

STAR TRACKER/ CREW OPTICAL ALIGNMENT SIGHT WORKBOOK

S TRK/ COAS 2102

**Advanced Training Series
For Training Purposes only**

**Training Division
Flight Training Branch**

September 30, 1983



National Aeronautics and
Space Administration

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Houston, Texas 77058

SECTION 1
INTRODUCTION

The Star Tracker subsystem is a part of the Shuttle navigation system. It consists of two units located just forward and to the left of the commander's +X window (see figure 1-1) and is used to align the Inertial Measurement Units (IMU's) on board the Shuttle. An additional function of the Star Trackers during future missions will be to track targets and to provide Line-Of-Sight (LOS) vectors for rendezvous calculations.

Alignment of the IMU's is required approximately every 12 hours to correct IMU drift; within 1 to 2 hours prior to a major burn; or after a Crew Optical Alignment Sight (COAS) IMU alignment. Alignment of the IMU is accomplished by using the Star Trackers to measure the LOS vector to at least two stars. Using this information, the General Purpose Computer (GPC) then calculates the orientation between these stars and the Shuttle to define the Shuttle's attitude. Comparing this attitude against the attitude measured by the IMU provides the correction factor necessary to null the IMU error.

The GPC memory contains inertial position information for 50 stars, chosen because they are bright enough for the Star Trackers to acquire and because they provide complete sky coverage.

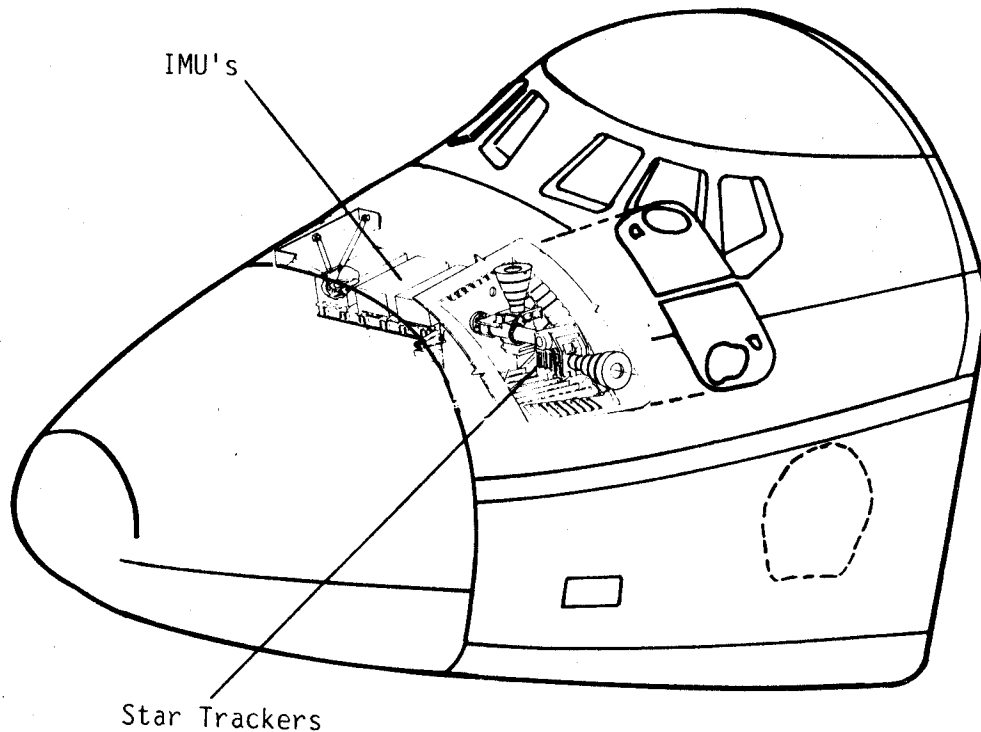


Figure 1-1. Location of Star Trackers Onboard Shuttle

SECTION 2

EQUIPMENT MOUNTING AND ORIENTATION

The Star Tracker units are mounted on an extension of the navigation base and are oriented such that the optical axis of the -Z Star Tracker is pointed approximately along the -Z axis of the Shuttle and the optical axis of the -Y Star Tracker is pointed approximately along the -Y axis of the Shuttle (see figure 2-1). The navigation base is a temperature-stable platform that serves as a focus for the Shuttle coordinate system. Since the navigation base provides the mount for the IMU's and the Star Trackers, the Star Tracker LOS is referenced to the navigation base and the Shuttle coordinate system; thus the GPC knows where the Star Tracker is pointed and its orientation with respect to the IMU's. (See figure 2-2.)

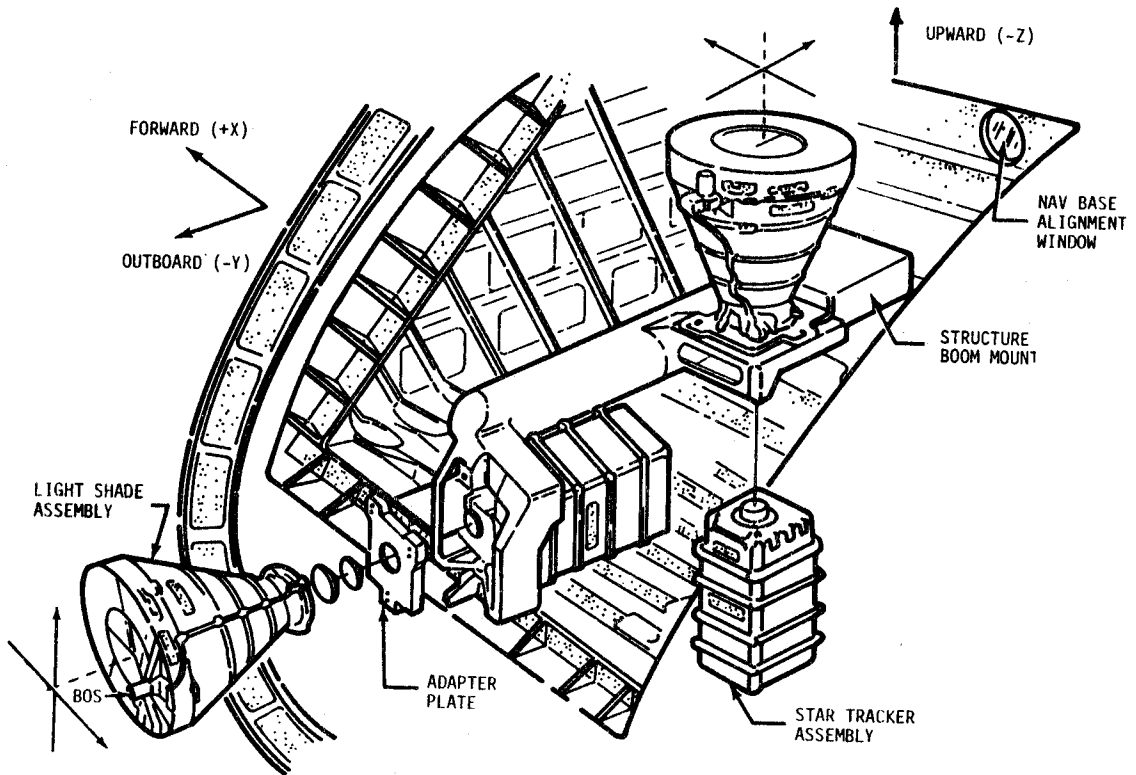
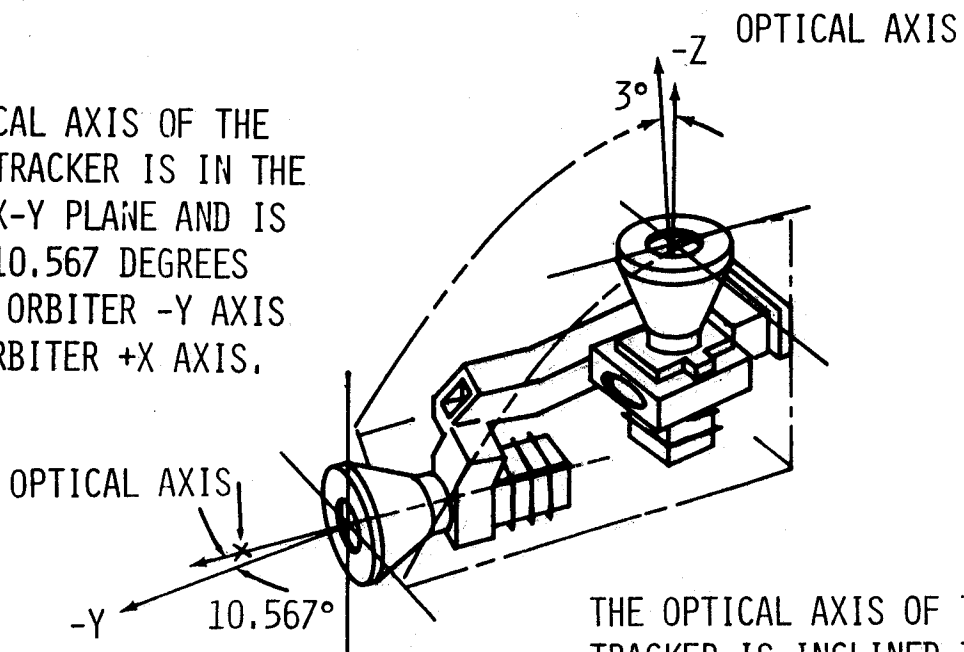


Figure 2-1. View into Star Tracker Cavity

THE OPTICAL AXIS OF THE
 -Y AXIS TRACKER IS IN THE
 ORBITER X-Y PLANE AND IS
 ROTATED 10.567 DEGREES
 FROM THE ORBITER -Y AXIS
 TO THE ORBITER +X AXIS.



THE OPTICAL AXIS OF THE -Z AXIS
 TRACKER IS INCLINED 3 DEGREES IN
 A PLANE ROTATED 41 DEGREES FROM
 THE ORBITER +X AXIS TOWARD THE
 ORBITER -Y AXIS.

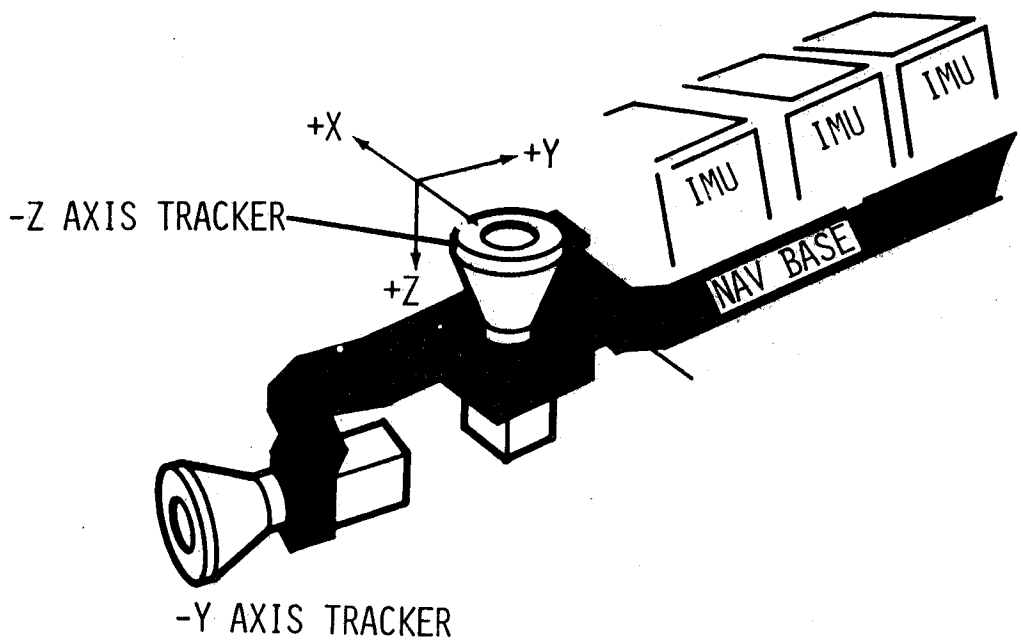


Figure 2-2. Star Tracker Orientation

SECTION 3
STAR TRACKER DOORS

The Star Tracker units are enclosed within the Shuttle structure and are protected by closed doors during ascent and entry. Each door is opened and closed by two motors operating through a differential gearbox. With both motors operating, the doors are opened or closed in 6 seconds. Should a motor or power to a motor fail, the operating time is increased to 12 seconds. Figures 3-1, 3-2, and 3-3 illustrate the location of these doors. Both doors rotate underneath the outer tile and metal surface of the Shuttle.

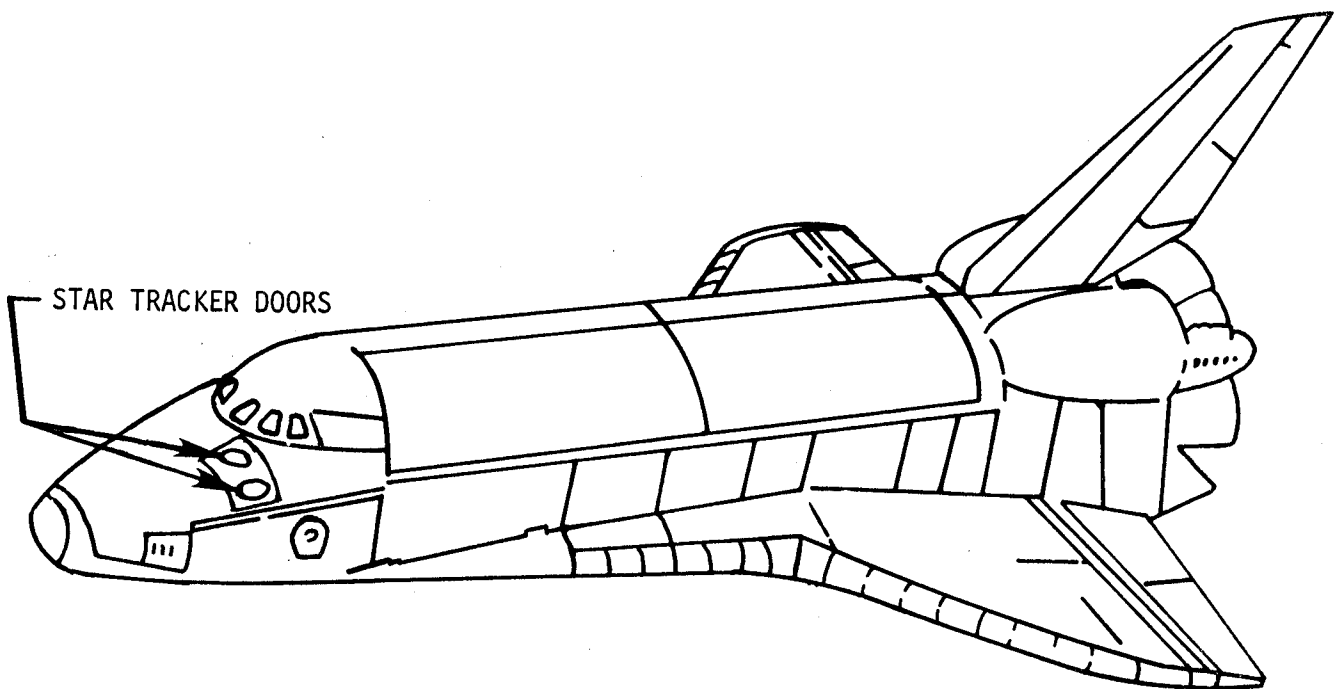


Figure 3-1. Star Tracker Door Locations

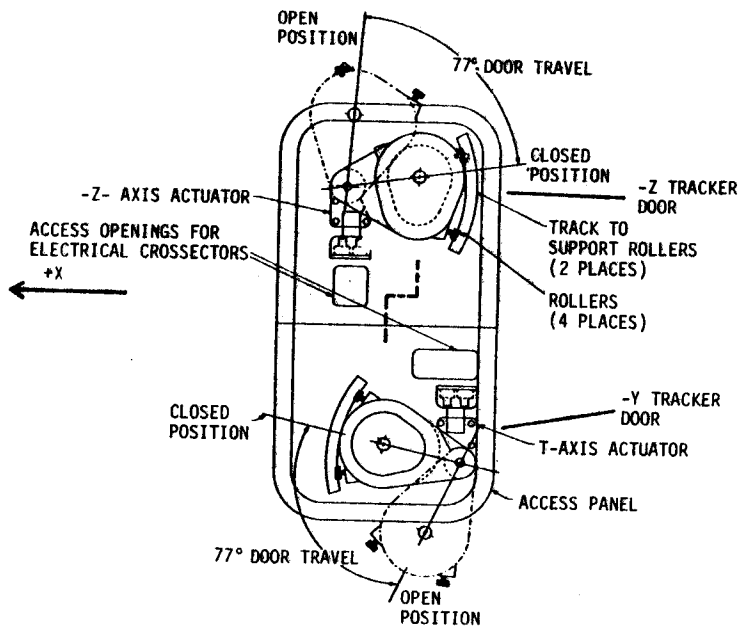


Figure 3-2. Tracker Door Travel Directions (viewed from outside)

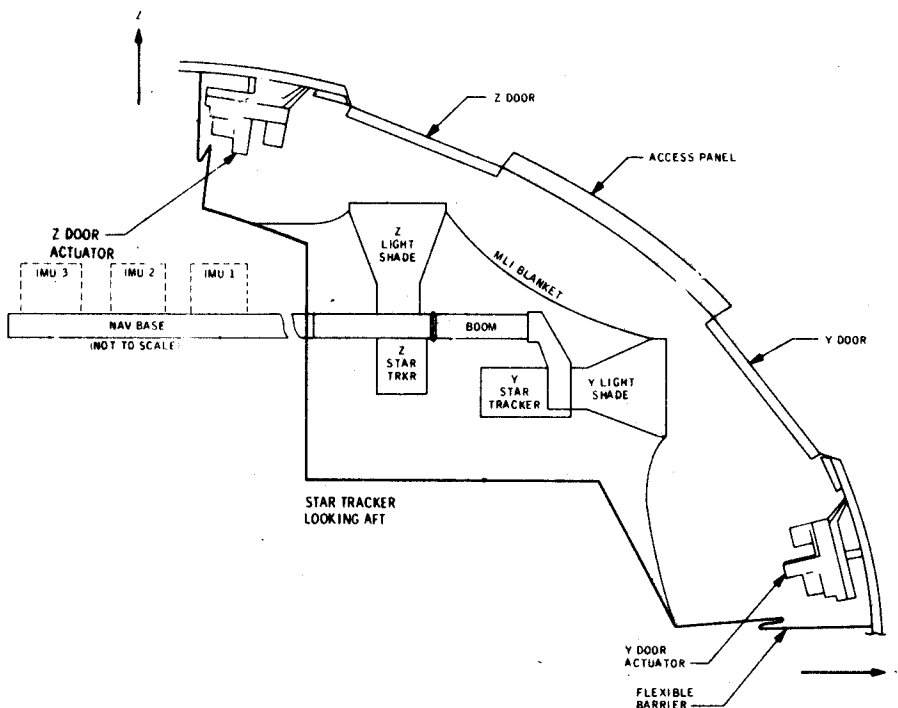


Figure 3-3. Internal View of Tracker Subsystem (looking aft)

3.1 TRACKER POWER AND DOOR CONTROLS

The controls and circuit breakers required to operate the Star Trackers and their doors are shown on figure 3-4. Each Star Tracker has associated circuit breakers and power switches that protect and control power to the unit and to the doors. When tracking a star, the Star Tracker doors must be open. The door control switches and associated talkbacks are located on Panel 06. The Star Tracker DOOR CONTROL switches are three-position switches (OPEN, OFF, and CLOSE). They are returned to OFF after each operation.

