE	where XXE or XXXE is the address of the flagword to be altered
XXXXXE	where XXXXX is octal no. of the bit or bits to be changed in the flagword
XE	where X is either a one or zero depending upon whether the above chosen bit or bits are to be set or reset

6.1.9 CMC Input-Output Channel Check

To determine the state of discretes to or from the CMC, the input and output channels can be checked. This is done as follows:

1. Key: V1 N10E or V11 N10E
2. Key: XXE, where XX is the number of the channel desired.
3. Monitor R1, which contains the 15 binary bits of the channel in octal. To determine the state of each bit, the octal number in the register must be converted to binary just as described in paragraph 6.1.4 (Erasable Memory Verification and Update)

Table 6-1 contains the bit assignment for the output channels and Table 6-2 for the input channels. The fourth column from the left gives the octal digit of R1 which contains the bit in column two. The last column contains those octal numbers which indicate that the bit is active. It should be noted that the output channels use positive logic; i.e., an active bit is a one and an inactive bit is a zero. The input channels 15 and 16 also use positive logic. Input channels 30 through 33 use negative logic; i.e., an active bit is a zero and an inactive bit is a one.

TABLE 6-1.

CMC OUTPUT CHANNELS BIT ASSIGNMENT

BIT	DESCRIPTION	DSKY DIGIT POSITION	NUMERALS WITH WHICH BIT IS SET
	CHANNEL 5		
	CHANNEL 5 CONTAINS PITCH AND YAW RCS JET COMMANDS AS FOLLOWS:		
1	S/M ENG. C3 (+PITCH, +X) C/M ENG. 13 (+PITCH, -X, +YAW)	E	1, 5 1, 3, 5, 7
2	S/M ENG. C4 (-PITCH, -X) C/M ENG. 24 (- PITCH, +Z)	E	2, 6 2, 3, 6, 7
3	S/M ENG. A3 (+PITCH, -X) C/M ENG. 23 (+PITCH, -X, -YAW)	E	4, 5, 6 4, 5, 6, 7
4	S/M ENG. A4 (-PITCH, +X) C/M ENG. 14 (-PITCH, +Z)	D	1, 3, 5 1, 3, 5, 7
5	S/M ENG. D3 (+YAW, +X) C/M ENG. 25 (+YAW, - X), -PITCH)	D	2, 3 2, 3, 6, 7
6	S/M ENG. D4 (-YAW, -X) C/M ENG. 16 (-YAW, -X, -PITCH)	D	4, 5 4, 5, 6, 7
7	S/M ENG. B3 (+YAW, -X) C/M ENG. 15 (+YAW, -X, +PITCH)	C	1, 3 1, 3
8	S/M ENG. B4 (-YAW, +X) C/M ENG. 26 (-YAW, -X, +PITCH)	C	2, 3 2, 3
	CHANNEL 6		
	CHANNEL 6 CONTAINS ROLL RCS JET COMMANDS AS FOLLOWS:		
1	S/M ENG. B1 (+ROLL, +Z) C/M ENG. 11 (+ROLL, +Z, +Y)	E	1, 5
2	S/M ENG. B2 (-ROLL, -Z) C/M ENG. 12 (-ROLL, -Z, -Y)	E	2, 6
3	S/M ENG. D2 (+ROLL, -Z) C/M ENG. 22 (+ROLL, -Z, +Y)	E	4, 5, 6
4	S/M ENG. D1 (-ROLL, +Z) C/M ENG. 21 (-ROLL, +Z, -Y)	D	1, 3, 5
5	S/M ENG. A1 (+ROLL, +Y)	D	2, 3
6	S/M ENG. A2 (-ROLL, -Y)	D	4, 5
7	S/M ENG. C1 (+ROLL, -Y)	C	1
8	S/M ENG. C2 (-ROLL, +Y)	C	2

CHANNEL 11

1	ISS WARNING	E	1, 3, 5, 7
2	COMPUTER ACTIVITY	E	2, 3, 6, 7
3	UPLINK ACTIVITY	E	4, 5, 6, 7
4	TEMPERATURE CAUTION	D	1, 3, 5, 7
5	KEY RELEASE FLASH	D	2, 3, 6, 7
6	VERB-NOUN FLASH	D	4, 5, 6, 7
7	OPERATOR ERROR FLASH	C	1, 5
8	SPARE		
9	TEST CONNECTOR OUTBIT	C	4, 5
10	CAUTION RESET	B	1
11	SPARE		
12	SPARE		
13	ENGINE ON	A	1
14	SPARE		

CHANNEL 12

1	ZERO OCDU'S	E	1, 3
2	ENABLE OPTICS ERROR COUNTER	E	2, 3
3	SPARE		
4	COARSE ALIGN ENABLE	D	1, 3, 5, 7
5	ZERO ICDU'S	D	2, 3, 6, 7
6	ENABLE IMU ERROR COUNTER	D	4, 5, 6, 7
7	SPARE		
8	TVC ENABLE	C	2, 6
9	SIVB TAKEOVER ENABLE	C	4, 6
10	ZERO OPTICS	B	1, 3
11	DISENGAGE OPTICS DAC	B	2, 3
12	SPARE		
13	SIVB INJECTION SEQUENCE START	A	1, 5
14	SIVB CUTOFF	A	2, 6
15	ISS TURN ON DELAY COMPLETE	A	4, 5, 6

CHANNEL 13

1-4	VHF RANGING (BITS 1 thru 4 must contain 1001 to obtain VHF CONTROL)		
5	NOT USED		
6	BLOCK INLINK (NOT SET BY PROGRAM)		
7	DOWNLINK WORD ORDER	C	1, 3

8	BMAG COUNTER ENABLE	C	2, 3
9	SPARE		
10	TEST DSKY LIGHTS	B	1, 3, 5, 7
11	ENABLE STANDBY	B	2, 3, 6, 7
12	RESET ROTATION CONTROL TRAP	B	4, 5, 6, 7
13	RESET TRANSLATION CONTROL TRAP	A	1, 3, 5, 7
14	RESET MINIMUM IMPULSE TRAP	A	2, 3, 6, 7
15	ENABLE T6 RUPT	A	4, 5, 6, 7

CHANNEL 14

1	OUTLINK ACTIVITY (NOT USED)	E	1
2-5	SPARE		
6	GYRO ENABLE	D	4
7	GYRO SELECT A	C	*
8	GYRO SELECT B	C	*
9	GYRO MINUS SIGN	C	*

*DIGIT C INDICATES GYRO AXIS SELECTED AS FOLLOWS:

0 = NONE	4 = NONE
1 = +X	5 = -X
2 = +Y	6 = -Y
3 = +Z	7 = -Z

10	GYRO ACTIVITY	B	1, 3, 5, 7
11	DRIVE SHAFT CDU	B	2, 3, 6, 7
12	DRIVE TRUNNION CDU	B	4, 5, 6, 7
13	DRIVE ICDU Z	A	1, 3, 5, 7
14	DRIVE ICDU Y	A	2, 3, 6, 7
15	DRIVE ICDU X	A	4, 5, 6, 7