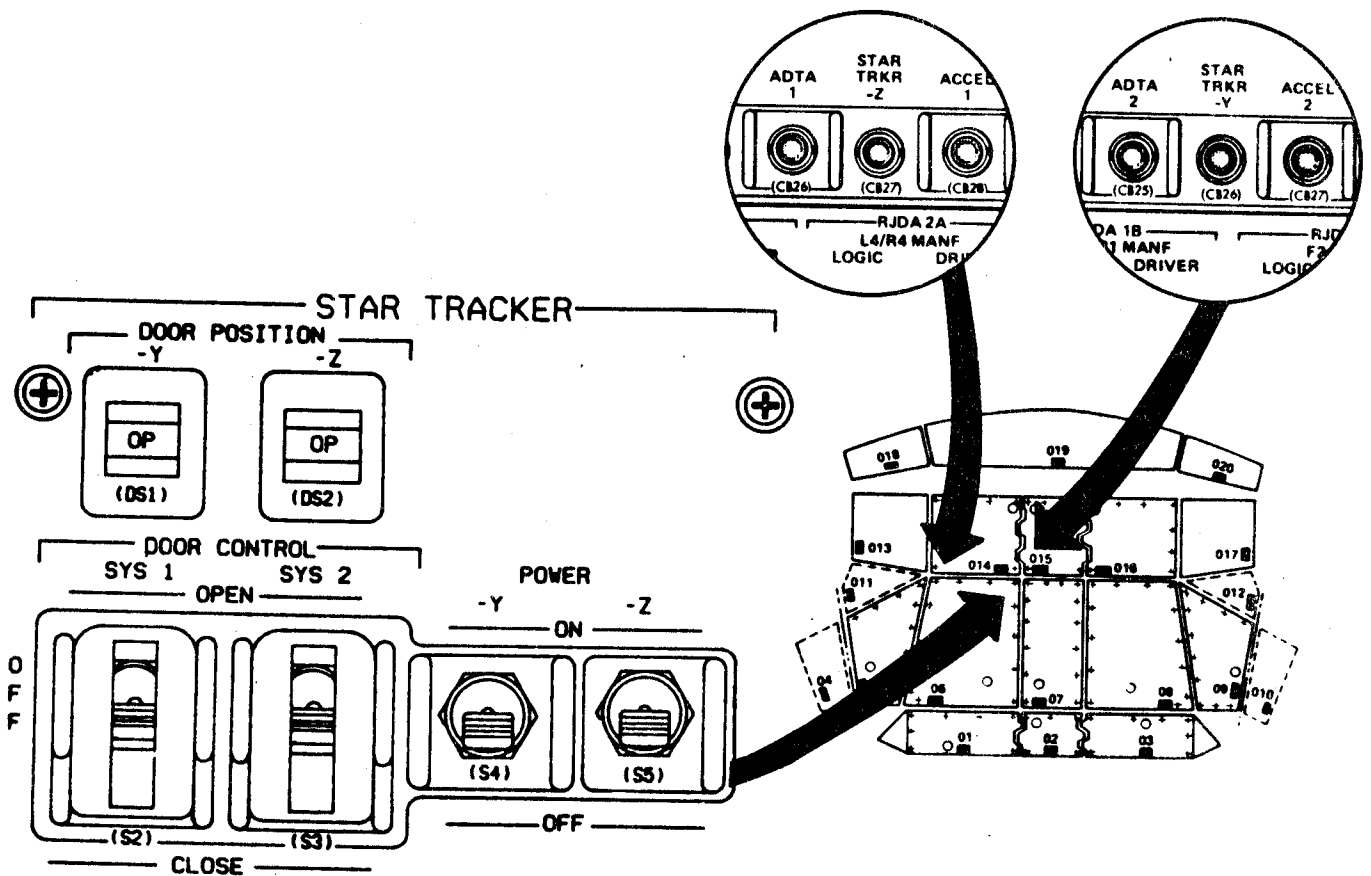


Figure 3-4. Star Tracker Controls

3.2 DOOR CONTROL LOGIC

The three-phase Star Tracker door motors are controlled by the Forward Motor Control Assemblies (FMCA). Refer to figure 3-5 while reading the following sequence of operation to open a door.

Assuming that the FMCA LOGIC (PNL MA73C) and STAR TRACKER POWER switches are on, the STAR TRACKER DOOR CONTROL switch is set to OPEN. Power is now applied to open drivers in the FMCA and to the open limit switch. Since the doors are closed, the open limit switch is also closed, allowing power to be routed through the limit switch to the open drivers in the FMCA. The open drivers energize two series connected open relays, applying three-phase ac power to the door motor. The door motor continues to run until the door reaches its open position, at which time the OPEN LIMIT switch opens. Power from the OPEN LIMIT switch is now removed from the open drivers, causing the open relays to be de-energized and removing power from the door motor. The SYSTEM 1 and SYSTEM 2 STAR TRACKER DOOR CONTROL switches control a single motor for each door. Therefore, to operate a door in two-motor time (6 seconds), both switches must be operated.

A similar series of events, using the close drivers, relays, and limit switches, occurs when the STAR TRACKER DOOR CONTROL switch is set to CLOSE. When the STAR TRACKER DOOR CONTROL switch is OFF, power is removed from the drivers in the FMCA. This protects the door motors against the event that a limit switch fails to open after a door has reached its limit. Also, as demonstrated by the door motor control logic, the Star Tracker doors can be closed with the STAR TRACKER POWER switch in the OFF position.

3.3 DOOR OPERATIONS

The Star Tracker doors are opened upon achieving orbit during the post-insertion timeline. The crew procedure for door opening is located in the Post Insertion Checklist. The crew procedure is given below.

STAR TRKR SELF TEST/DOOR OPEN [9A]	
C	06 ✓ STAR TRK PWR (two) - ON GNC, I/O RESET EXEC
[1: GNC 22 S TRK/DOOR CNTL]	
CRT	IF SHUTTER -CL ITEM 15(16) EXEC (*) ITEM 15(16) EXEC (No*)
	✓ S TRK -Y, -Z STATUS (two) - blank SELF-TEST -Y, -Z (two) - ITEM 1,2 EXEC ✓ S TRK -Y, -Z STATUS (two) - ST PASS (- 30 sec) # If self test fails, redo once & proceed #
06	STAR TRKR DR CNTL SYS (two) - OP ✓ POS tb (two) - bp (start timer) When both tb-OP (8-24 sec), or either tb - bp for >24 sec, CNTL SYS (two) - OFF
CRT	STAR TRK - ITEM 3,4 EXEC
NOTE If tb-bp > 12 sec (one mtr problem), or > 24 sec (two mtr problem), notify MCC	

The Tracker doors are usually left open throughout the mission and are closed during the deorbit preparation. An example of the door closing procedure from the Deorbit Prep Checklist is shown below.

DEACT STAR TRKRS & CLOSE DOORS [1Z]	
C	06 STAR TRKR PWR (two) - OFF DR CNTL SYS (two) - CL ✓ POS tb (two) - bp (start timer) When both tb - CL (-8-24 sec) or either tb - bp > 24 sec: STAR TRKR DR CNTL SYS (two) - OFF
NOTE If tb - bp > 12 sec (one mtr problem) or > 24 sec (two mtr problem) notify MCC	

SECTION 4
STAR TRACKER HARDWARE

4.1 COMPONENTS

The Star Tracker subsystem is composed of the following components (see figure 4-1):

- Electronics assembly. Contains optics and electronics for converting optical images into digital data
- Adapter plate. Provides common mount for Star Tracker subsystem
- Protective window. Provides a seal that protects and allows electronics assembly to be pressurized
- Light shade assembly. Protects lens from glare. Also provides mount for Bright Object Sensor (BOS) and shutter mechanism.

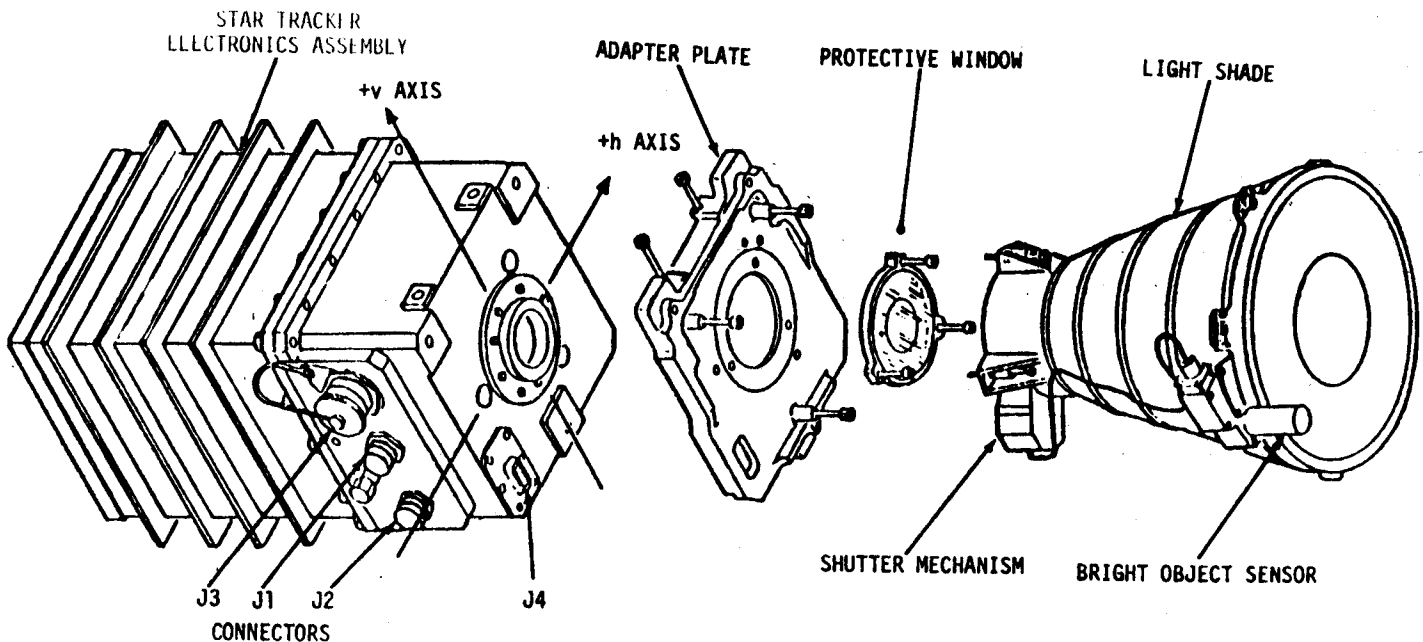


Figure 4-1. Star Tracker Components

4.2 COORDINATE SYSTEM

A right-hand orthogonal system consisting of horizontal (H), vertical (V), and boresight axes is used in the Star Tracker (see figure 4-2). The plane of the H and V axes is coplanar with the front face of the Star Tracker. The -Z Star Tracker is mounted such that the +V axis lies in approximately the same direction as the -Y Shuttle body coordinate axis, and the +H axis lies in approximately the same direction as the +X Shuttle body coordinate axis. These coordinates correspond to those displayed on SPEC 22 for -Z COAS use.

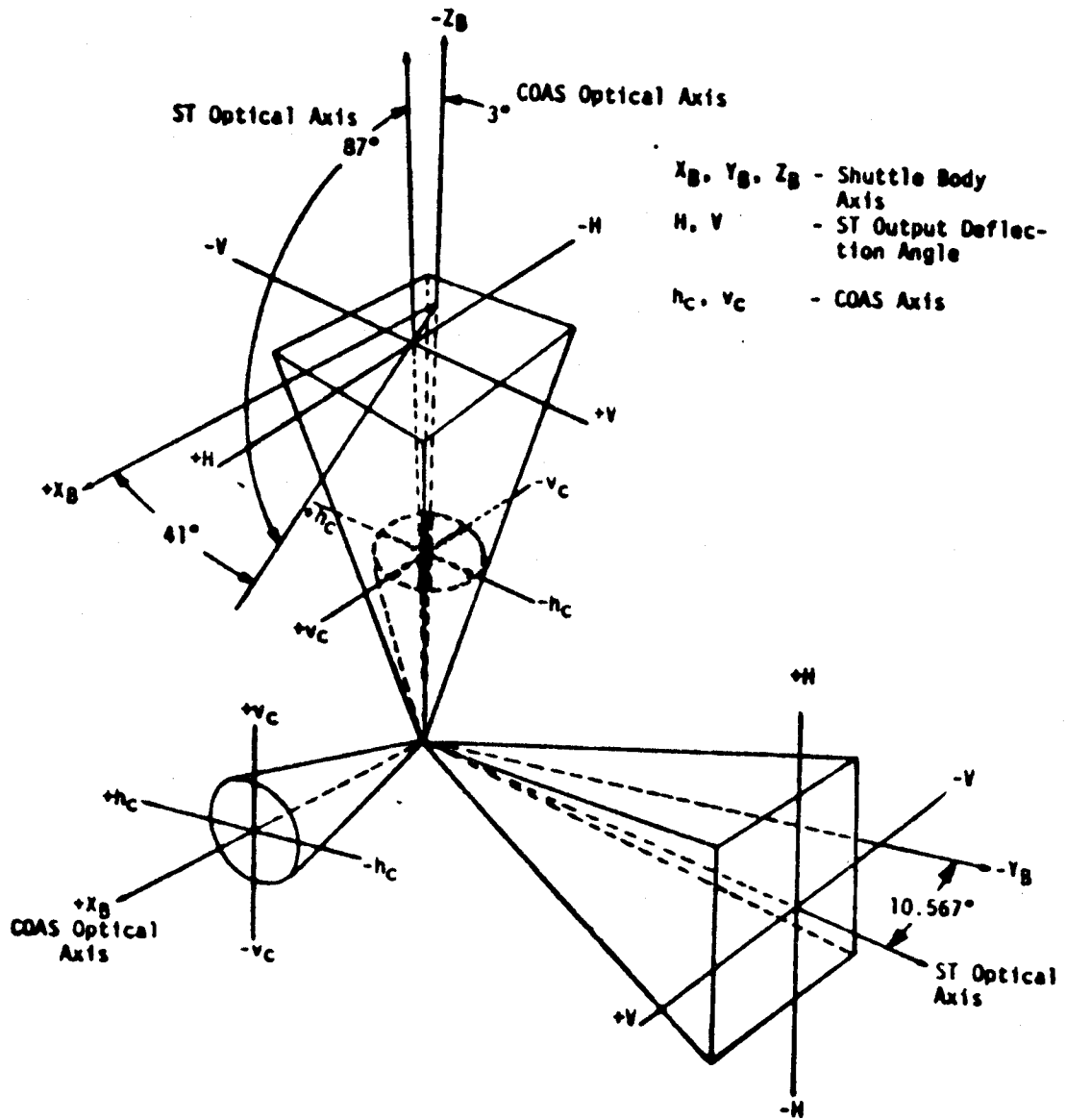


Figure 4-2. Coordinate System

4.3 OPERATING MODES

The four operating modes of the Star Tracker subsystem are as follows:

1. Full field scan. This is the normal operating mode and the one that will be entered when power is applied to the subsystem, provided no other mode is selected. In this mode the Star Tracker searches a $10^{\circ} \times 10^{\circ}$ field of view and acquires and tracks the first object that exceeds the threshold level (see figure 4-3).
2. Offset scan mode. When commanded by the GPC, the search area is reduced to a $1^{\circ} \times 1^{\circ}$ field of view. Along with the selection of this mode, the vertical and horizontal position of the search area must be specified by the GPC.
3. Track scan mode. When the Star Tracker locates an object exceeding the threshold level, the vertical and horizontal scan is switched to a cruciform pattern centered on the object (see figure 4-3). The intensity of the object is monitored and the position of the cruciform pattern is altered to keep the pattern centered on the point of highest intensity. Tracking will continue as the object moves across the field of view at up to $.2^{\circ}$ /second with guaranteed accuracy and up to $.5^{\circ}$ /second at reduced accuracy.
4. Self-test mode. In this mode, light from a simulated star is reflected from an aluminized spot on the inner surface of the protective window to a point displaced 4.25° horizontally and vertically. When this mode is selected, the subsystem is automatically placed in the offset mode until the simulated star is located. After acquiring the star, the angular position and magnitude are compared with internally stored standards to verify subsystem accuracy. Should this internal test fail, an output word to the GPC denotes the failure.

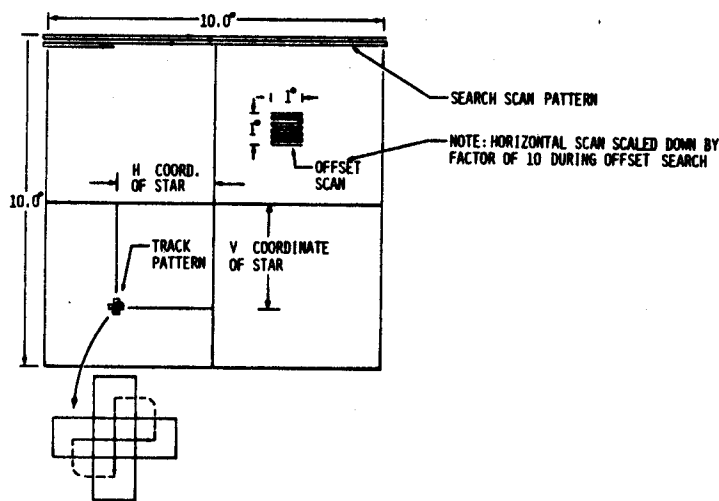


Figure 4-3. Scan Geometry

4.4 IMAGE DISSECTOR TUBE

The image dissector tube (see figure 4-4) is the heart of the Star Tracker subsystem. In the image dissector tube, light from an object is focused on a photocathode, causing it to emit electrons. These electrons are focused into a beam and deflected through a hole in the dissecting aperture by an electrical current flowing in the deflection coils. The amount of current required in the deflection coils to deflect the beam through the aperture is a measure of the angular offset from boresight of the optical image. Therefore, by scanning the photocathode in a regular pattern (full field), any optical image within the field of view can be located.

After passing through the hole in the dissecting aperture, the electron beam enters the electron multiplier, where it is amplified to a usable level at the anode output. Acquisition of an image occurs when the output voltage exceeds a predefined detection threshold level. At this time the scan pattern is changed from a full field or offset scan pattern to a cruciform pattern, and automatic tracking of the object begins. Appendix E contains a generalized block diagram and description of the operation.

The detection threshold level can be set to any of four levels by crew input. These levels control the sensitivity of the Tracker to star magnitude. Magnitude is a scale of star brightness that is logarithmic and decreases as a star's brightness increases. Visible stars are brighter than 5-6 magnitude. The sun has a magnitude of approximately -26. A magnitude change of 5 indicates a hundredfold change in brightness. The four levels are defined as follows:

1. Level 0. Maximum sensitivity level. Acquires objects brighter than +3 magnitude (150 to 153 stars)
2. Level 1. Detects objects brighter than +2.4 magnitude
3. Level 2. Detects objects brighter than +2 magnitude
4. Level 3. Detects objects brighter than +1 magnitude.

The detection threshold level is defaulted to level 0 for normal star tracking operations.

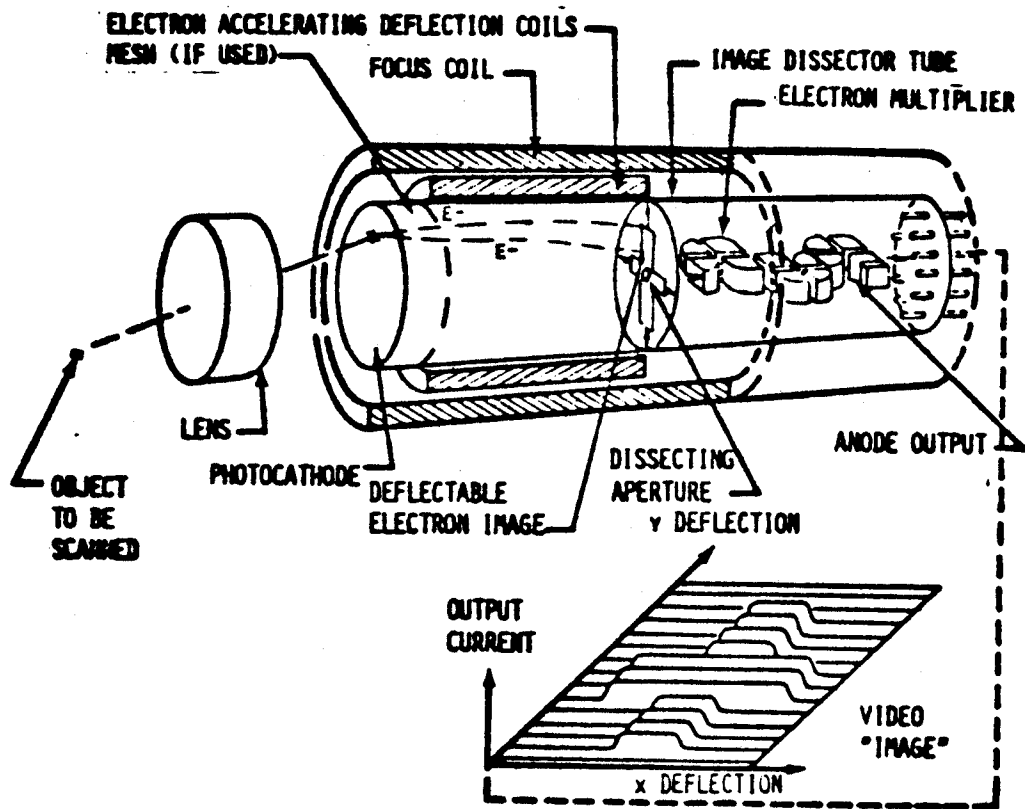


Figure 4-4. Image Dissector Tube

4.5 BRIGHT OBJECT SENSOR

As illustrated previously in figure 4-1, the bright object sensor (BOS) is mounted at the forward end of the light shield so that its field of view extends beyond that of the Star Tracker. The purpose of the BOS is to sense objects coming into the Star Tracker field of view that are so bright that they could damage the Star Tracker system. If the BOS detects an object brighter than a magnitude of -12 approaching at rates up to 10 deg/sec, it will close a mechanical shutter that protects the Star Tracker system. As a matter of reference, the moon between the first and third quarters will close the shutter about 90° from the Star Tracker line of sight, while a crescent moon will not close it at all. A sunlit horizon will close the shutter at 140-170° from the line of sight. The BOS will not close the shutter for objects dimmer than -8 magnitude. The BOS allows the shutter to open at specified limits from the Tracker LOS. The open limits are wider than the close limits, as indicated in figure 4-5 below.

The mechanical shutter is spring loaded such that any loss of power to the BOS or to the Tracker will cause it to spring closed. In the case of loss of power to the BOS, the shutter can still be manually controlled by crew input.

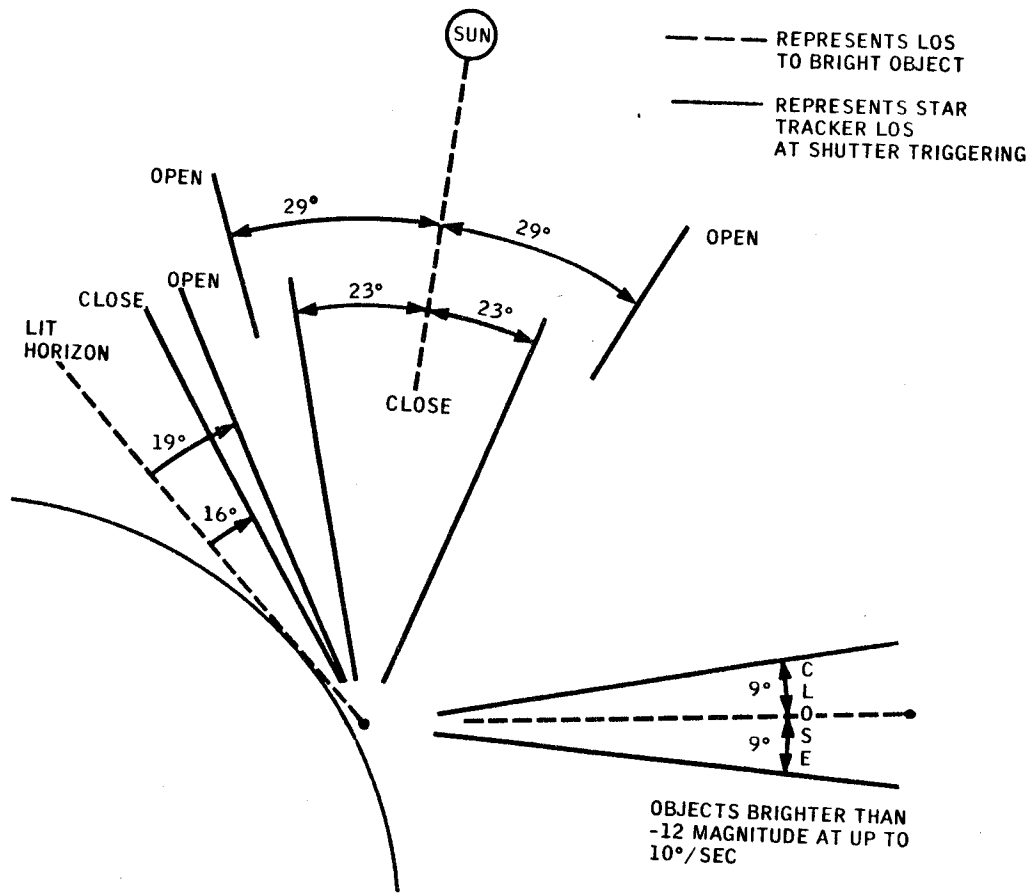


Figure 4-5. BOS Operational Limits

QUESTIONS

1. The bright object sensor
 - a. looks for bright objects to establish a reference.
 - b. closes the Star Tracker shutter when a bright object is sensed.
 - c. changes the gain of the Star Tracker.
 - d. closes the Star Tracker door.
2. How much time does it take to open the Star Tracker doors when both motors are operational?
 - a. 6 seconds.
 - b. 60 seconds.
 - c. 12 seconds.
 - d. 45 seconds.
3. The Star Tracker coordinate system is referenced to the
 - a. GPC.
 - b. Rate gyro.
 - c. Nav base.
 - d. Accelerometer assembly.
4. The desired output from the Star Tracker is
 - a. angle from boresight.
 - b. image dimensions.
 - c. image and angle from boresight.
 - d. none of the above.
5. When commanded to the offset mode by the GPC, which of the following statements is true?
 - a. The Star Tracker searches a $10^0 \times 10^0$ field of view.
 - b. The Star Tracker searches a 1^0 square field of view.
 - c. The Star Tracker searches a 2^0 field of view.

- d. The Star Tracker will search in this mode for 44 seconds.
6. Which of the following statements is true?
- a. The crew has no control over the detection threshold level of the Star Tracker.
 - b. The MCC controls the detection threshold level of each Star Tracker.
 - c. There are four levels of detection threshold level control.
 - d. The detection threshold level can be controlled only for targets.
7. Loss of Star Tracker power causes
- a. the Star Tracker doors to spring closed.
 - b. the shutter to spring open.
 - c. the Star Tracker circuit breaker to pop open.
 - d. the shutter to spring closed.

ANSWERS

1. The bright object sensor
 - a. looks for bright objects to establish a reference.
 - b. closes the Star Tracker shutter when a bright object is sensed.
 - c. changes the gain of the Star Tracker.
 - d. closes the Star Tracker door.
2. How much time does it take to open the Star Tracker doors when both motors are operational?
 - a. 6 seconds.
 - b. 60 seconds.
 - c. 12 seconds.
 - d. 45 seconds.
3. The Star Tracker coordinate system is referenced to the
 - a. GPC.
 - b. Rate gyro.
 - c. Nav base.
 - d. Accelerometer assembly.
4. The desired output from the Star Tracker is
 - a. angle from boresight.
 - b. image dimensions.
 - c. image and angle from boresight.
 - d. none of the above.
5. When commanded to the offset mode by the GPC, which of the following statements is true?
 - a. The Star Tracker searches a $10^0 \times 10^0$ field of view.
 - b. The Star Tracker searches a 10 square field of view.
 - c. The Star Tracker searches a 2^0 field of view.

- d. The Star Tracker will search in this mode for 44 seconds.
6. Which of the following statements is true?
- a. The crew has no control over the detection threshold level of the Star Tracker.
 - b. The MCC controls the detection threshold level of each Star Tracker.
 - c. There are four levels of detection threshold control.
 - d. The detection threshold level can be controlled only for targets.
7. Loss of Star Tracker power causes
- a. the Star Tracker doors to spring closed.
 - b. the shutter to spring open.
 - c. the Star Tracker circuit breaker to pop open.
 - d. the shutter to spring closed.

SECTION 5

STAR TRACKER/COAS CONTROL DISPLAY (STAR TRACKER OPERATIONS)

SPEC 22 provides the control and monitoring capability required to operate and evaluate the Star Tracker and COAS units after the doors are opened and power is applied. It is illustrated in figure 5-1.

This display is available in GNC OPS 2 and OPS 3, Major Mode 301. It is called up using the keyboard to input SPEC 22 PRO. The lower right side of this display is used for COAS operation, and the rest, except the sighting table (upper right) depicts Star Tracker operation. The sighting table is shared by the Star Tracker and COAS.

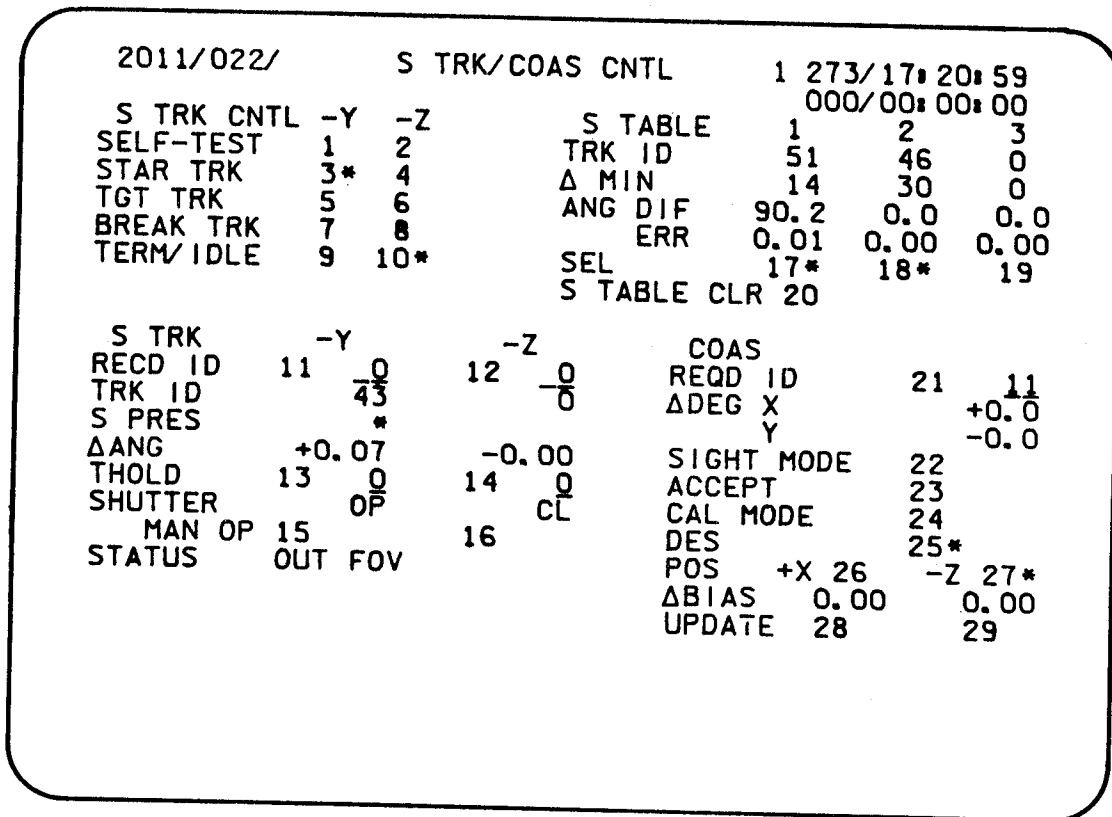


Figure 5-1. S TRK/COAS CNTL Display

The upper left portion of the display (see figure 5-2) contains the controls required to select various Star Tracker submodes.

```
2011/022/      S
S TRK CNTL -Y -Z
SELF-TEST      1  2
STAR TRK       3* 4
TGT TRK        5  6
BREAK TRK      7  8
TERM/IDLE     9 10*
```

Figure 5-2. S TRK/COAS CNTL Display (upper left portion)

- ITEMS 1 and 2 select the SELF-TEST mode for the -Y and -Z Star Trackers.
- ITEMS 3 and 4 select the Star Track (STAR TRK) mode of operation.
- ITEMS 5 and 6 select the Target Track (TGT TRK) submode. Selection of this mode will command the Trackers to track. The software will provide angular information for rendezvous computations.
- ITEMS 7 and 8 are used to force the Star Tracker to stop tracking (BREAK TRK) the star/target that it is locked on currently and to search the remaining commanded FOV (offset or total) for another star or target. This will be most useful during target tracking operations when an incorrect target is being tracked.
- ITEMS 9 and 10 select the Terminate/Idle (TERM/IDLE) submode. This submode stops all GPC commands to the hardware. The Tracker itself will continue to operate, but there will be no return of star data to the GPC. ITEMS 1, 3, 5, 9 and 2, 4, 6, 10 are mutually exclusive items. Both the crew and the GPC control ITEMS 7, 8, 9, and 10. It should be noted that any GNC OPS transition or OPS mode recall will default the Trackers to the TERM/IDLE submode. Executing an IMU alignment also modes the Star

Trackers to TERM/IDLE to preclude entering star data in the Star Table (S TABLE) during the alignment. Below the submode controls, in the lower left-hand portion of the display, are data and controls to monitor and control Star Tracker functions (see figure 5-3).