BLANK

TABLE 6-2

CMC INPUT CHANNELS BIT ASSIGNMENT

BIT	DESCRIPTION	DSKY DIGIT POSITION	NUMERALS WITH WHICH BIT IS SET
	CHANNEL 15		
1-5	CHANNEL 15, BITS 1 THROUGH 5 CONTAIN THE KEYCODE FROM THE MAIN PANEL DSKY. IT APPEARS IN DIGITS D AND E OF THE REGISTER AS AN OCTAL NUMBER, 0 THROUGH 37.		
	CHANNEL 16		
1-5	CHANNEL 16, BITS 1 THROUGH 5 CONTAIN THE KEYCODE FROM THE NAVIGATION PANEL DSKY. IT APPEARS IN DIGITS D AND E OF THE REGISTER AS AN OCTAL NUMBER, 0 THROUGH 37.		
6	MARK DISCRETE	D	4, 5, 6, 7
7	MARK REJECT	C	1
	CHANNEL 30		
1	ULLAGE PRESENT (NOT SENSED BY PROG.)	E	2, 6
2	SM SEPARATE (NOT SENSED BY PROG.)	E	4
3	SPS READY (NOT SENSED BY PROG.)	E	2, 3
4	SIVB SEPARATE, ABORT(NOT SENSED BY PROG)	D	4
5	LIFTOFF	D	4, 5
6	SPARE		
7	OCDU FAIL	C	2, 6
8	SPARE		
9	IMU OPERATE	C	2, 3
10	S/C CONTROL OF SATURN	B	0, 2, 4, 6
11	IMU CAGE	B	0, 1, 4, 5
12	ICDU FAIL	B	0, 1, 2, 3
13	IMU FAIL	A	0, 2, 4, 6
14	ISS TURN ON REQUEST	A	0, 1, 4, 5
15	IMU TEMPERATURE WITHIN LIMITS	A	0, 1, 2, 3

CHANNEL 31

1	+PITCH MANUAL ROTATION	E	2, 6
2	-PITCH MANUAL ROTATION	E	1, 5
3	+YAW MANUAL ROTATION	E	1, 2, 3
4	-YAW MANUAL ROTATION	D	2, 4, 6
5	+ROLL MANUAL ROTATION	D	4, 5
6	-ROLL MANUAL ROTATION	D	2, 3
7	+X TRANSLATION	C	2, 6
8	-X TRANSLATION	C	1, 5
9	+Y TRANSLATION	C	1, 2, 3
10	-Y TRANSLATION	B	2, 4, 6
11	+Z TRANSLATION	B	4, 5
12	-Z TRANSLATION	B	2, 3
13	CMC ATTITUDE HOLD MODE	A	2
14	CMC FREE MODE	A	1
15	CMC SC CONTROL (*3 IN POSITION A INDICATES CMC AUTO MODE)	A	1, 2, 3*

CHANNEL 32

1	+PITCH MININUM IMPULSE	E	2, 6
2	-PITCH MINIMUM IMPULSE	E	1, 5
3	+ YAW MINIMUM IMPULSE	E	1, 2, 3
4	-YAW MINIMUM IMPULSE	D	2, 4, 6
5	+ROLL MINIMUM IMPULSE	D	4, 5
6	-ROLL MINIMUM IMPULSE	D	2, 3
7-10	SPARE		
11	LM ATTACHED (NOT USED BY PROG)	B	5
12	SPARE		
13	SPARE		
14	PROCEED	A	5
15	SPARE		

CHANNEL 33

1	SPARE		
2	VHF DATA QUALITY	E	0,1,4,5
3	SPARE		
4	ZERO OPTICS	D	6
5	OPTICS CMC MODE	D	5
6-9	SPARE		
10	BLOCK UPLINK	B	2, 6
11	UPLINK TOO FAST	B	1, 5
12	DOWNLINK TOO FAST	B	1, 2, 3

13	PIPA FAIL	A	0, 2, 4, 6
14	CMC WARNING	A	0, 1, 4, 5
15	OSC ALARM	A	0, 1, 2, 3

6.2 EMERGENCY PROCEDURES

6.2.1 Tumbling IMU

1. Hold IMU CAGE switch in the **on (up)** position until the gimbals settle at the zero position (about 5 seconds); then set to off (down) position.
2. Perform IMU orientation determination program, P51.

6.2.2 IMU Turn On When CMC Is Not Operating

1. Check that IMU and IMU/HTR circuit breakers are closed.
2. Set G/N POWER, IMU switch to on (up) position.
3. Wait 90 seconds.
4. Momentarily (about 5 seconds), set IMU CAGE switch to on (up) position, then return to off (down) position.

The IMU is then aligned to the spacecraft axes. To align the IMU to a particular inertial orientation, maneuver the spacecraft to the desired orientation and cage the IMU (step 4 above).

6.3 MALFUNCTION PROCEDURES

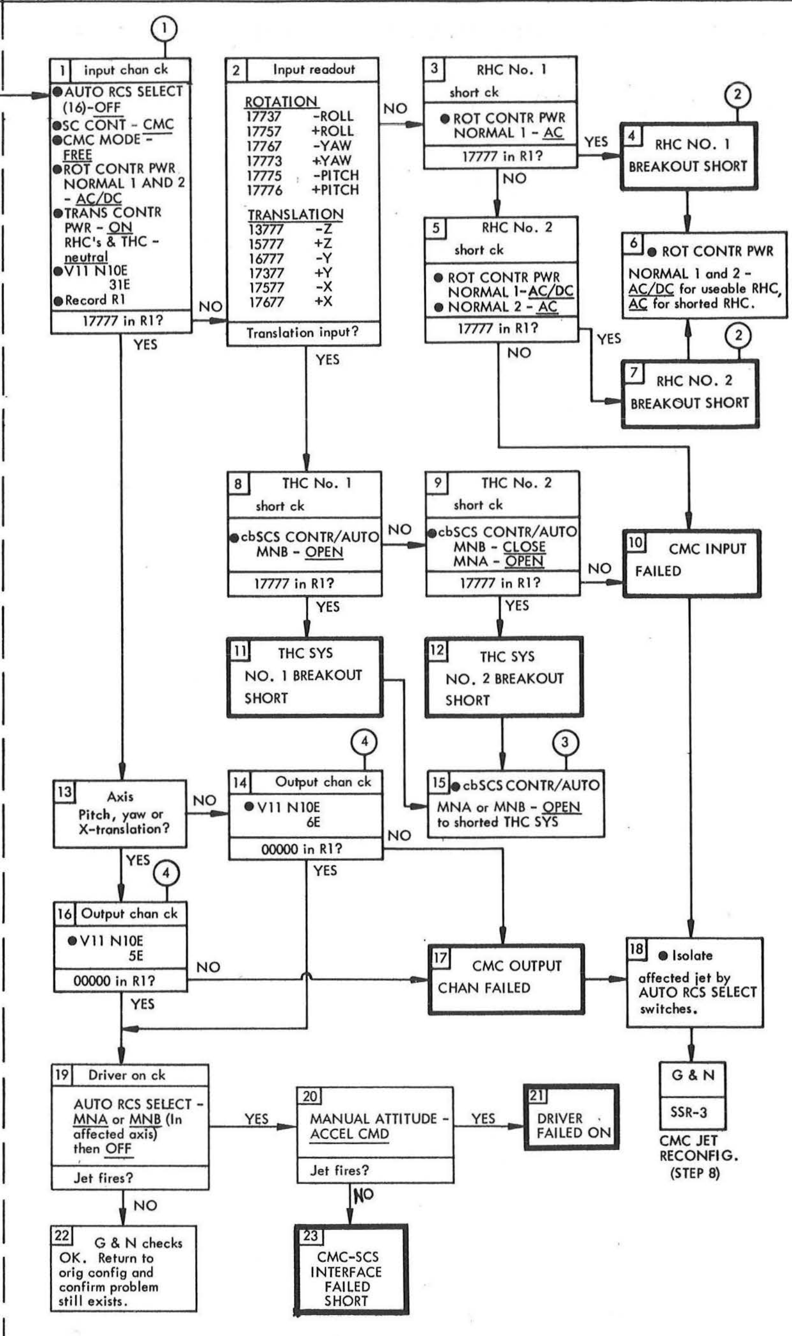
Table 6-3 lists GNCS caution and warning indicators and other malfunction indications and the corrective action to be performed for each.

To test the reliability of the DSKY alarm indicators (GIMBAL LOCK, PROG, TRACKER, TEMP, and RESTART) key in V35E, when in Program P00. This will also light the UPLINK ACTY, KEY REL, OPR ERR, NO ATT, and STBY indicators and display 8's and +'s on the numerical registers. The displays will go out after five seconds.

Table 6-4 provides corrective action for alarm codes which appear with program alarms (PROG indicator lighted). Most alarms require keying V5 N9E to have the alarm code displayed. Alarm codes which are caused by procedural errors are not included in Table 6-4. A complete list of alarm codes is given in Table 2-2.