S TRK	-Y	-Z
RECD ID	11 0	12 0
TRK ID	43	0
S PRES	*	
Δ ANG	+0.07	-0.00
THOLD	13 0	14 0
SHUTTER	OP	CL
MAN OP	15	16
STATUS	OUT	FOV

Figure 5-3. S TRK/COAS CONTL Display (lower left portion)

- ITEMS 11 and 12 are used to input the identification number (REQD ID) of a star to be tracked. Stars currently in the GPC star catalog are numbered 11-60. The default value is always 0 when SPEC 22 is called. Commanding track with REQD ID equals 0 results in GPC selection of a star which is currently within the FOV. See Appendix B for the star catalog.
- TRK ID displays the number that identifies the star or target that should be within the FOV.
- S PRES location contains an asterisk (*) when a star is in the FOV.
- Δ ANG displays the angle between the expected line of sight and the actual measured line of sight. This angle represents the IMU misalignment error and Tracker system errors.
- ITEMS 13 and 14 are control inputs used to enter a magnitude threshold level for star tracking. As discussed earlier, possible inputs are 0, 1,

2, or 3. Default will be 0 when SPEC 22 is called and after the Star Tracker has locked on to the star/target.

- SHUTTER indicates shutter position (OP for open; CL for closed) for each Star Tracker. This does NOT indicate door position.
- ITEMS 15 and 16 inhibit the automatic shutter mode for the appropriate Star Tracker, causing it to be commanded open and to remain open. Re-execution of ITEMS 15 or 16 returns automatic control.
- Below the shutter controls are displayed status information for both Star Trackers. The status information will be blank or display any one of the following for the period of time that the condition exists:

ST FAIL - indicates a SELF-TEST failure.

ST PASS - indicates a completed SELF-TEST with no detected failures.

OUT FOV - indicates that the required star is not in the Star Tracker FOV or that it is already in the S TABLE.

HIGH RATE - indicates that the star/target is passing through the FOV at an excessive rate ($>.75^{\circ}/\text{second}$).

NO TARGET - indicates that the desired star/target has not been detected.

FALSE TRK - indicates that an incorrect star/target has been tracked.

- Below the status display is the Built-in Test Equipment (BITE) output location. During normal operation "BITE" is displayed for any of the following conditions:

1. Power supply failure
2. Star Tracker depressurization
3. Bit count error
4. Manchester invalid
5. Parity error

During SELF-TEST operation, "BITE" can be displayed for the following in addition to the above:

6. SELF-TEST mode failure
7. SELF-TEST angle error
8. SELF-TEST magnitude error
9. Bright object alert failure

10. Optics shutter failure

11. Star presence indication failure

Refer to Appendix E for a BITE hardware diagram.

Located in the upper right hand corner of the display is the Star Table (S TABLE) (see figure 5-4). It is used to monitor and control the data available to the GPC for IMU alignments.

```
TRK/COAS CNTL      1 273/17: 20: 59
                   000/00: 00: 00
S TABLE           1      2      3
TRK ID             51     46     0
Δ MIN              14     30     0
ANG DIF            90.2   0.0   0.0
ERR                0.01  0.00  0.00
SEL                17*   18*   19
S TABLE CLR      20
```

Figure 5-4. S TRK/COAS CNTL Display (upper right portion)

- TRK ID indicates star ID (11-60) associated with each star in the table.
- ΔMIN indicates the age of each input in minutes.
- ANG DIF displays the measured separation angle between two stars in the table. The ANG DIF in column 1 represents the separation angle between stars in columns 1 and 2; that in column 2, between columns 2 and 3; and that in column 3, between columns 3 and 1.
- ANG ERR is defined as the difference between the actual star separation angle (calculated from the star catalog) and the ANG DIF computed from Star Tracker measurements.
- ITEMS 17, 18, and 19 are controls to select a star pair to be used by the software to compute alignment data.
- ITEM 20 (S TABLE CLEAR) is used to eliminate all sighting data currently in the table. The S TABLE will automatically clear at the termination of any IMU alignment.

SECTION 6
SOFTWARE PROCESSING

6.1 SELF-TEST

A Star Tracker SELF-TEST tests the Tracker hardware and BITE. The hardware self-test closes the shutter and activates a light-emitting diode whose light is reflected by an aluminized spot on the inner window, producing an optical input at a predefined set of angles and at a given magnitude. The hardware measures these angles and magnitude, compares the measurements against a standard, and outputs a fail or pass status.

SELF-TEST also issues several commands that are checked for proper hardware responses. For instance, during one portion of the test, forced self-test fail output from the hardware causes a BITE indication.

It may take up to 7 seconds to run a SELF-TEST on one Tracker. If both are commanded to SELF-TEST, the first one must finish its SELF-TEST before the other can start. Self-testing both units takes approximately 10 seconds. At the completion of the SELF-TEST, a status of ST PASS or ST FAIL will be displayed.

See Appendix D for a ST SELF-TEST flow diagram.

Below is an example of the crew procedure for performing a SELF-TEST on the Star Trackers. This procedure is located in the Orbit Ops Checklist of the FDF.

S TRK SELF-TEST, GNC 201, 301

Mnvr to avoid bright objects in both BOSs

```

GNC 22 S TRK/COAS CRTL
CRT  ✓ S TRK -Y,-Z: STATUS - (no BITE)
      SHUTTER - OP

      * If SHUTTER - CL          *
      * ITEM 15(16) - EXEC (*)   *
      * ITEM 15(16) - EXEC (no *) *

SELF-TEST - ITEM 1,2 EXEC (*)
✓ S TRK -Y,-Z: SHUTTER - CL
      S PRES - (*)
      STATUS - BITE (momentarily)
      SHUTTER - OP
      STATUS - ST PASS

      * If STATUS - ST FAIL, repeat *
      * SELF-TEST                    *
      * If still FAIL, use only if directed *
      * by MCC                        *
  
```

NOTE

If S TRK(s) to be left in auto
star-select mode, go to IMU
ALIGN - S TRK, step 5

6.2 STAR TRACK

The Star Track software controls the function and inputs to the Star Tracker from initiation of star tracking to completion. As part of the operation, it compares Star Tracker data to preset limits to verify its validity. (See flow diagram in Appendix D.)

There are three modes of star tracking that can be done, based upon the required identification (REQD ID):

1. If no REQD ID is entered, the default value of 0 will remain in the space for each Tracker. With initiation of STAR TRK, an automatic star data collection ("star of opportunity") mode will be entered, in which the GPC will continually cycle through the star catalog to determine whether a star is within the FOV. If a star is present, the GPC will track it and enter data into the S TABLE. In this mode, when the table is filled, old data will be dropped as new data is entered. This mode continues until commanded otherwise (crew input, OPS transition, etc.).
2. If a REQD ID = 0 is entered by crew input, the star catalog will be cycled through once. Any catalog star within the FOV will be tracked and data stored in the table. Upon completion of one cycle through the star catalog, the tracker will mode to TERM/IDLE.
3. If a REQD ID = "desired star number" is entered by crew input, the GPC checks to see if the star is within the FOV. If it is, the star is tracked, data is stored in the table, and the Tracker modes to TERM/IDLE. If it is not, the status message OUT FOV is displayed, and the Star Tracker modes to TERM/IDLE.

Initiation of Star Tracker software is accomplished by commanding the STAR TRK mode. The GPC looks up the vector to the star and compares it with the Star Tracker boresight vector. If the difference exceeds 5° , the requested star is out of the FOV. This is displayed on the status line and the Star Tracker software is moded to TERM/IDLE. If it is within the FOV, the software issues the properly formatted offset commands to the Star Tracker to search a particular portion of the FOV, i.e., where the GPC thinks the star should be, and outputs a TRK ID equal to the REQD ID.

The software waits 4 seconds while the Star Tracker searches a $1^\circ \times 1^\circ$ FOV four times. If it does not acquire a star, the GPC removes the offset command and searches the total field of view, $10^\circ \times 10^\circ$, four times. If it still does not acquire the proper star after 40 seconds, it will output the status message NO TARGET. If the Star Tracker acquires a star in either of the search periods, it outputs the "star present" asterisk. At this time it also calls a data filter module that develops a horizontal and vertical average angle, time tag, and vertical and horizontal rate information; however, if the Shuttle body rates exceed $.75^\circ/\text{sec}$, the status message HI RATE is output.

If the rates are within tolerance, the GPC checks the relative rates and measured line of sight versus calculated line of sight. If the star is confirmed, the data goes into column 1 and pushes the first star into column 2. At

this time, ANG DIFF and ANG ERR will be displayed in column 1 for these two stars. ANG DIFF is the separation angle between the two stars and ANG ERR is the difference between the actual separation angle and the calculated separation angle. The GPC checks the separation angle to see if it is between 35° and 145°. If it is, asterisks are placed beside ITEMS 17 and 18, and ALIGN ENA appears on the IMU ALIGN display (SPEC 21). If a third star is now tracked and confirmed, it will shift into column 1, shifting column 1 data to column 2 and column 2 data to column 3. ANG DIFF and ANG ERR is now displayed in all 3 columns. The ANG DIFF and ANG ERR in column 2 are for stars in columns 2 and 3, and ANG DIFF and ANG ERR in column 3 are for the stars in column 3 and column 1.

The GPC selects two stars with a separation angle (ANG DIFF) closest to 90° by activating an asterisk beside two of the three ITEMS (17, 18, 19). The crew may change this selection by first activating the ITEM number they want to deselect, then activating the ITEM number they want to select.

In the "star of opportunity" mode, the Star Tracker will continue to search for stars. If another star is tracked by GPC command after there are three stars in the table, the new star will be compared to each star in the table to determine whether its separation angle is closer to 90°. If it is, the GPC will save the new star and the one it makes the angle with and delete the older of the two remaining stars. The new star is then entered in column 1 and the data and current star pair selected for IMU alignment are displayed.

The GPC has one additional criterion for determining which stars will appear in the S TABLE: if the data on one or more stars is 60 minutes old or older as shown in the Δ MIN slot, it will be deleted with the next star input. Therefore, the S TABLE will always select the star pair closest to 90° that is less than 60 minutes old.

The previous description of software operation illustrates the need for the capability to clear the S TABLE (ITEM 20). If there is a good angle between two stars, but one or both of them is quite old (45-60 minutes), new star data cannot be taken if the old star data is closer to 90° unless the S TABLE (ITEM 20 EXEC) is cleared and tracking is restarted.

On the next page is an example of a crew procedure for collecting star data for an IMU alignment. This procedure begins by assuming that the desired stars have been chosen beforehand and that the Shuttle has been maneuvered to the proper attitude for tracking by each Star Tracker. It is located in the Orbit Ops Checklist.

IMU ALIGN - S TRK, GNC 201, 301

1 COLLECT STAR DATA

C3
(A6U)

✓DAP: A/AUTO/VERN

CRT

GNC 22 S TRK/COAS CNTL

✓S TRK -Y,-Z: REQD ID, ITEM 11,12 - 0
STATUS - (no BITE)
SHUTTER - OP

* If SHUTTER - CL: *
* ✓Att,MET - correct *
* MAN OP - ITEM 15(16) EXEC (*) *

✓S TABLE CLR, ITEM 20 - (no unwanted data)
STAR TRK - ITEM 3,4 EXEC (*)

2 VERIFY STAR DATA

✓S TABLE: TRK ID 1,2 - (correct #s)
ANG ERR 1 - < .08, Rcd ____
SEL, ITEM 17,18 - (*)

* If no data after 3 min or bad data: *
* ✓Att,stars,MET - correct *
* ✓Rot Rate - < .50/sec *
* ✓S TRK -Y,-Z: TRK ID - (correct #s) *
* ΔANG - < 1.0 *
* If preceding checks are good: *
* Perform S TRK SELF-TEST then, *
* If both STATUS - ST FAIL: *
* | Inform MCC before proceeding *
* If both STATUS - ST PASS: *
* | Repeat step 1 at new att, stars *
* If one STATUS - ST PASS: *
* ✓TERM/IDLE, ITEM 9(10) - (*) *
* STAR TRK, GOOD S TRK - ITEM 3(4) EXEC (*) *
* S TABLE CLR - ITEM 20 EXEC *
* ✓S TABLE: TRK ID 1 - (correct #) *
* TERM/IDLE, GOOD S TRK - ITEM 9(10) EXEC (*) *
* Mnv'r to 2nd att, star *
* STAR TRK, GOOD S TRK - ITEM 3(4) EXEC (*) *
* Repeat step 2 with good S TRK only *

6.3 IMU ALIGN

IMU alignment is accomplished using controls on the IMU ALIGN display (SPEC 21) (see figure 6-1). As with SPEC 22, this display is available in OPS 2 and OPS 3, Major Mode 301.

The following ITEMS and data in the upper right hand corner of SPEC 21 are used during IMU alignments using star data.

- ENA will appear to the right of ALIGN if there is good star data (usable for an alignment) in the S TABLE on SPEC 22, and a pair has been selected for use in alignment (asterisk beside two SEL ITEM numbers).
- ITEMS 10, 11, and 12 allow crew selection of IMU or IMU's to be aligned. ITEM number execution places an asterisk beside the ITEM number of the IMU selected, indicating selection for alignment.
- ITEM 13 (STAR ALIGN) will appear with an asterisk beside it each time the display is called. This indicates that the IMU's will be aligned using data in the S TABLE.
- ITEM 14 and 15 select other means of aligning IMU's which are explained in the IMU workbook.
- ITEM 16 (EXEC) begins the selected alignment mode for the selected IMU's. An asterisk will appear upon execution of the alignment and disappear upon completion.
- ITEM 17 (TERM) allows crew termination of an alignment at any time. Alignments normally terminate automatically.

In the lower left hand corner of SPEC 21 is more data of interest during alignment operations.

- ANG, ΔX , ΔY , and ΔZ indicate torquing angles through which IMU's must traverse to become aligned. These angles will appear when at least two stars are in the S TABLE and two are selected for use in alignment. The angles will decrease to 0 as the alignment progresses. Torquing rate is .0220/second. The IMU with the largest torquing angle will take the longest time, and when completed, ENA will disappear from beside ALIGN at the top right side of the display, as will the asterisk beside ITEM 16 (EXEC). Also, on SPEC 22, at completion of the alignment, the S TABLE will be cleared of all data.

```

2011/021/          IMU ALIGN          1 273/17: 20: 59
IMU                000/00: 00: 00

STAT              ALIGN ENA
TEMP             OK   OK   OK   IMU  1 10* STAR ALIGN 13*
STBY             1   2   3       2 11* 14 IMU/IMU
OPER             4*  5*  6*       3 12  MATRIX    15-
DES              7   8   9

                                           EXEC 16
                                           TERM 17

ACC
  1       2       3
X -0.01 +0.00 -0.02
Y +0.01 +0.00 +0.01
Z -0.00 -0.03 +0.02

ANG
  1       1       1
X 155.75 155.65 155.50
Y 343.35 343.33 343.31
Z 256.03 256.05 255.94
ΔX - 0.07 - 0.21 + 0.03
ΔY - 0.20 + 0.06 + 0.01
ΔZ - 0.06 - 0.06 + 0.05

NAV ΔV THRESH
18 ----3840

MM READ 19

```

Figure 6-1. IMU ALIGN Typical Display

Below is an example of a crew procedure for an IMU alignment using star data previously collected. It is located in the Orbit Ops Checklist.

3 CHECK IMU ΔANGs

CRT GNC 21 IMU ALIGN
√IMU 1,2,3: STAT - blank
√STAR ALIGN, ITEM 13 - (*)
√ANG 1,2,3: ΔX,ΔY,ΔZ - ≤ .80
Rcd ANG 1 2 3
ΔX() . () . () .
ΔY() . () . () .
ΔZ() . () . () .