Table 6-5 provides special subroutines which are used in conjunction with malfunction procedures of Tables 6-3 and 6-4.

SYMPTOM	PROCEDURE	REMARKS
G & N 1 RCS FAILED ON	see flowchart below	see remarks below



REMARKS

1. An R1 of 17777 indicates no jet commands into CMC.
2. Direct switches in affected RHC still functional. SCS rate command with failed RHC still possible when breakout switches closed in same axis by operable RHC. (Hand control power at operable RHC.)
3. Locking an RHC mechanically opens breakout switches.
4. An R1 of 00000 indicates no jet commands from computer.

Table 6-4. Malfunction Procedures (Sheet 1 of 6)

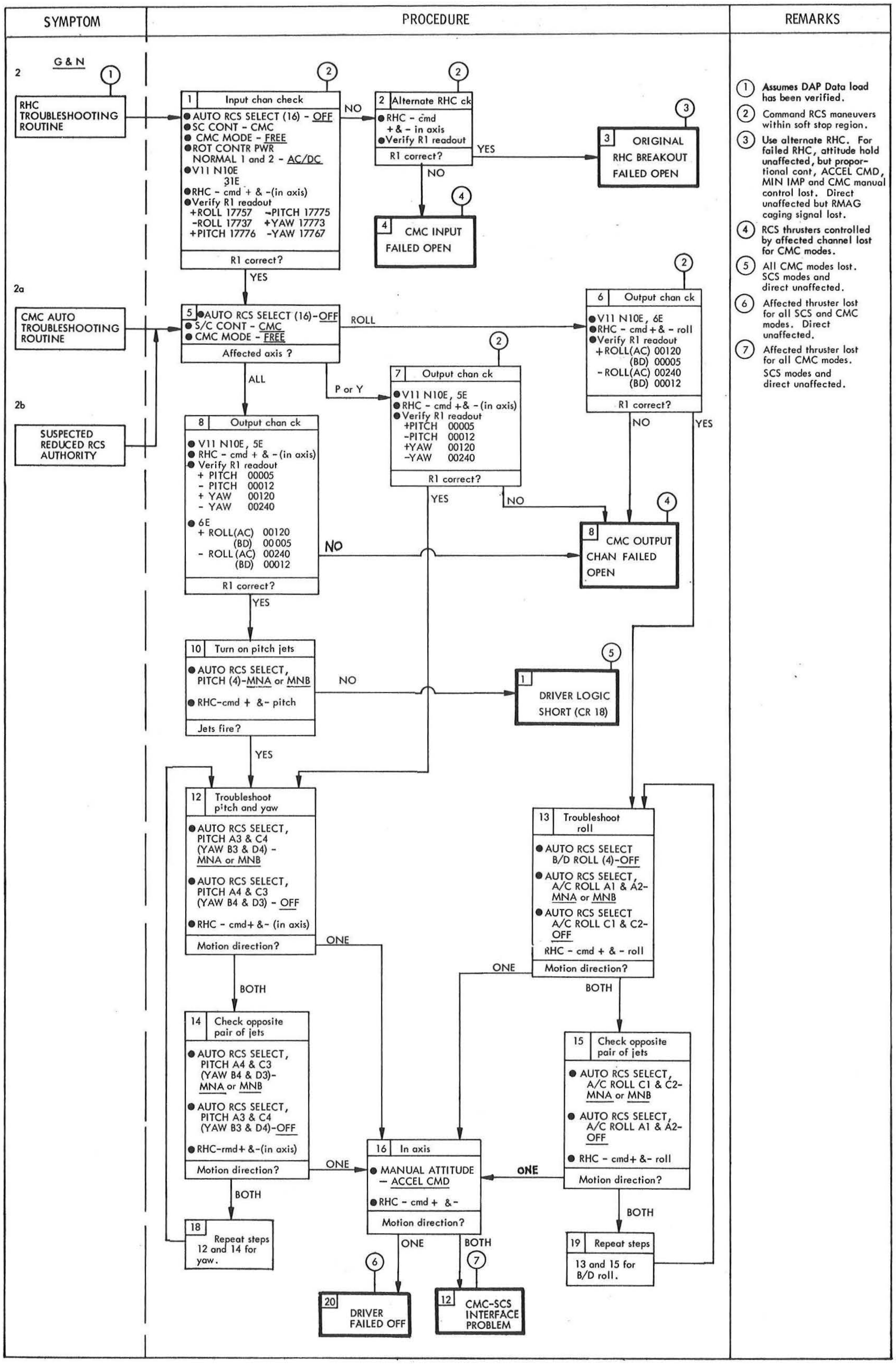
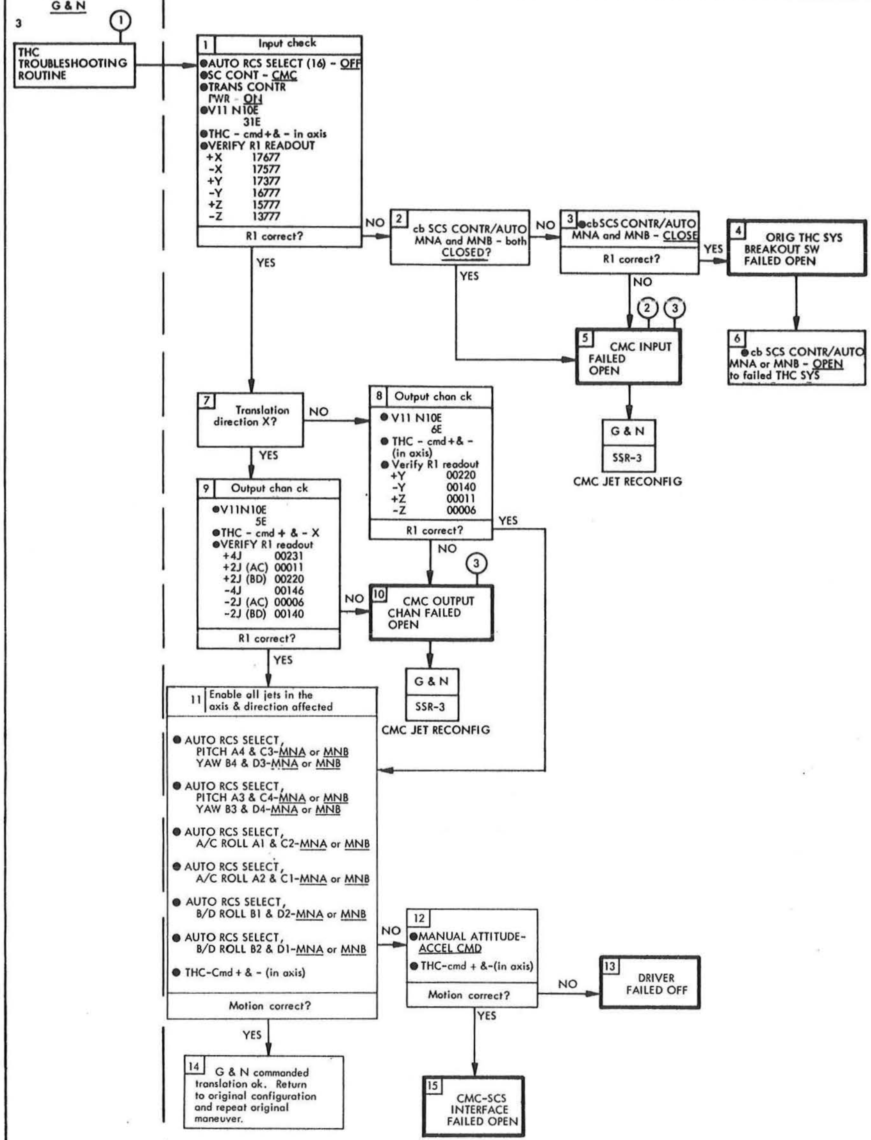


Table 6-4. Malfunction Procedures (Sheet 2 of 6)

SYMPTOM	PROCEDURE	REMARKS

3



REMARKS

(1) Assumes DAP Data Load has been verified.