* If ANG ΔX,ΔY or ΔZ > .80 for two or *
* more IMUs, repeat steps 1,2 and 3 *

CAUTION
If ANG ΔX,ΔY or ΔZ still > .80 for 2 or more IMUs: DO NOT TORQUE PLATFORMS EXCEPT UNDER MCC INSTRUCTIONS

4 ALIGN IMUs

ALIGN IMU 1(2,3) - ITEM 10(11,12) EXEC (*)
EXEC - ITEM 16 EXEC (*), Rcd MET _/_ _:_ _
√Data transcribed into CAP
√EXEC, ITEM 16 - (no *)

NOTE

VERIFICATION: If reqd, repeat steps
1,2 and 3 at prescribed attitude. If
ANG ΔX, ΔY or ΔZ > .1, repeat step 4
and notify MCC

5 S TRK AUTO STAR-SELECT

CRT GNC 22 S TRK/COAS CNTL
√S TRK -Y(-Z): REQD ID, ITEM 11(12) - 0
STAR TRK - ITEM 3(4) EXEC (*)
√Shutter not MAN OP, ITEM 15,16 - (no *)

6.4 STAR TRACKER SOFTWARE CONTROL RULES

Star Tracker Software processing control rules are as follows:

- When SPEC 22 is called up in an OPS, releasing the SPEC will not terminate Tracker operation. It remains active in the same mode as when released.
- Initial callup during orbit will be in the TERM/IDLE mode. Any subsequent OPS mode transitions or recalls cause the mode to return to TERM/IDLE. Execution of an IMU alignment on SPEC 21 or selecting a COAS submode on SPEC 22 will mode the Trackers to TERM/IDLE.
- The software will remain active until termination of the OPS sequence.
- Star Tracker and COAS operations cannot occur simultaneously.
- No ITEM entries or executions may be made on SPEC 22 during an IMU alignment. Attempts to do so will result in an ILLEGAL ENTRY fault message.
- If the current attitude source IMU is misaligned by more than 1.4° , the star tracking software will not accept stars. A COAS based alignment will have to be done.

QUESTIONS

1. SPEC 22 (S TRK/COAS CNTL) and SPEC 21 (IMU ALIGN) are available during
 - a. all of OPS 1 and OPS 2.
 - b. all of OPS 2 and OPS 3.
 - c. all of OPS 2 and 301.
 - d. OPS 1 and OPS 3.
2. The "star of opportunity" mode
 - a. fills the S TABLE with 3 stars and modes the Tracker to TERM/IDLE.
 - b. selects any star within the FOV for input to the table.
 - c. searches through the star catalog once for stars in the FOV.
 - d. continually cycles through the star catalog searching for stars to track that are within the FOV.
3. Δ ANG is the
 - a. difference between the measured vector and calculated vector to a star.
 - b. difference between this star and previous star.
 - c. angle to be added to star vector.
 - d. angle to be subtracted from star vector.
4. How many stars are in the star catalog?
 - a. 151
 - b. 50
 - c. 60
 - d. 150
5. What is the REQD ID to command auto star data collection?
 - a. a crew input of 0
 - b. 1
 - c. 11

- d. 60
 - e. a default 0
6. Activating ITEM 15 MAN OP for the shutter causes which of the following?
- a. -Y door opens.
 - b. -Y shutter opens and disables BOS.
 - c. causes -Y Star Tracker BITE.
 - d. forces manual tracking of stars.
7. The ANG DIFF and ANG ERR in column 2 relate to the angles between which stars?
- a. column 1 and column 2.
 - b. column 2 and column 3.
 - c. column 3 and column 1.
 - d. column 2 and a newly collected star not yet in the table.
8. ITEM numbers 17, 18, 19
- a. require crew selection to activate.
 - b. reflect GPC or crew selection of stars.
 - c. show the two best ANG DIFF and ANG ERR.
 - d. show the two newest stars in the table.
9. S TABLE CLEAR, ITEM 20
- a. clears the whole table.
 - b. clears the newest star.
 - c. clears the oldest star.
 - d. selectively clears one star.

ANSWERS

1. SPEC 22 (S TRK/COAS CNTL) and SPEC 21 (IMU ALIGN) are available during
 - a. all of OPS 1 and OPS 2.
 - b. all of OPS 2 and OPS 3.
 - c. all of OPS 2 and 301.
 - d. OPS 1 and OPS 3.
2. The "star of opportunity" mode
 - a. fills the S TABLE with 3 stars and modes the Tracker to TERM/IDLE.
 - b. selects any star within the FOV for input to the table.
 - c. searches through the star catalog once for stars in the FOV.
 - d. continually cycles through the star catalog searching for stars to track that are within the FOV.
3. Δ ANG is the
 - a. difference between the measured vector and calculated vector to a star.
 - b. difference between this star and previous star.
 - c. angle to be added to star vector.
 - d. angle to be subtracted from star vector.
4. How many stars are in the star catalog?
 - a. 151
 - b. 50
 - c. 60
 - d. 150
5. What is the REQD ID to command auto star data collection?
 - a. a crew input of 0
 - b. 1
 - c. 11

- d. 60
 - e. a default 0
6. Activating ITEM 15 MAN OP for the shutter causes which of the following?
- a. -Y door opens.
 - b. -Y shutter opens and disables BOS.
 - c. causes -Y Star Tracker BITE.
 - d. forces manual tracking of stars.
7. The ANG DIFF and ANG ERR in column 2 relate to the angles between which stars?
- a. column 1 and column 2.
 - b. column 2 and column 3.
 - c. column 3 and column 1.
 - d. column 2 and a newly collected star not yet in the table.
8. ITEM numbers 17, 18, 19
- a. require crew selection to activate.
 - b. reflect GPC or crew selection of stars.
 - c. show the two best ANG DIFF and ANG ERR.
 - d. show the two newest stars in the table.
9. S TABLE CLEAR, ITEM 20
- a. clears the whole table.
 - b. clears the newest star.
 - c. clears the oldest star.
 - d. selectively clears one star.

SECTION 7

CREW OPTICAL ALIGNMENT SIGHT INTRODUCTION

The Crew Optical Alignment Sight (COAS) (see figure 7-1) is used as a backup to the Star Tracker for aligning the IMU's. In later flights it will be used for tracking targets and may also be used to provide visual cues for attitude burns.

As discussed earlier in the Star Tracker section of the workbook, the Star Tracker software will not accept stars for IMU alignments if the stars are more than 1.4° away from where the GPC thinks they should be. Therefore, if the IMU's become misaligned by more than 1.4° , another method of tracking stars is needed. The COAS serves as the alternate method of star tracking. Like the Star Trackers, the COAS is used to establish a line of sight vector to a star, thereby enabling determination of the orientation of the IMU's with respect to the stars. It can serve as a method of coarse alignment with the Star Tracker completing with a fine alignment or it can be the redundant method in case of failure of both Star Trackers.

Using the COAS requires some knowledge of nav star locations in the sky, since its application as a contingency method of IMU alignment implies there may be no attitude reference to aid in star sighting. Refer to the Navigation Stars Identification Workbook for nav star location and constellation recognition. The IMU Alignment Procedures Handbook will also be useful for detailed explanations of COAS-based IMU alignments. The Flight Maps and Charts of the Flight Data File contain rectangular and polar star charts to aid in nav star location.

The COAS used on the Shuttle is a modified unit developed for Apollo. Modifications included changing the reticle dimmer and the mounting so that repetitive mount/demount cycles have little effect on sighting accuracy. Flight experience has shown that this is the case.

The only interface between the COAS and other Shuttle systems is an electrical connection to power a light which illuminates a reticle in the barrel.

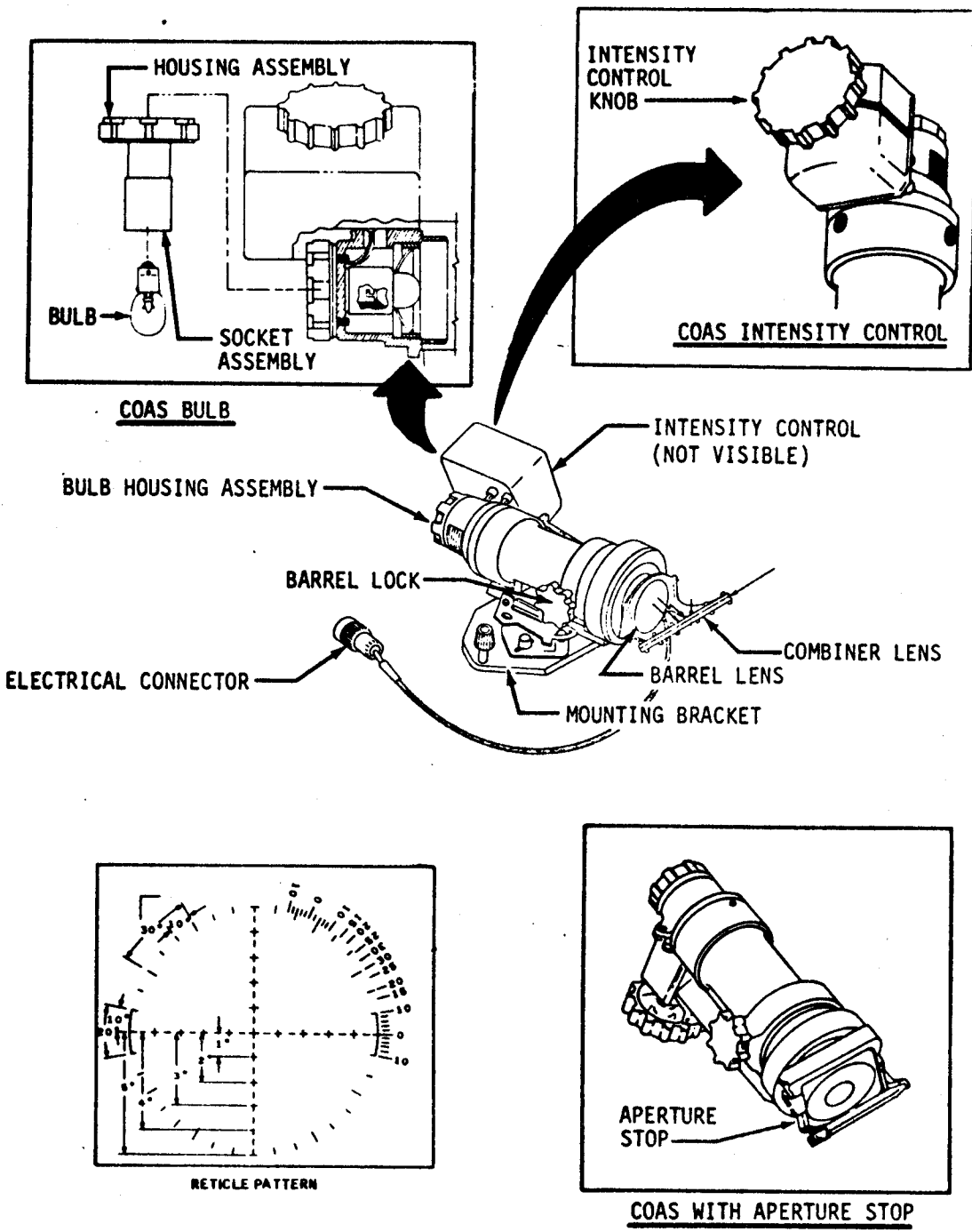


Figure 7-1. Crew Optical Alignment Sight

7.1 DESCRIPTION

The COAS is a cylindrically shaped device about 8 inches long, with a combining glass at one end, a boxlike attachment at the other end (containing a rheostat for light intensity control), and a mounting plate attached to the central portion of the cylinder (see figure 7-2). Alignment pins are located on the bottom of the mount. Phase self-centering alignment pins maintain the boresight aiming point after many mount and demount cycles. The line of sight, as shown, is looking through the combining glass. This is used to project the reticle pattern onto the FOV of the star or target. The knurled knob drives the rheostat, which controls the brightness of the reticle pattern.

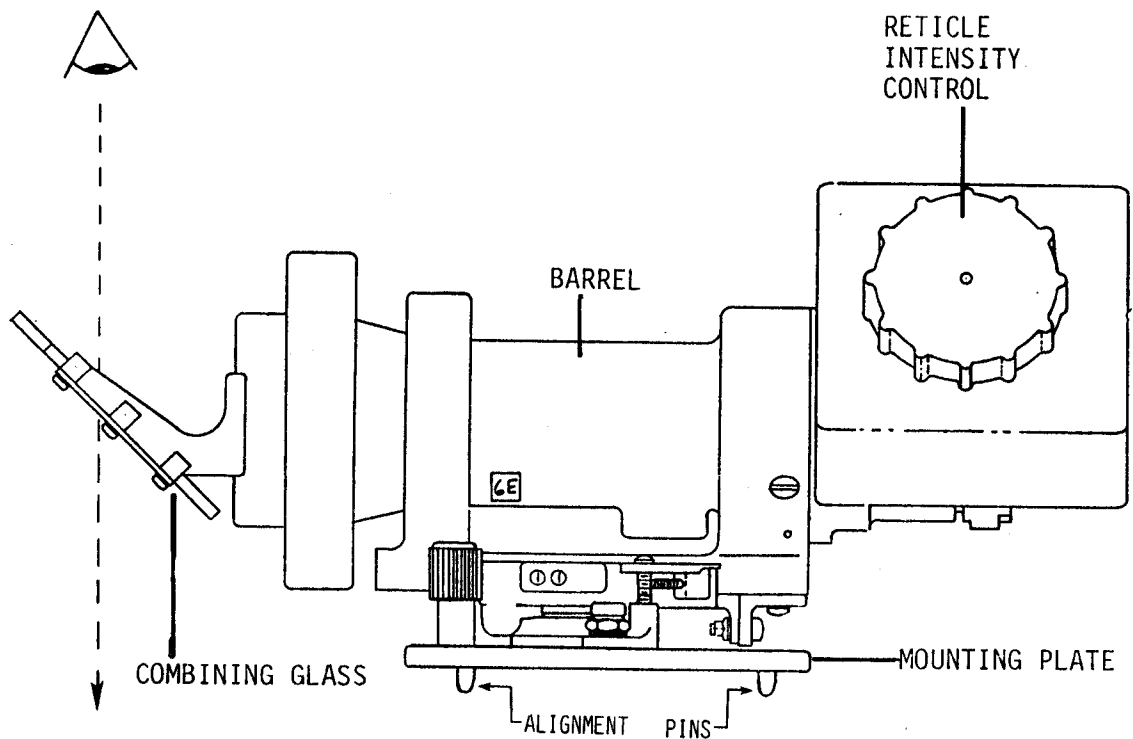


Figure 7-2. COAS Side View

Pictured on the combining glass is the reticle pattern as seen when looking through the combining glass at a star or target (see figure 7-3 below). Also shown are the two mounting thumbscrews used to lock the COAS into position.

The cross adjustments, which mount the COAS to the mounting plate, are preset prior to ground calibration and should not be moved.

In order that the COAS be properly aligned, it must be oriented for the position in which it is mounted. The barrel index allows selection of either Forward Window (FW) or Overhead Window (OW) orientation. This orientation is a rotation of the reticle glass and lower portion of the COAS relative to the upper portion and mounting plate. The rotation aligns the COAS boresight axis with the Shuttle body axis associated with the mounting position. The barrel lock fixes the barrel at the correct orientation.

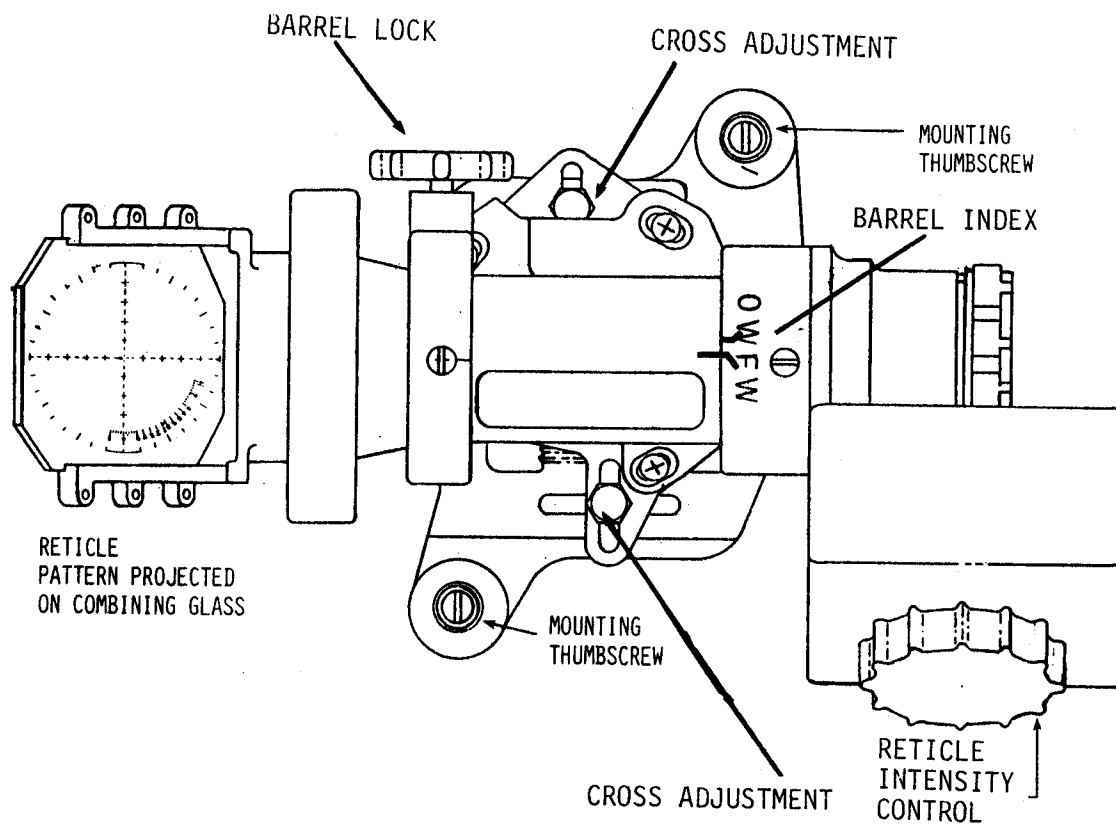


Figure 7-3. COAS Top View

7.2 MOUNTING

The COAS has two mounting positions: one above the CDR +X (forward) window (W3) and one in front of the starboard overhead window (W7) above the aft flight station. See figure 7-4 for COAS viewing directions. The +X mount is bore-sighted parallel to the +X axis and the -Z mount parallel to the -Z axis of the Shuttle. Figures 7-5 and 7-7 illustrate the COAS mounted in the forward and aft position.

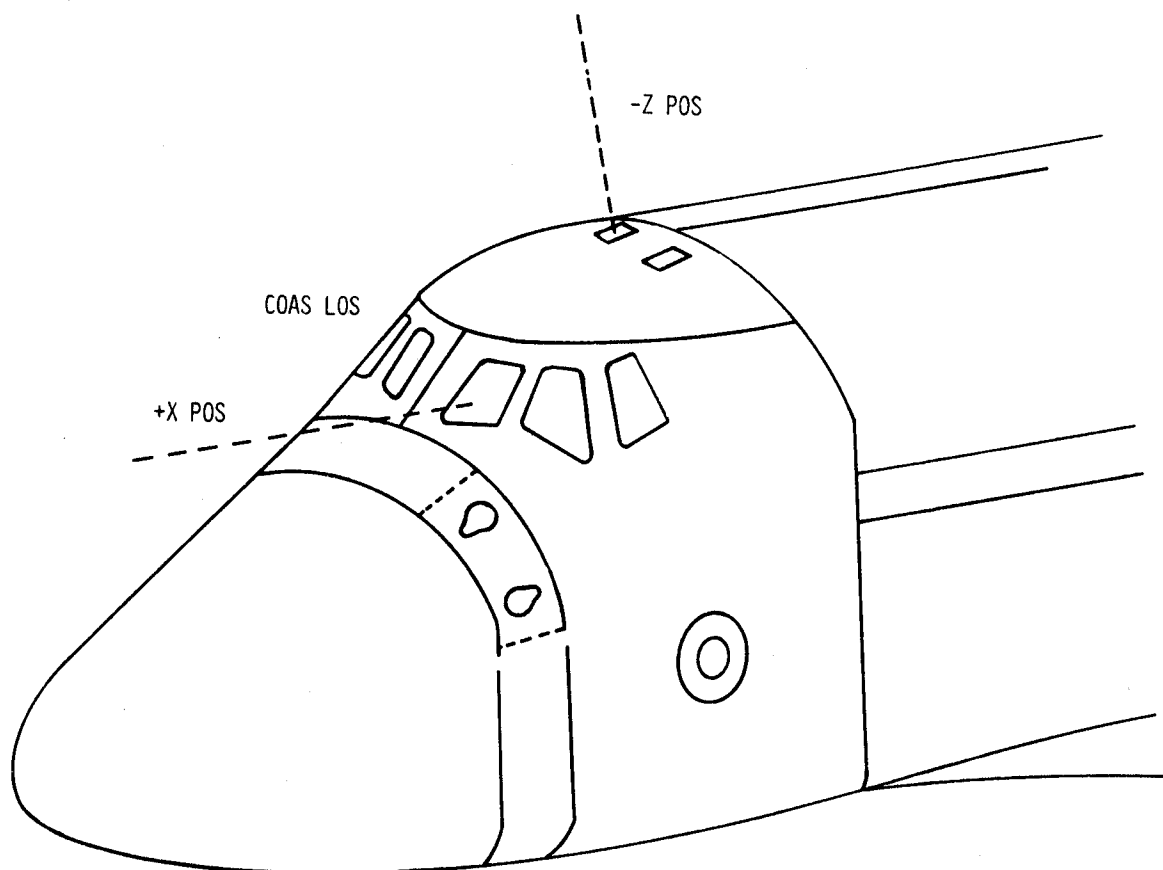


Figure 7-4. COAS Viewing Directions

7.2.1 Forward Mounting. When taking sightings along the +X axis (see figure 7-5 and 7-6), the COAS is mounted on Panel 01 and sighted through window W-3. With the COAS mounted on Panel 01, power to illuminate the reticle is provided from the COAS POWER switch on Panel 01. Reticle brightness is controlled by the intensity control on the COAS. A mounting bracket is attached to the COAS prior to mounting it in this position. This bracket is required to lower the unit so that the view through the forward window is unobstructed.

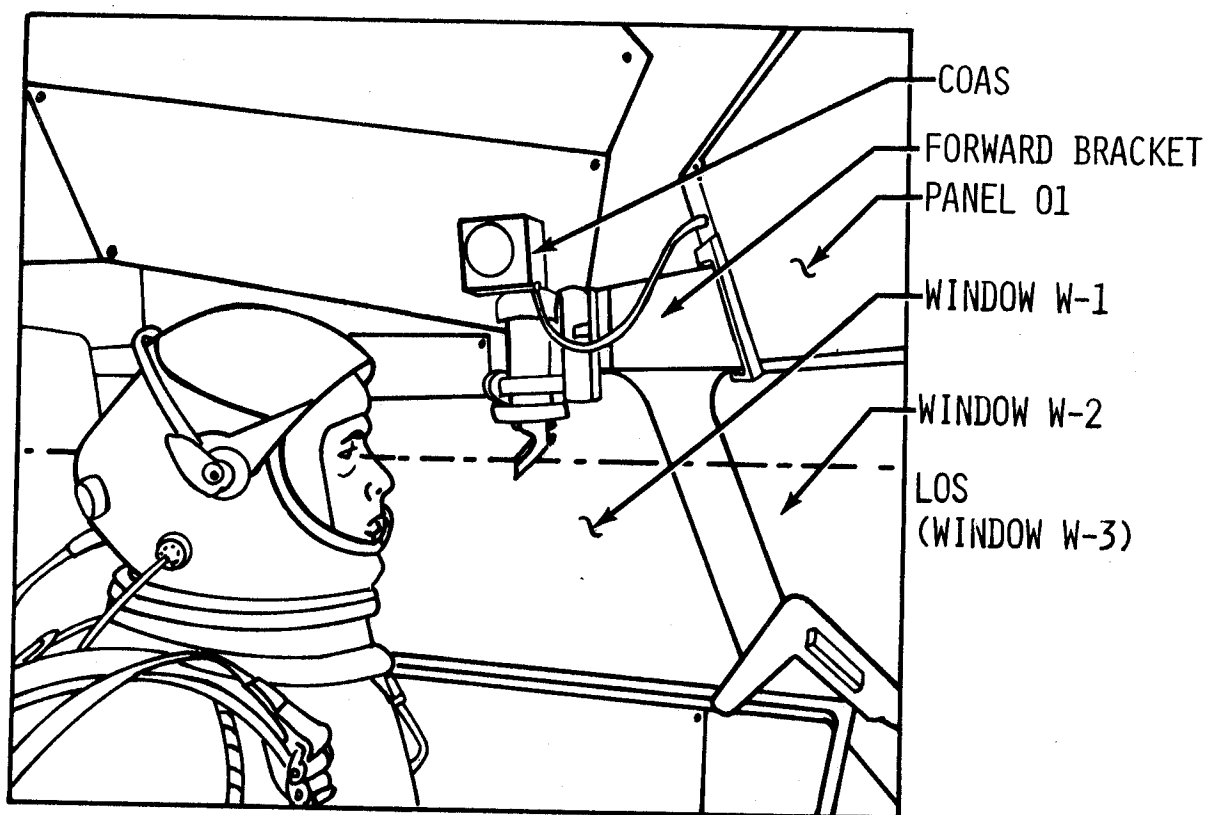


Figure 7-5. Using COAS in Forward Position

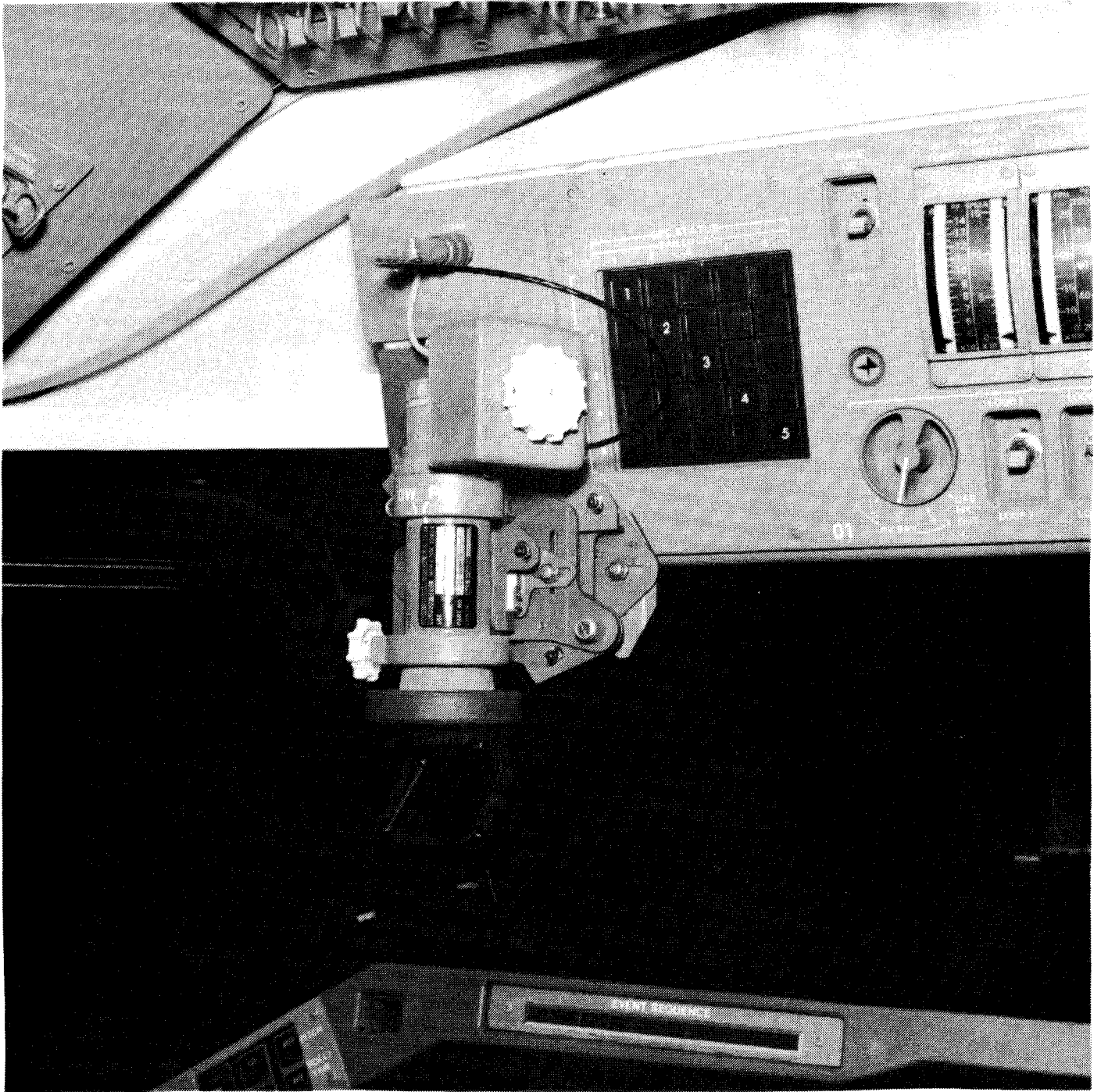


Figure 7-6. COAS Mounted in Forward Location

7.2.2 Aft Mounting. A COAS mount near the forward edge of the starboard overhead window (W7) is the aft COAS location for star sighting or rendezvous. Sightings from this position are made in the -Z direction of the Shuttle body coordinate system. From this location the Shuttle attitude is controlled using the aft Rotational Hand Controller (RHC) (see figure 7-7). COAS power at the aft mount is controlled by a COAS POWER switch on Panel 019. The mounting bracket used at the +X position is not required here and should not be attached.

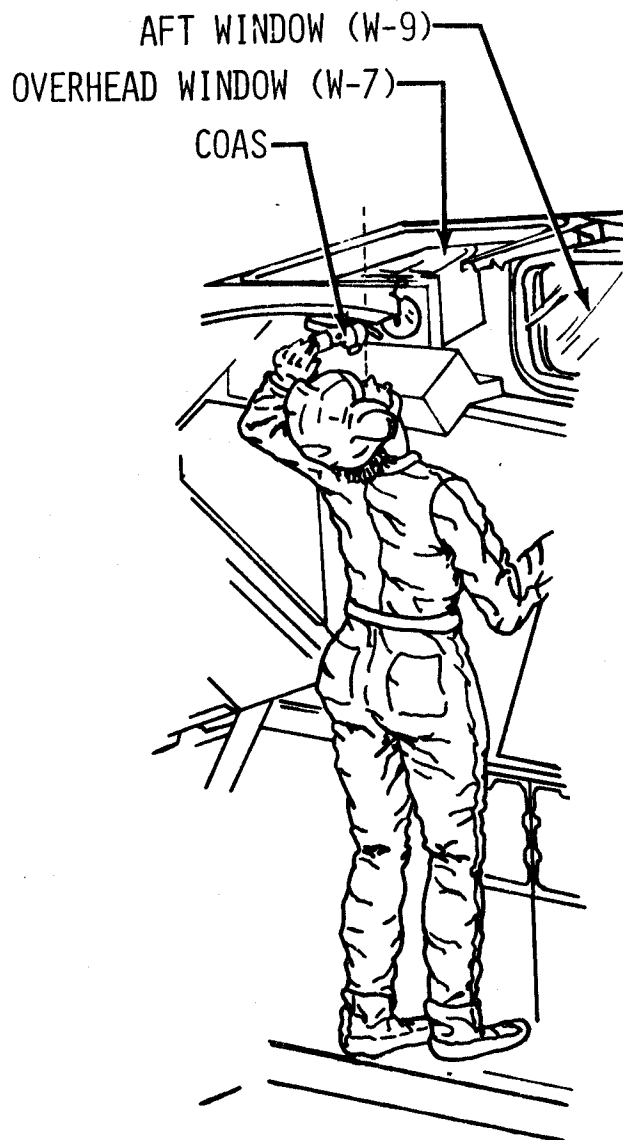


Figure 7-7. Using COAS in Aft Position



Figure 7-8. COAS Mounted in Aft Location

7.3 COAS POWER

Power for both the forward and aft COAS stations is supplied from circuit breaker CB 127 (COAS) located on Panel L4. From this circuit breaker, power is routed to Panels 01 and 019 (see figure 7-9 through 7-12). The state of the COAS power is monitored by flight controllers through the telemetry system. In the event of a COAS power failure, the end of the COAS barrel opposite the reticle can be unscrewed and a flashlight shone through the barrel to illuminate the reticle.

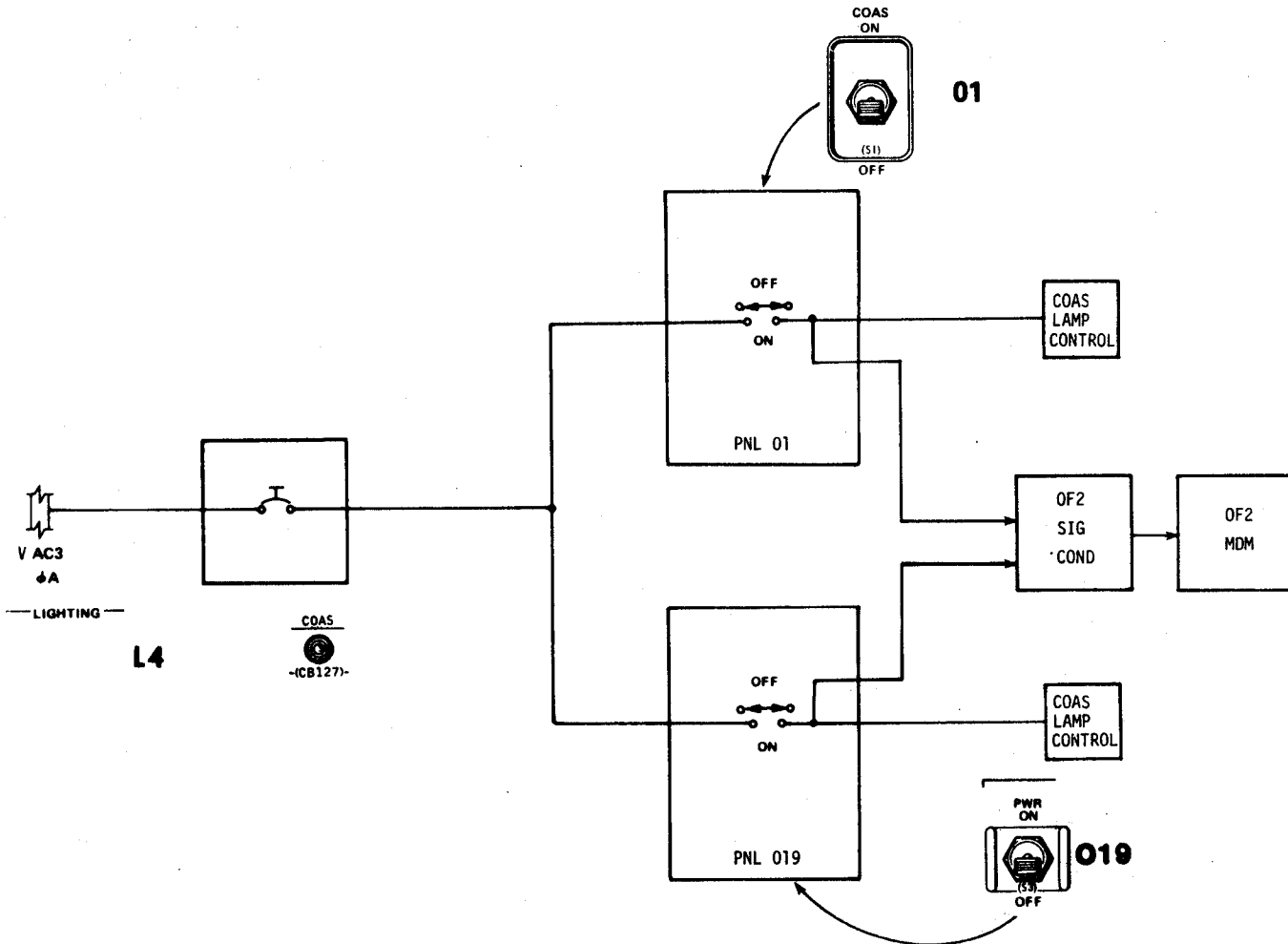


Figure 7-9. COAS Power Distribution Diagram

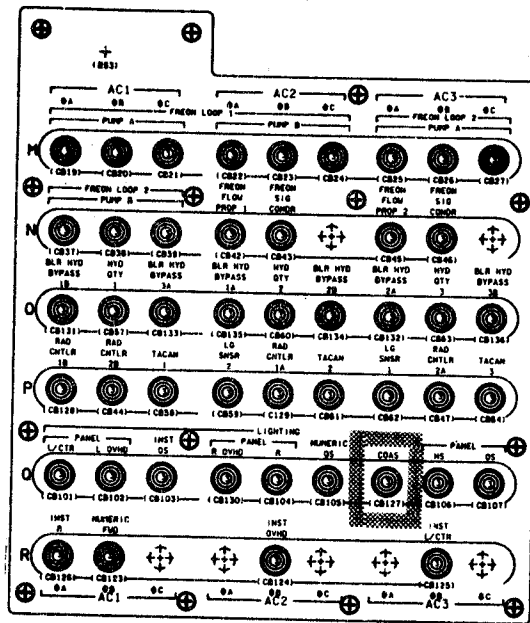


Figure 7-10. CB 127 on Panel L4 (right portion of panel)