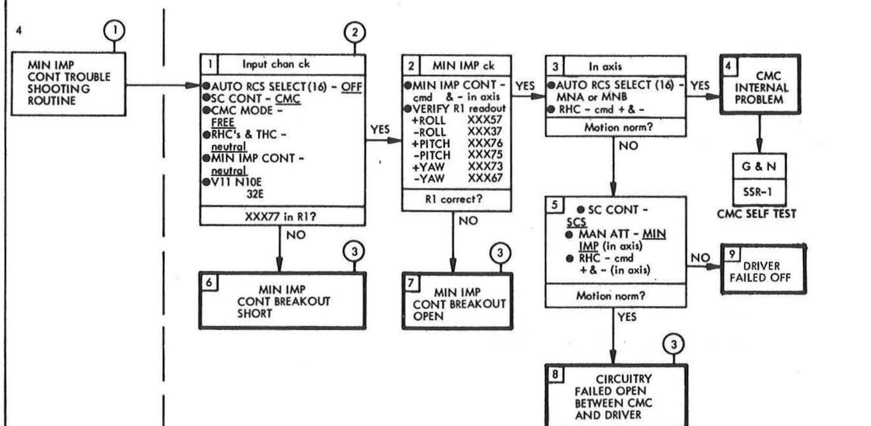
(2) The remote possibility of both THC system breakout switches failing open can be determined by attempting a translation with the S/C CONT - SCS.

(3) Translation lost in CMC modes for affected direction.

(4) Translation lost for both SCS and CMC modes for affected direction. Attitude affected also.

(5) Translation and attitude control lost for CMC control modes.

4



REMARKS

(1) Assumes DAP Data Load has been verified.

(2) An R1 of XXX77 indicates no input commands to CMC.

(3) CMC MIN IMP lost. SCS MIN IMP available with RHC in LEB.

Table 6-4. Malfunction Procedures (Sheet 3 of 6)

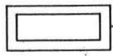
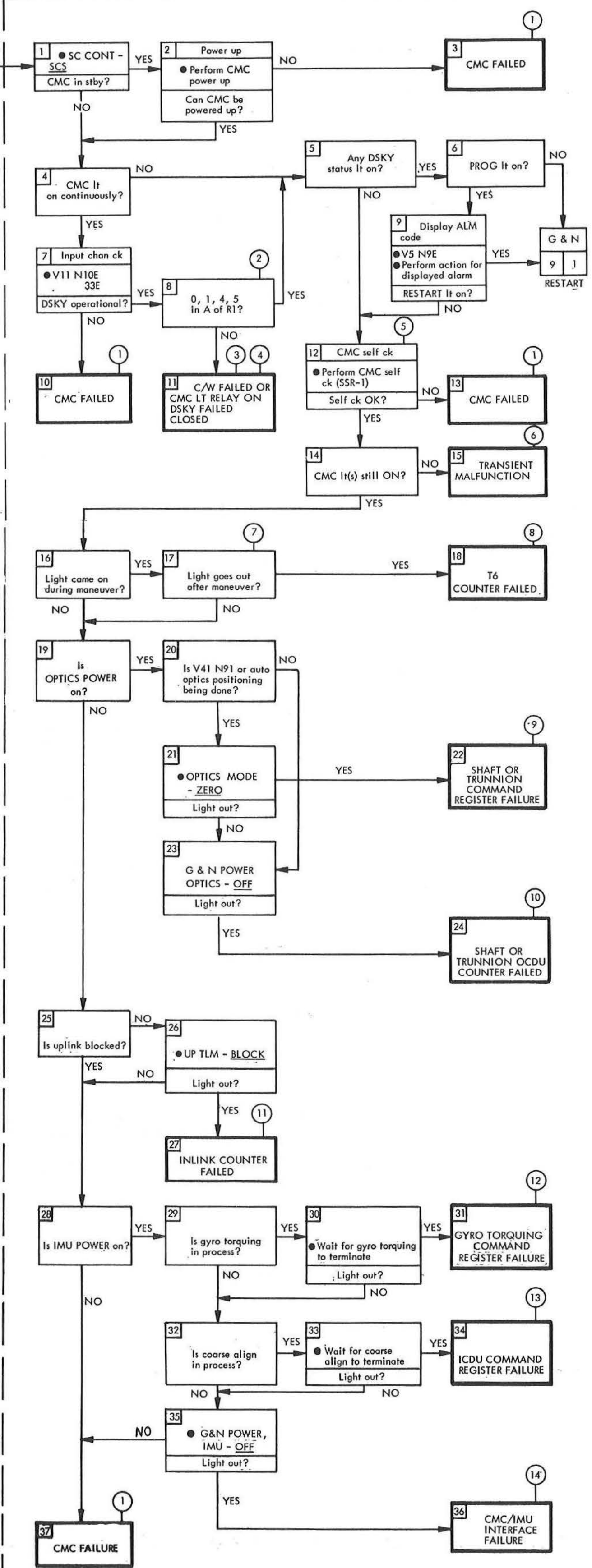
SYMPTOM	PROCEDURE	REMARKS
 Lighted in STBY and OPR modes by: Prime power failure or Scaler failure. Lighted for 5 sec in STBY or OPR modes by repeated (>0.9 pps) issuance of counter failure or double/frequency scaler failure. Lighted for 5 sec only in OPR mode by repeated (>0.4 pps) restarts. Restart is caused by: RUPT LOCK TC TRAP OSCILLATOR FAIL PARITY FAIL NIGHTWATCHMAN or VOLTAGE FAIL. Lighted for 5 sec only in STBY mode by repeated (>0.9 pps)issuance of VOLTAGE FAILURE of +28v, +14v, or +4v power supplies.	 	(1) All CMC functions lost. (2) This R1 readout indicates no CMC FAIL signal to CMC. (3) Subsequent CMC malfunction indication from unaffected CMC light. (4) If the LEB CMC lt. is on, all gyro torquing and PIPA capability lost. CMC monitor and control of both TVC and Entry lost. (5) If DSKY will not accept inputs, force a restart by simultaneously pressing RESET and MARK REJECT pb's. (6) Transient condition could have existed in either CMC or C/W system. (7) Do not use CMC control for attitude maneuvers. (8) RCS DAP unusable; the T6 counter controls DAP jet firing time. (9) TVC DAP and auto optics lost. (10) Optics/CMC interface lost. Use alternate LOS marking program (P53, P54). (11) CMC uplink unusable. (12) IMU cannot be fine aligned. (13) IMU cannot be coarse aligned. Align by caging and/or fine align. (14) Use IMU for attitude reference only.

Table 6-4. Malfunction Procedures (Sheet 4 of 6)

SYMPTOM	PROCEDURE	REMARKS

SYMPTOM

6 G & N

ISS

RED

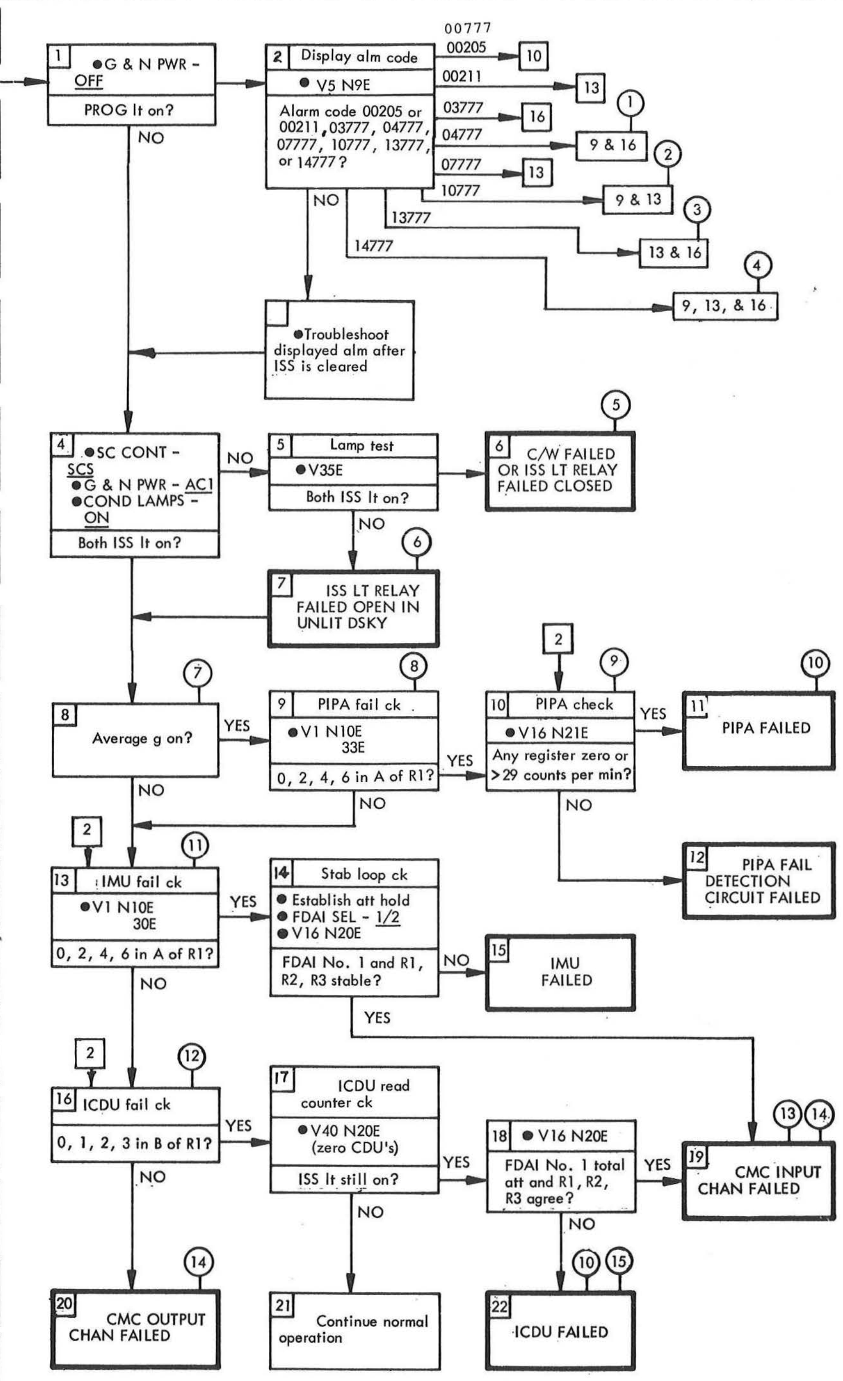
Light on if:
PIPA FAIL during thrusting
IMU FAIL
or
ICDU FAIL

PIPA FAIL if:
No PIPA pulses for 312.5μ seconds, both + & - pulses, or a long time (1.28 to 3.84 sec) without at least one + and one - pulse.

IMU FAIL if:
Any gimbal servo error >2.9 milliradians for 2 sec or more, loss of 3200 cps power, or loss of gyro wheel power.

ICDU FAIL if:
Fine error >1.0 VRMS, coarse error >2.5 VRMS, read counter limit cycle >160 cps, cos (θ - φ) < 2.0V or +14V power supply failure.

PROCEDURE



REMARKS

(1) Alarm code 04777 is caused by PIPA and ICDU fail.

(2) Alarm code 10777 is caused by PIPA and IMU fail.

(3) Alarm code 13777 is caused by IMU and ICDU fail.

(4) Alarm code 14777 is caused by PIPA, IMU, and ICDU fail.

(5) Subsequent ISS malfunction indications from unaffected ISS light.

(6) ISS malfunction indication lost from this warning light.

(7) PIPA failure during AV G will cause an ISS light which will go out at the end of AV G.

(8) If alarm code 04777, 10777, or 14777 occurred and 0, 2, 4, or 6 does not appear in A of R1, a transient PIPA fail discrete has been generated.

(9) If PIPA counts per minute are between 6 and 29 perform PIPA bias check; if less than 6, no further action is necessary.

(10) CMC monitor and control of both TVC and entry lost.

(11) If alarm code 07777, 10777, 13777, or 14777 occurred and 0, 2, 4, or 6 does not appear in A of R1, a transient IMU fail discrete has been generated.

(12) If alarm code 03777, 04777, 13777, or 14777 occurred and 0, 1, 2, or 3 does not appear in B of R1, a transient ICDU fail discrete has been generated.

(13) Affects issuance of an ISS light command.

(14) Subsequent indications of an ISS failure lost.

(15) CMC/IMU attitude interface lost. IMU may be used as a total attitude reference only.

Table 6-4. Malfunction Procedures (Sheet 5 of 6)

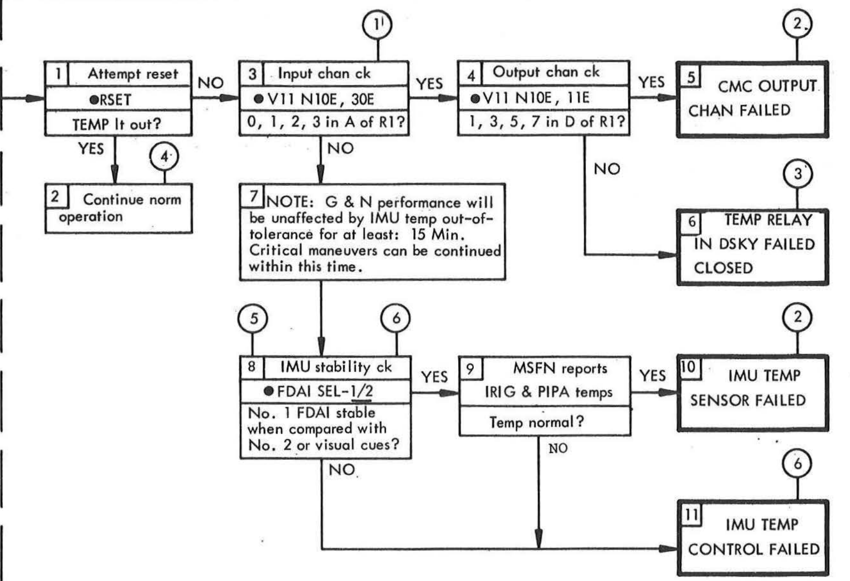
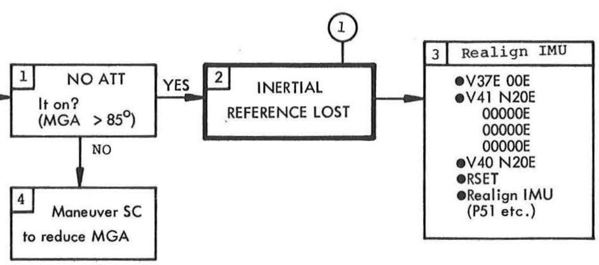
SYMPTOM	PROCEDURE	REMARKS
7 G & N TEMP YELLOW Light on if: IMU temperature is out of limits < 126 or > 134°F.		(1) This R1 readout indicates IMU temp within limits. (2) All IMU temp abnormal indications lost. Temp available from MSFN only. (3) IMU temp abnormal indication available from unaffected DSKY. (4) Transient abnormal condition. (5) Assumes normal operation of No. 1 FDAI has been verified. (6) IMU may be used as long as FDAI No. 1 indicates that the IMU is stable.
8 GIMBAL LOCK YELLOW Light on if: MGA > 70°		(1) IMU in coarse align and must be realigned to a new inertial reference.