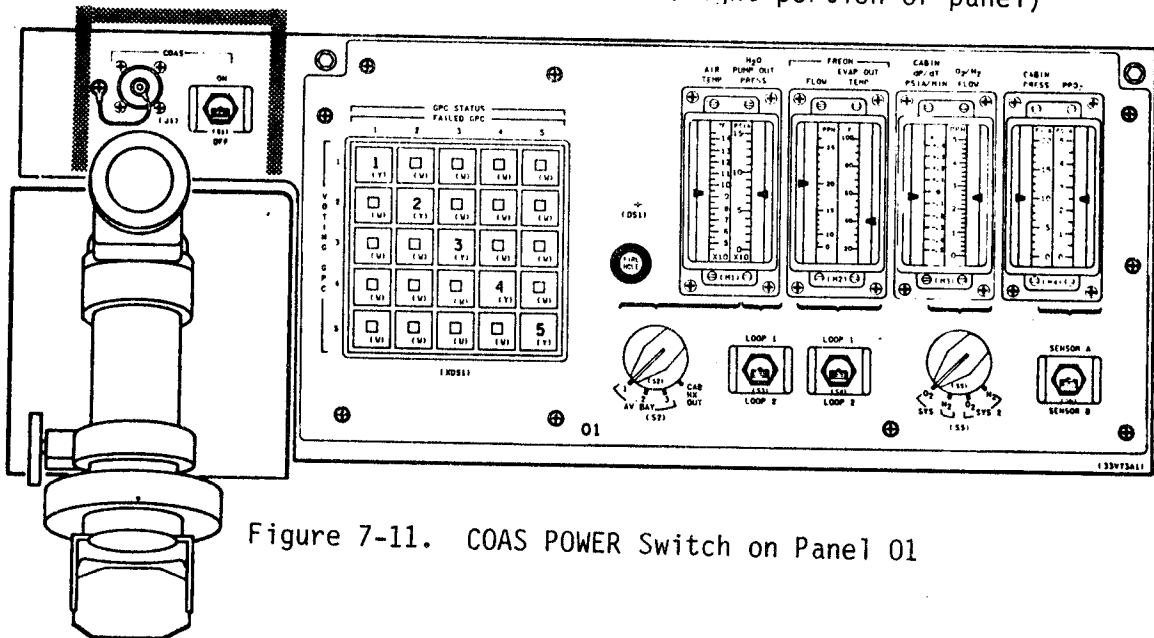


Figure 7-11. COAS POWER Switch on Panel 01

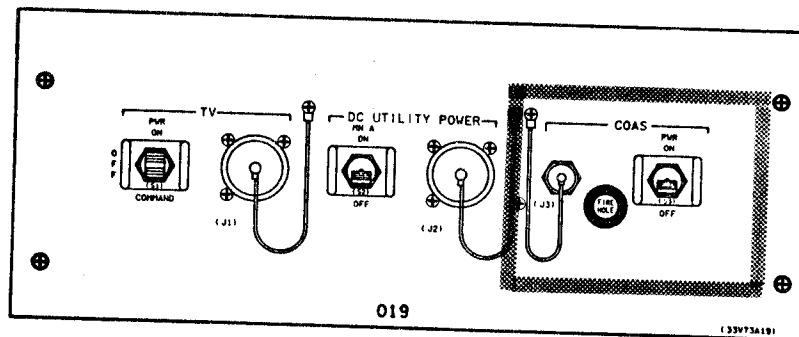


Figure 7-12. COAS POWER Switch on Panel 019

7.4 RETICLE PATTERN

When using the COAS, the Orbiter is slowly maneuvered so that the star or target moves through the center of the cross on the reticle (see figure 7-13). The desired position of the star is exactly at the intersection of the two perpendicular dashed lines. Once this is achieved, the ATT REF pushbutton, described in the following subsection, is depressed to indicate to the GPC that the star is centered in the reticle.

Refer to figure 4-2 for COAS coordinate system definition as it relates to the reticle and the Tracker coordinate system.

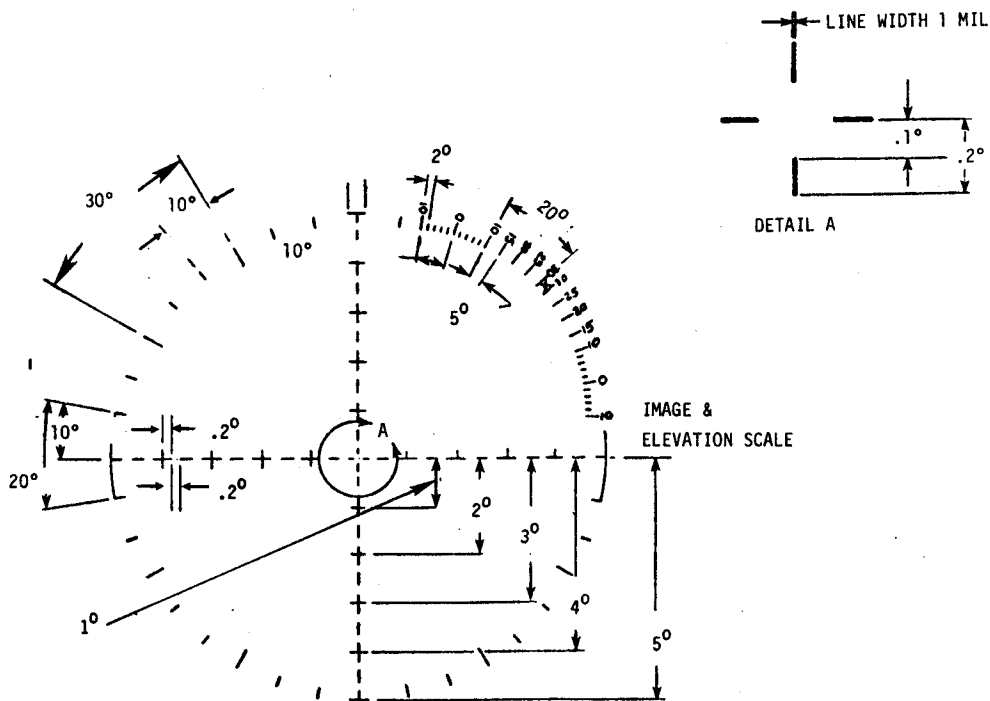


Figure 7-13. COAS Reticle Pattern

7.6 APERTURE STOP AND FILTER

An aperture stop that reduces the field of view is provided to assist in "sighting on" a star. A filter that facilitates daylight sightings is also provided. The aperture stop and filter both clip on the COAS lens mounting bracket; therefore, they cannot be used simultaneously (see figures 7-16 and 7-17).

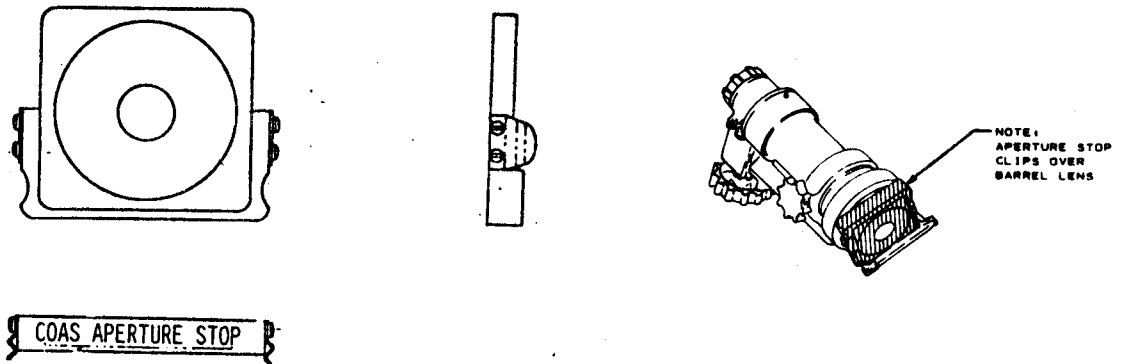


Figure 7-16. COAS Aperture Stop Installation

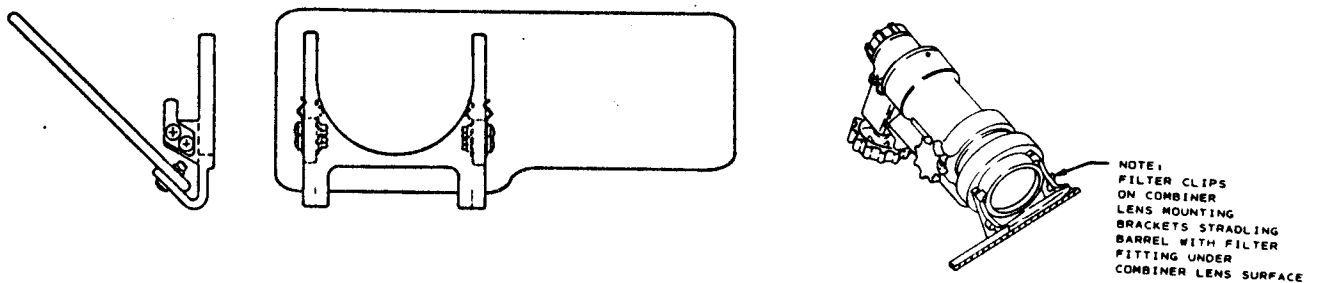


Figure 7-17. COAS Filter Installation

SECTION 8

STAR TRACKER/COAS CONTROL DISPLAY (COAS OPERATIONS)

As discussed in the Star Tracker portion of this workbook, SPEC 22 provides crew monitoring and control for Star Tracker and COAS operations.

COAS controls are located in the lower right-hand portion of the display (see figure 8-1).

- REQD ID (ITEM 21) allows input of the ID number of the star being sighted.
- Δ DEG X and Y display the angular offset of a star/target, tracked by the -Z Tracker, from the -Z COAS boresight. X corresponds to the vertical axis of the reticle pattern (parallel to the X body axis of the Shuttle) and Y corresponds to the horizontal axis of the reticle pattern (parallel to the Y body axis).
- SIGHT MODE (ITEM 22) enables the star tracking software to accept COAS sighting marks on stars to be used for IMU alignments.

COAS		
REQD ID	21	<u>11</u>
Δ DEG X		+0.0
Y		-0.0
SIGHT MODE	22	
ACCEPT	23	
CAL MODE	24	
DES	25*	
POS	+X 26	-Z 27*
Δ BIAS	0.00	0.00
UPDATE	28	29

Figure 8-1. S TRK/COAS CNTL Display (Lower Right Portion)

- ACCEPT (ITEM 23) allows a star sighting mark to be displayed in the S TABLE.
- CAL MODE (ITEM 24) enables software which accepts a star sighting mark for the purpose of COAS calibration on-orbit.
- DES (ITEM 25) disables SIGHT MODE or CAL MODE. It restores the ADI definition function of the ATT REF pushbutton and enables Star Tracker operations.
- POS allows specification to the software of which COAS mount position is being used. +X (ITEM 26) specifies +X COAS mount and -Z (ITEM 27) specifies -Z COAS mount.
- Δ BIAS displays compensation computed by software (after a mark on a star) that is needed to calibrate the COAS in the position selected by ITEMS 26 or 27. Displayed will be a number representing an angular correction (in degrees).
- UPDATE (ITEMS 28 and 29) allows a command to incorporate the BIAS into software. ITEMS 28 and 29 represent respectively the +X and -Z positions displayed above. Upon execution, the Δ BIAS returns to zero.

Using the COAS SIGHT MODE or CAL MODE will mode the Trackers to TERM/IDLE from any other mode of operation. Only one optical system can be selected at any time.

COAS-sighted stars will always be inserted into columns 1 and 2 of the S TABLE. The first star sighted will be inserted into column 2, and the second into column 1. However, stars are inserted into the table only after an ITEM 23 (ACCEPT), not after the "mark". Column 3 of the S TABLE is not used in COAS operations. COAS calibrations do not use the S TABLE. In the sighting mode, data on any number of stars subsequent to the first will always be placed into column 1. To replace data in column 2, the S TABLE has to be cleared first, or the sighting mode deselected and reselected.

SECTION 9
COAS OPERATIONS

9.1 CALIBRATION

The COAS mounting locations are calibrated prior to launch so that the GPC knows the boresighted look angle of each position relative to the navigation base. When the Shuttle reaches orbit, the structural forces applied to the vehicle by its environment have changed; therefore, the structural bending of the vehicle may be different than on the ground. Consequently, the GPC may no longer know the correct COAS boresight in orbit. To correct this condition an on-orbit calibration of the COAS is performed.

On-orbit calibration is accomplished by sighting on a nav star while the IMU's are accurately aligned. At this time, the GPC knows the vector to that star. The difference between the two vectors is the error in the COAS look angle, called the "delta bias" (Δ BIAS). The GPC then uses the bias in future COAS sightings to correct for misalignment. Once the COAS is calibrated, subsequent demountings and remountings should have no effect on calibration. Refer to figure 9-1 for COAS calibration.

In both calibration and star sighting for alignment, the ATT REF pushbutton defines the LOS vector to the star when depressed. In either case, it is possible to depress the ATT REF pushbutton any number of times until there is confidence that an accurate sighting has been performed. The last "mark" is the one which will be used by software when an UPDATE or ACCEPT is executed.

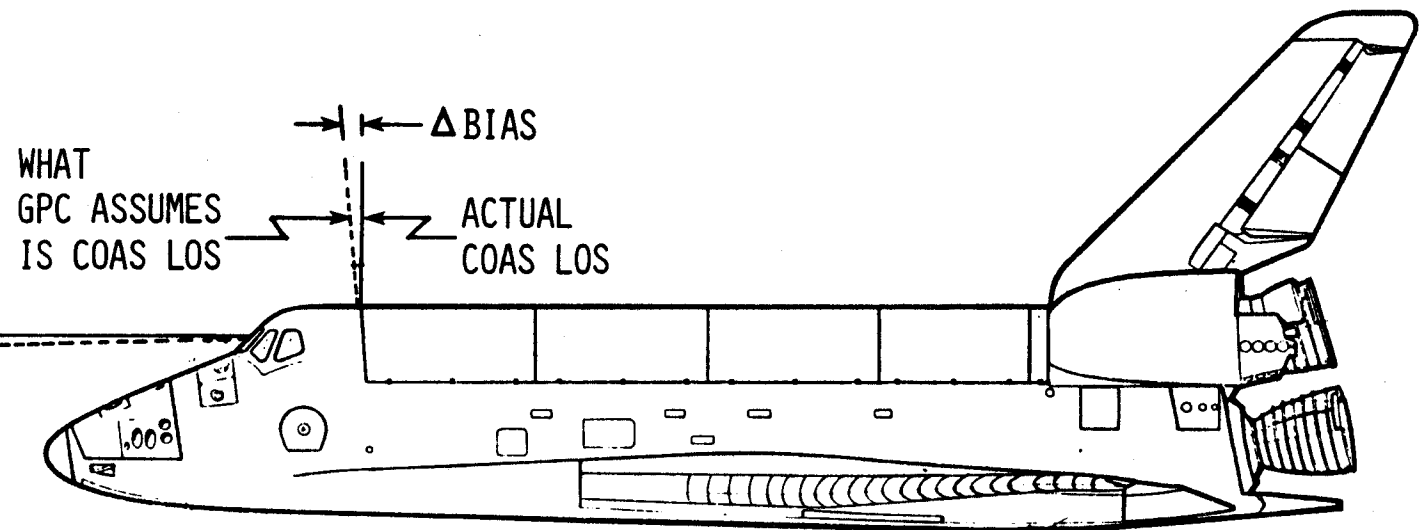


Figure 9-1. COAS Δ BIAS Rationale (typical for both COAS positions)

Below is an example of a crew procedure for COAS calibration after achieving orbit. This procedure requires the crew to sight a nav star, incorporate the Δ BIAS into the COAS software, and then verify the sighting accuracy by resighting. It is located in the Orbit Ops Checklist.