Table 6-4. Malfunction Procedures (Sheet 5A of 6)

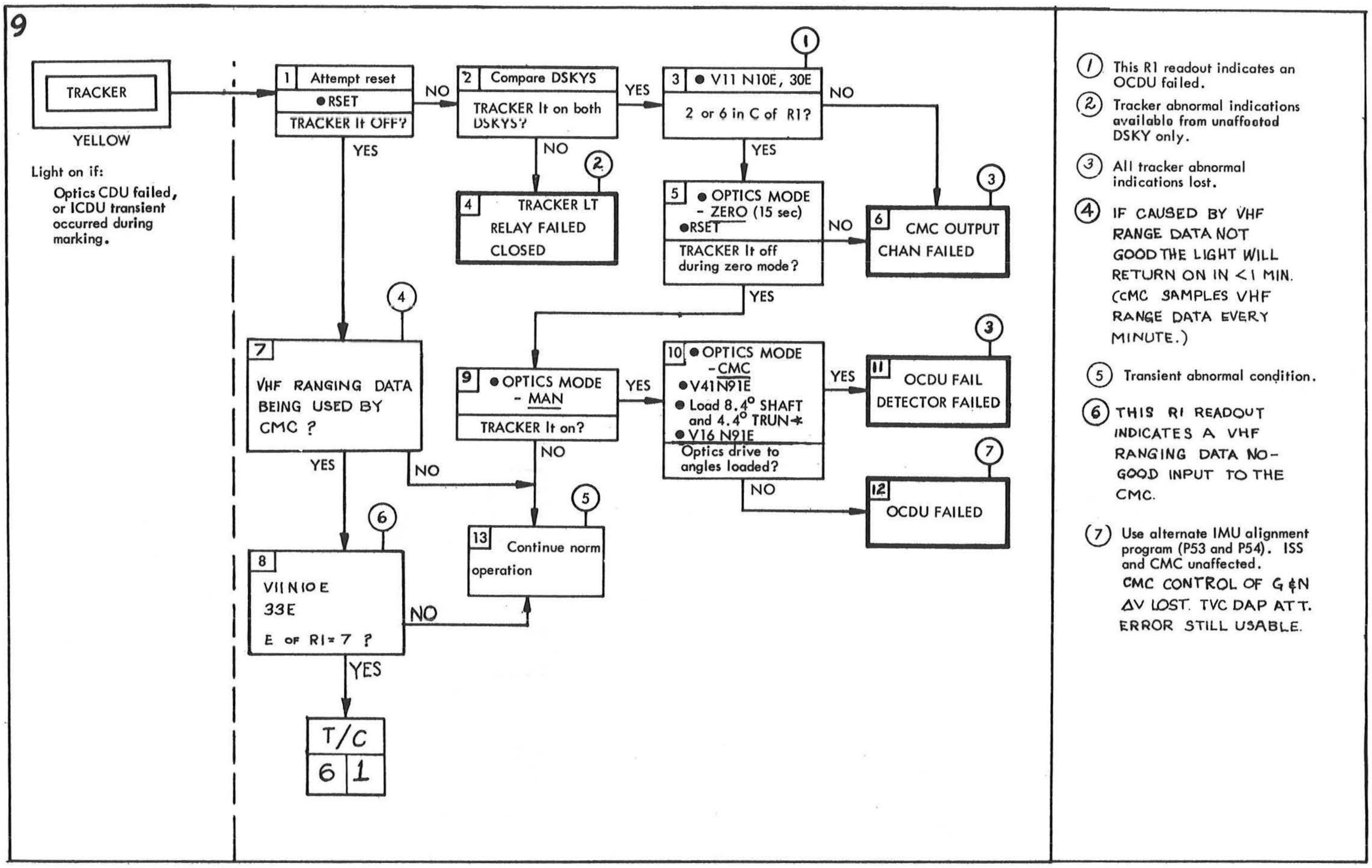


Table 6-4. Malfunction procedures (Sheet 5B of 6)

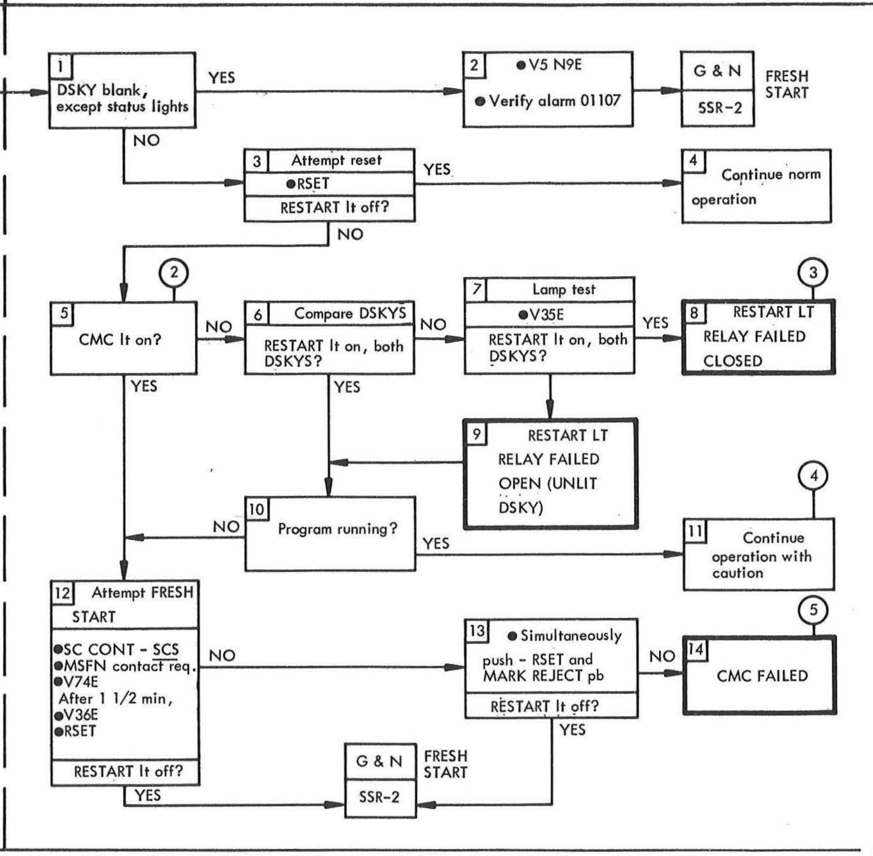
SYMPTOM	PROCEDURE	REMARKS

10 G & N (1)

RESTART

YELLOW

Lighted by any of the following:
PARITY FAIL
RUPT LOCK
TC TRAP
NIGHT WATCHMAN
or VOLTAGE FAIL



(1) If PROG lt on, display the alarm code and perform the required action before proceeding.

(2) Restarts at a higher rate than 1/sec will trigger CMC light. Restarts at a rate higher than 1/2 second will sustain CMC light.

(3) Restart indication available from unaffected DSKY.

(4) Recurring restarts at a rate insufficient to trigger CMC light.

(5) All CMC functions lost.

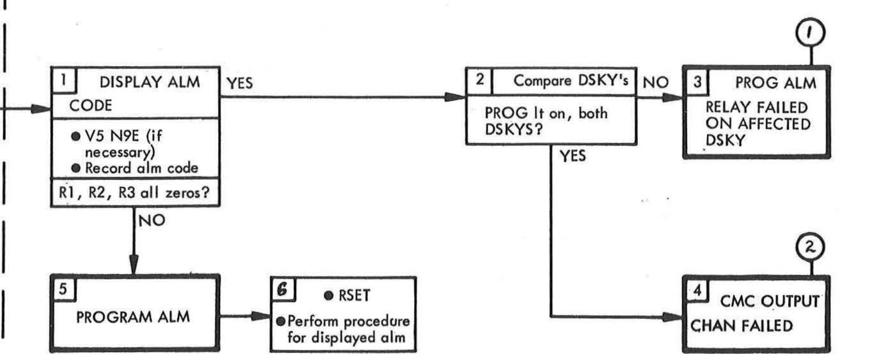
---

11 G & N

PROG

YELLOW

Light on if:
CMC program alarm or by bad PIPA reading during nonthrusting modes.



(1) Program alarm indication available from other DSKY.

(2) PROG light failed on. Program alarm indication available by keying V5N9E, if not displayed

Table 6-4. Malfunction Procedures (Sheet 6 of 6)

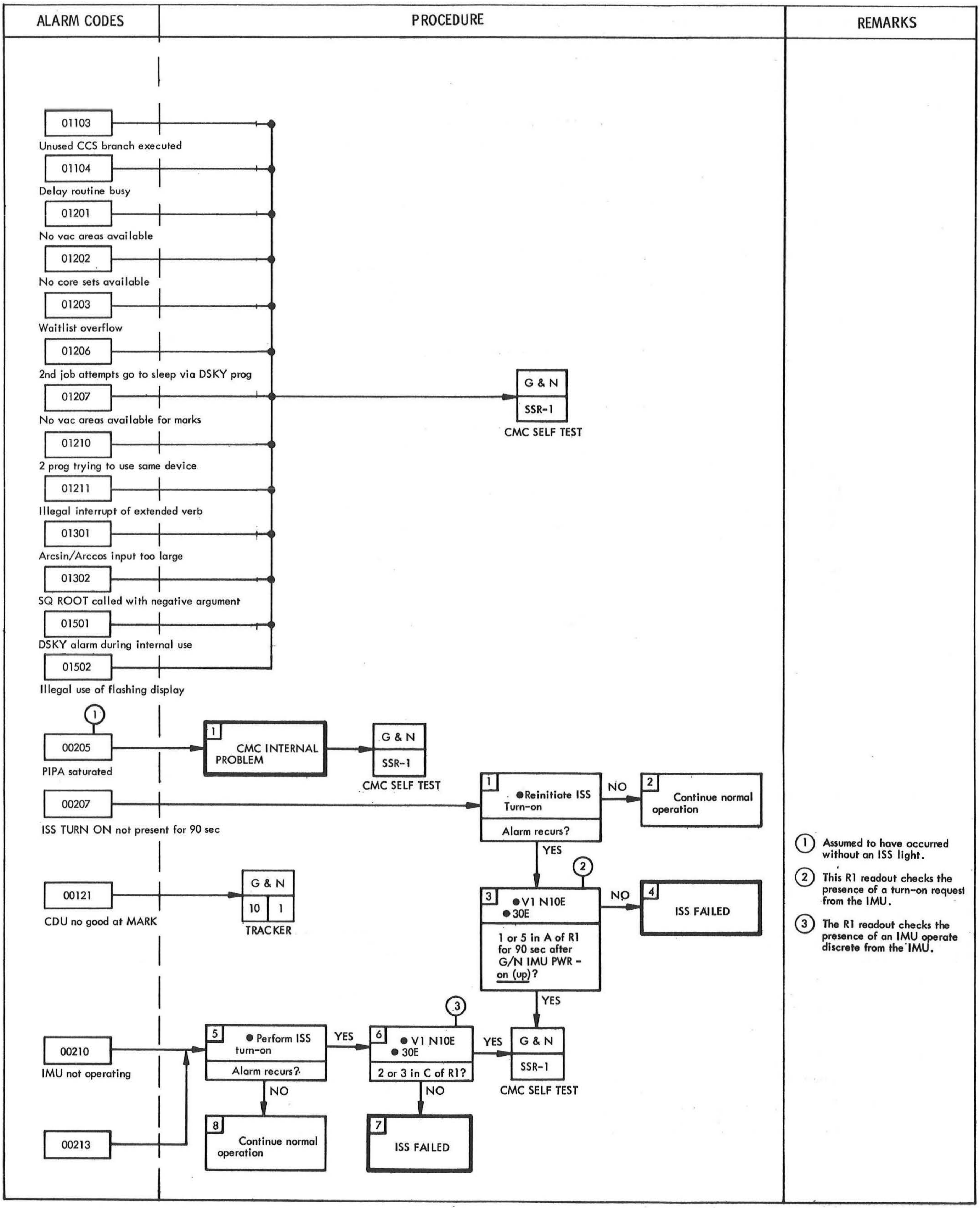


Table 6-5. Program Alarm Procedures (Sheet 1 of 2)

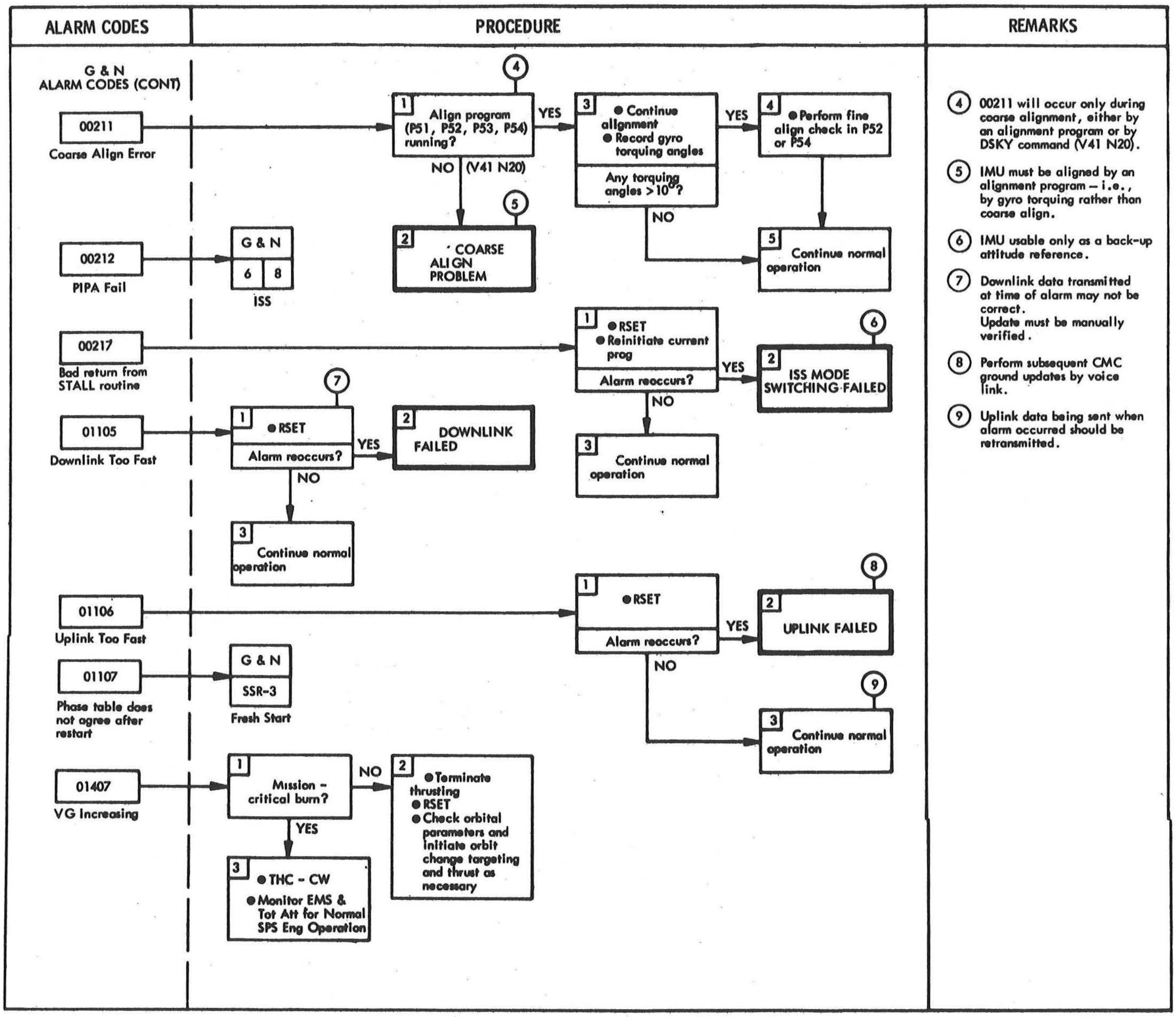


Table 6-5. Program Alarm Procedures (Sheet 2 of 2).

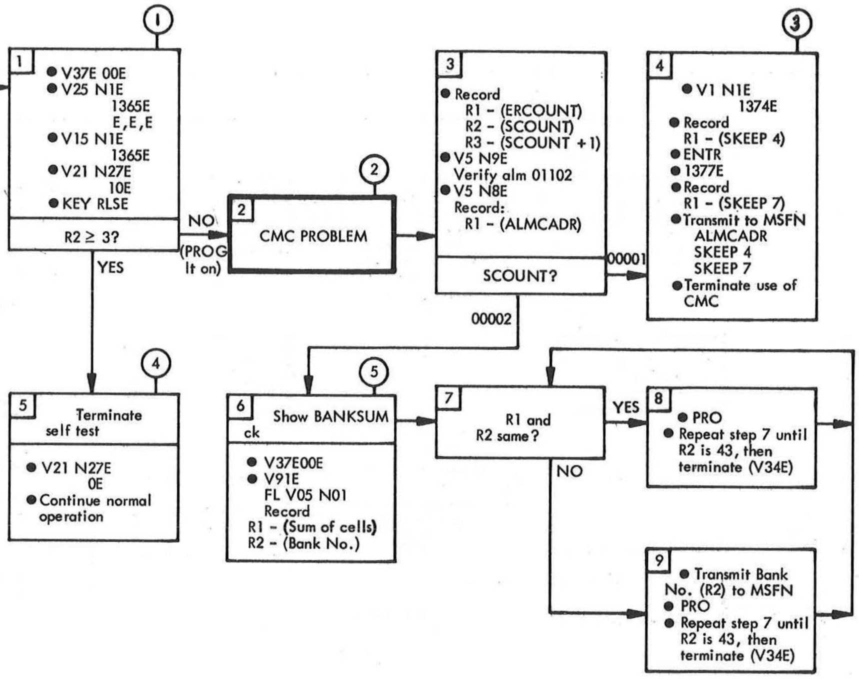
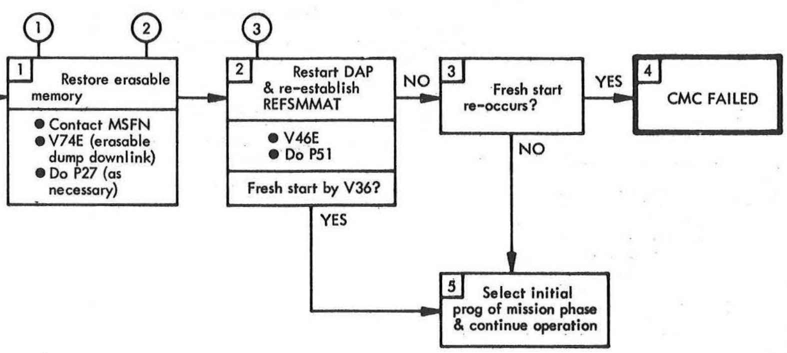
SPECIAL SUBROUTINE	PROCEDURE	REMARKS
CMC Self Check		(1) R2 00001 for 7 SEC; R2 00002 for 43 SEC (2) Subsequent use of CMC dependent on MSFN evaluation (via downlink) of the succeeding steps in self-test. (3) Problem is in erasable memory. (4) CMC self check tests only erasable and fixed memory; other internal CMC problems cannot be determined by CMC self check. (5) Problem is in fixed memory.
SSR-2 FRESH START		(1) State vector and CMC time should be updated. All non-pad-loaded parameters, except time & state vector, will be properly updated by CMC programs in their proper sequence as if CMC had just been turned on when Fresh Start occurred. (2) Extended V74 permits MSFN to examine all pertinent erasable locations to determine if any parameters need reloading. (3) DAP is shut off by Fresh Start & must be re-initiated by V46.

Table 6-6. Special Subroutines (Sheet 1 of 2)

SPECIAL SUBROUTINE	PROCEDURE	REMARKS
SSR-3 CMC JET RE-CONFIG	see flowchart below	see remarks below

SSR-3 — CMC JET RE-CONFIG

1 Rotation? — YES → 2; NO → 3

2 Axis? — PITCH or YAW → 4; ROLL → 5

3 Translation direction? — X → 7; Y or Z → 6

4 Jet determination (1)

Output Chan 5	Jet	Input Chan 31
00001*	C3	-
00002*	C4	-
00010*	A4	-
00005	A3,C3	X7776
00004*	A3	-
00012	A4,C4	X7775
00020*	D3	-
00040*	D4	-
00100*	B3	-
00120	B3,D3	X7773
00200*	B4	-
00240	B4,D4	X7767

5 Jet determination (1)

Output Chan 6	Jet	Input Chan 31
00001*	B1	-
00002*	B2	-
00004*	D1	-
00005	B1,D1	X7757
00010*	D2	-
00012	B2,D2	X7737
00020*	A1	-
00040*	A2	-
00100*	C1	-
00120	A1,C1	X7757
00200*	C2	-
00240	A2,C2	X7737

6 Jet determination (2)

Output Chan 6	Dir	Jet	Input Chan 31
00006	-Z	B2,D1	X3777
00011	+Z	B1,D2	X5777
00140	-Y	A2,C1	X6777
00220	+Y	A1,C2	X7377

7 Jet determination (2)

Output Chan 5	Dir	Jet	Input Chan 31
00006	-(2J)	A3,C4	X7577
00011	+(2J)	A4,C3	X7677
00140	-(2J)	B3,D4	X7577
00146	-(4J)	A3,B3 C4,D4	X7577
00220	+(2J)	B4,D3	X7677
00231	+(4J)	A4,B4, C3,D3	X7677

(4, 5, 6, 7 → 8)

8 Axis of failed jet? — ROLL → 9; PITCH or YAW → 12

9 Initiate DAP load
- V48E
- FL V04 N46
- V24E

Failed jet in quad? — A or C → 10; B or D → 11

10 A(C) isolation (3) (4)
- AUTO RCS SELECT A/C ROLL failed thruster - <u>OFF</u> (RCS failed on only)
- IBCDE E
- 01111 E
- PRO

11 B(D) isolation (3) (4)
- AUTO RCS SELECT B/D ROLL failed thruster - <u>OFF</u> (RCS failed on only)
- IBCDE E
- 11111 E
- PRO

12 Initiate DAP load
- V48E
- FL V04 N46
- V24E

Failed jet in quads? — A or C → 13; B or D → 14

13 A(C) isolation (3) (5)
- AUTO RCS SELECT PITCH failed thruster - <u>OFF</u> (RCS failed on only)
- 101DE E
- 11111 E
- PRO

14 B(D) isolation (3) (5)
- AUTO RCS SELECT YAW failed thruster - <u>OFF</u> (RCS failed on only)
- 110DE E
- 11111 E
- PRO

(10, 11, 13, 14 → 15)

15 Complete DAP load (6)

FL V06 N47
- PRO

FL V06 N48
- PRO

REMARKS

(1) Starred (*) outputs are single jet commands. For RCS failed on, the failed jet is the indicated jet. For output channel failed open, the failed jet is the corresponding jet in the rotational couple.

(2) If R1 (output chan) contains a number not listed, determine the failed jet from the R1 (output) readout when a rotation command is given.

(3) In R1, B is quad A/C for X translation:
  0 - FAIL A/C
  1 - USE A/C
In R1, C is quad B/D for X translation:
  0 - FAIL B/D
  1 - USE B/D
In R1, D is DAP deadband
  0 - 0.5°
  1 - 5.0°
E is the DAP rate
  0 - 0.05°/sec
  1 - 0.20°/sec
  2 - 0.5°/sec
  3 - 2.0°/sec
In R2, A is roll selection
  0 - Use B/D
  1 - Use A/C

(4) Translation (Y or Z) will be single jet and result in excessive RCS prplnt consumption.

(5) Rotations (pitch or yaw) will be single jet. X translations will be 2 jet.

(6) N47 and N48 display other DAP parameters assumed to be correct.

Table 6-6. Special Subroutines (sheet 2 of 2).

E-2442

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