COAS CALIBRATION, GNC 201, 301

1 COAS CALIBRATION PREP

O1
(O19)
COAS
C3
(A6U)

COAS - ON

✓Barrel Index - FW(OW)
✓DAP: A/AUTO/VERN

CRT

GNC 20 DAP CONFIG - Config DAP to A1,B1

...IF +X COAS WITH PRCS...

:
: Config DAP to B2 :
:.....:

GNC 22 S TRK/COAS CNTL

COAS: REQD ID - ITEM 21 + EXEC
POS +X(-Z) - ITEM 26(27) EXEC (*)
CAL MODE - ITEM 24 EXEC (*)

F6/F7
(A6U)

FLT CNTLR PWR - ON

2 MARK ON STAR

C3
(A6U)

DAP ROT: PULSE/PULSE/PULSE
DAP: A/MAN/VERN (COARSE CNTL)
B/MAN/VERN (FINE CNTL)
B/MAN/NORM (PRCS)

F6
(A6U)

Mnvr to center star in COAS:
ATT REF pb - push

NOTE

Repeat mark to ensure Δ BIAS consistency

C3
(A6U)

DAP: A/AUTO/VERN

3 CALIBRATE COAS AND VERIFY

CRT

Rcd CAL +X(-Z) ΔBIAS: _____
UPDATE - ITEM 28(29) EXEC, Rcd MET _/_ _:_ _
✓ΔBIAS goes to zero
Repeat 'MARK ON STAR'
✓ΔBIAS < .12

- * If ΔBIAS > .12, repeat step 3 *
- * If still > .12, notify MCC *

4 CLEAN-UP

COAS: DES - ITEM 25 EXEC (*)

01
(019)
F6/F7
(A6U)

COAS - OFF

FLT CNTLR PWR - OFF

✓Data transcribed into CAP

NOTE

If S TRK(s) to be left in auto
star-select mode, go to IMU
ALIGNMENT - S TRK, step 5

Reconfig to CAP DAP

A software logic flow diagram for the COAS calibration is located in Appendix F.

9.2 STAR SIGHTING

Use of the COAS for actually aligning IMU's occurs only when the IMU's become so badly misaligned that the Star Tracker cannot be used or when both Star Trackers have failed. In either event, a COAS-based IMU alignment is a contingency procedure and, as such, is located in the GNC section of the Flight Data File Systems Malfunction Procedures book as a Failure Recovery Procedure (FRP).

The following procedure is a typical part of the FRP. It is assumed that any IMU failures/problems have been corrected and at least one IMU is available for alignment.

GNC SSR-2

MATRIX (STAR) ALIGN USING COAS STAR DATA

CAUTION
If RMS/payload unberthed, either enable only aft PRCS or berth payload before proceeding

NOTE
If OPS 301, AFT station and GNC SPEC 20 (DAP CONFIG) are not available. Therefore use +X COAS location (Barrel Index - FW) and PULSE MODE

GNC 21 IMU ALIGN

019(01) COAS PWR - ON
COAS ✓Barrel Index - OW (FW)
A6(F7) ✓FLT CNTLR PWR - ON

--- IF +X COAS WITH PRCS ---

GNC 23 RCS
(CRT)
RCS FWD - ITEM 1 EXEC (*)
JET DES F1U - ITEM 11 EXEC (*)
F2U - ITEM 19 EXEC (*)
F3U - ITEM 27 EXEC (*)

If OPS 2:

CRT **GNC 20 DAP CONFIG**
COMP, VERN - ITEM 21(7) +.0 0 3 EXEC

GNC 22 S TRK/COAS CNTL

✓S TABLE CL - ITEM 20 EXEC
COAS: REQD ID - ITEM 21 + EXEC
POS -Z(+X) - ITEM 27(26) EXEC
SIGHT MODE - ITEM 22 EXEC - (*)
A6(C3) DAP: as reqd for precise manual mnvr
(F6) Mnvr to center star in COAS:
ATT REF pb - push
(Repeat mark if desired)
CRT COAS: ACCEPT - ITEM 23 EXEC
✓S TABLE: TRK ID 2 - (REQD ID)

CAUTION
Do not deselect COAS SIGHT mode between sightings

GNC SSR-2 (Cont)

A6(C3) DAP: as reqd for large manual mnvr
Mnvr to second COAS star att

NOTE

Second star must be > 35 deg and < 145 deg from the first

CRT |GNC 22 S TRK/COAS CNTL|
COAS: REQD ID - ITEM 21 + ___ EXEC
A6(C3) DAP: as reqd for precise manual mnvr
Mnvr to center star in COAS:
(F6) ATT REF pb - push
(Repeat mark if desired)
CRT COAS: ACCEPT - ITEM 23 EXEC
✓S TABLE: TRK ID 1 - (REQD ID)
ANG DIF 1 - > 35 deg, < 145 deg
ERR 1 - < .2
✓SEL, ITEM 17,18 - (*)
A6(F7) FLT CNTLR PWR - OFF

A6(C3) |GNC 21 IMU ALIGN|
✓IMU I(2,3): STAT - (blank)
MATRIX (STAR) - ITEM 15(13) EXEC
Align IMU 1(2,3) - ITEM 10(11,12) EXEC - (*)
✓DAP: MAN
DAP ROT: PULSE/PULSE/PULSE
EXEC - ITEM 16 EXEC, Rcd MET _ _ : _ _ _
✓EXEC - ITEM 16 - (no *)
COAS PWR - OFF

019(01) If OPS 2:
|GNC 20 DAP CONFIG|
COMP, VERN - ITEM 21(7) +.0 0 0 EXEC
_ _ _ IF +X COAS WITH PRCS _ _ _

|GNC 23 RCS|
(CRT)
RCS FWD - ITEM 1 EXEC (*)
JET DES F1U - ITEM 11 EXEC (no *)
F2U - ITEM 19 EXEC (no *)
F3U - ITEM 27 EXEC (no *)

A software logic flow diagram for the COAS sighting procedure is located in Appendix F.

QUESTIONS

1. The COAS is used to sight stars through which of the following windows?
 - a. CDR +X window and the starboard overhead window.
 - b. CDR +X window and the port overhead window.
 - c. PLT +X window and the port overhead window.
 - d. Starboard overhead window and the -X aft window.
2. The COAS is locked into place by
 - a. alignment pins.
 - b. mounting thumbscrews.
 - c. barrel lock.
 - d. electrical connectors.
3. The COAS "mark" switch is a secondary function of
 - a. GAIN ENA switch on the Panels F2 and R10.
 - b. ADI ATT REF PBI on A6 and F6.
 - c. ENTER SW on Panels A8 and F5.
 - d. None of the above.
4. COAS power for both stations is supplied from:
 - a. Single CB and individual switches.
 - b. Single switch and individual CB's.
 - c. Separate CB and switch for each.
 - d. CB for each.
5. In the COAS SIGHT MODE, where does the data go in the S TABLE?
 - a. First star goes into column 1, second star goes into column 2.
 - b. First star goes into column 1, second star forces column 1 into column 2 and inserts second star into column 1.
 - c. First star goes into column 3, second star goes into column 2.
 - d. First star goes into column 2, second star goes into column 1.

6. Operation of the COAS in the CAL MODE requires activation of the following ITEM numbers for complete calibration (use SPEC 22 display):

7. Star sighting with the COAS is

- a. the nominal method of IMU alignment.
- b. its only function.
- c. a backup method of IMU alignment.
- d. done to calibrate the Star Trackers for IMU alignments.

8. The Δ BIAS acquired during calibration

- a. can only be computed with the first "mark".
- b. should be repeated to ensure consistency after ITEM 28(29) EXEC (UPDATE).
- c. can never be expected to be less than .12 degrees.
- d. should be repeated to ensure consistency before ITEM 28(29) EXEC (UPDATE).

9. Which of the following statements is true?

- a. The COAS SIGHT MODE must be deselected between sightings.
- b. A COAS calibration of the -Z position will not be good at the +X position.
- c. COAS sighted stars for an IMU alignment must be between 85° and 95° from each other.
- d. In the COAS auto star select mode, no REQD ID input is required.

ANSWERS

1. The COAS is used to sight stars through which of the following windows?
 - a. CDR +X window and the starboard overhead window.
 - b. CDR +X window and the port overhead window.
 - c. PLT +X window and the port overhead window.
 - d. Starboard overhead window and the -X aft window.
2. The COAS is locked into place by
 - a. alignment pins.
 - b. mounting thumbscrews.
 - c. barrel lock.
 - d. electrical connectors.
3. The COAS "mark" switch is the secondary function of
 - a. GAIN ENA switch on panels F2 and R10.
 - b. ADI ATT REF PBI on A6 and F6.
 - c. ENTER SW on panels A8 and F5.
 - d. None of the above.
4. COAS power for both stations is supplied from:
 - a. Single CB and individual switches.
 - b. Single switch and individual CB's.
 - c. Separate CB and switch for each.
 - d. CB for each.
5. In the COAS SIGHT MODE, where does the data go in the S TABLE?
 - a. First star goes into column 1, second star goes into column 2.
 - b. First star goes into column 1, second star forces column 1 into column 2 and inserts second star into column 1.
 - c. First star goes into column 3, second star goes into column 2.
 - d. First star goes into column 2, second star goes into column 1.

6. Operation of the COAS in the CAL MODE requires activation of the following ITEM numbers for complete calibration (use SPEC 22 display):

21, 26 or 27, 24, 28 or 29, 25

7. Star sighting with the COAS is

- a. the nominal method of IMU alignment.
- b. its only function.
- c. a backup method of IMU alignment.
- d. done to calibrate the Star Trackers for IMU alignments.

8. The Δ BIAS acquired during calibration

- a. can only be computed with the first "mark".
- b. should be repeated to ensure consistency after the ITEM 28(29) EXEC (UPDATE).
- c. can never be expected to be less than .12 degrees.
- d. should be repeated to ensure consistency before the ITEM 28(29) EXEC (UPDATE).

9. Which of the following statements is true?

- a. The COAS SIGHT MODE must be deselected between sightings.
- b. A COAS calibration at the -Z position will not be good at the +X position.
- c. COAS sighted stars for an IMU alignment must be between 85° and 95° from each other.
- d. In the COAS auto star select mode, no REQD ID input is required.

APPENDIX A

ACRONYMS

A	Aft
ADI	Attitude Direction Indicator
ANG	Angle
ATT	Attitude
ATT REF	Attitude Reference
AUTO	Automatic
BITE	Built in Test Equipment
BOA	Bright Object Alert
BOS	Bright Object Sensor
BP	Barberpole
CAL	Calibration
CAP	Crew Activity Plan
CB	Circuit Breaker
CL	Close (Clear)
CMD	Command
CNTL(R)	Control (Controller)
COAS	Crew Optical Alignment Sight
COMP	Compensation
CONFIG	Configuration
COORD	Coordinate
CRT	Cathode Ray Tube
C&W	Caution and Warning
DAP	Digital Auto Pilot
DES	Deselect
DEU	Display Electronics Unit
DIFF	Difference
DR	Door
E	Electron
ENA	Enable
ERR	Error
EXEC	Execute
DFD	Flight Data File
FOV	Field of View
FRP	Failure Recovery Procedure
FW	Forward Window
FWD	Forward
G	Gravity or Gravitational Unit
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
H	Horizontal
H/W	Hardware

ID	Identification
IML	Inner Mold Line
IMU	Inertial Measurement Unit
I/O	Input/Output
LED	Light Emitting Diode
LOS	Line of Sight
MAN	Manual
MCA	Motor Control Assembly
MCC	Mission Control Center
MDM	Multiplexer Demultiplexer
MET	Mission Elapsed Time
MIN	Minute
MLI	Multi Layered Insulation
MNA (B)	Main A - Main B
MTR	Motor
NAV	Navigation
O	Overhead
OML	Outer Mold Line
OP	Open, Operate
OPS	Operations
OPT	Option
OW	Overhead Window
P	Pitch
PB	Pushbutton
PBI	Pushbutton Indicator
PNL	Panel
POS	Position
(P)RCS	(Primary) Reaction Control System
PREP	Preparation
PRES	Present
PWR	Power
R	Roll
RCD	Record
REQD	Required
RMS	Remote Manipulator System
ROT	Rotation
S	Star
SEC	Seconds
SEL	Select
SM	Systems Management
ST	Self-test
S TRK	Star Tracker
SYS	Systems
S/W	Software

TB	Talkback
TERM	Terminate
TPS	Thermal Protection System
TRK	Track
U	Up
V	Vertical
VERN	Vernier
Y	Yaw

APPENDIX B

SHUTTLE STAR CATALOG & CHART

This section contains the parametric data associated with 50 pre-defined navigation stars that have been selected for use with the Shuttle Star Tracker. The parameters listed for each star include: (1) star number, (2) S-20 star intensity, (3) star unit vector components (as of 1 January 1975) in M50 coordinates, and (4) common name. Star data for the catalog stars (unit vectors) is required whenever S TRK software processing functions are being performed. Note: Star Catalog data is preliminary. The 50 star unit vector coordinates are pre-mission loaded and will be updated as required. The star catalog contains 60 entries, presently ordered as follows:

- 1 OTHER ORBITING VEHICLE
- 2 CENTER OF EARTH
- 3 SURFACE OF EARTH
- 4 CENTER OF MOON
- 5 EARTH SITE
- 6-10 MANUALLY ENTERED STARS/TARGETS
- 11-60 NAV STARS (MISSION INDEPENDENT)

The non-nav star entries are used to support the Universal Pointing SPEC functions and target tracking operations.

Also included is a star chart from which nav star identification and location can be determined.

SHUTTLE NAV (50) STARS FOR EARLY FLIGHTS

No.	Name	S20 magnitude	Visual magnitude	Right ascension	Declination
11	Sirius	3.150	-1.59	100.73	-16.66
12	Canopus	1.500	-0.79	95.71	-52.67
13	Rigel	.861	-0.18	78.03	-8.26
14	Vega	.803	-0.11	278.81	38.74
15	Hadar	.745	-0.03	210.07	-60.13
16	Achernar	.691	0.06	23.97	-57.49
17	Acrux	.667	0.09	185.95	-62.82
18	Capella	.514	0.38	78.25	45.95
19	Spica	.513	0.38	200.64	-10.90
20	Arcturus	.488	0.43	213.34	19.42
21	Procyon	.477	0.46	114.17	5.35
22	Altair	.369	0.74	297.09	8.74
23	Betelgeuse	.308	0.93	88.12	7.40
24	Bellatrix	.274	1.06	80.61	6.31
25	Regulus	.269	1.08	151.43	12.21
26	Fomalhaut	.267	1.09	343.73	-29.89
27	Deneb	.254	1.14	309.93	45.10
28	Al Na'ir	.205	1.38	331.27	-47.21
29	Alkaid	.197	1.42	206.39	49.56
30	Antares	.193	1.44	246.58	-26.32
31	Castor	.191	1.45	112.85	32.00
32	Aldebaran	.191	1.45	68.26	16.41
33	Peacock	.188	1.47	305.43	-56.90
34	Miaplacidus	.187	1.47	138.16	-69.51
35	Nunki	.183	1.50	283.04	-26.36
36	Kaus Australis	.158	1.66	275.21	-34.41
37	Alpheratz	.148	1.73	1.45	28.81
38	Navi	.146	1.74	13.42	60.45
39	Alhena	.137	1.81	98.71	16.44
40	Mirfak	.116	1.99	50.19	49.69
41	Denebola	.112	2.03	176.62	14.85
42	Alphecca	.110	2.05	233.14	26.88
43	Rasalhague	.109	2.06	263.15	12.59
44	Merak	.096	2.20	164.71	56.65
45	Polaris	.096	2.20	27.23	89.03
46	Phecda	.090	2.27	177.80	53.97
47	Gienah	.089	2.28	183.31	-17.26
48	Zubeneschemali	.087	2.31	228.58	-9.20
49	Kochab	.063	2.65	222.71	74.36
50	Avior	.076	2.45	125.37	-59.35
51	Atria	.074	2.48	250.84	-68.94
52	Hamal	.072	2.51	31.09	23.23
53	Menkent	.071	2.52	210.93	-36.13
54	Diphda	.070	2.54	10.27	-18.26
55	Alphard	.068	2.57	141.28	-8.44
56	Al Suhail	.054	2.82	136.54	-43.23
57	Acamar	.054	2.82	44.09	-40.50
58	Deneb Algeid	.050	2.92	326.07	-16.36
59	Scheat	.047	2.97	345.34	27.81
60	Enif	.046	3.00	325.43	9.65

APPENDIX C
MCC STAR TRACKER DOWNLIST DATA

TITLE	CRT	EVENT LIGHT
ALIGN IMU 1	X	IMU 1 ALIGN
ALIGN IMU 2	X	IMU 2 ALIGN
ALIGN IMU 3	X	IMU 3 ALIGN
ALIGN ALL IMUs	X	ALL IMUs ALIGN
STAR ALIGN MODE	X	STAR ALIGN MODE
IMU/IMU MODE	X	IMU/IMU MODE
MATRIX ALIGN MODE	X	MATRIX ALIGN MD
-Y STAR PRESENT	X	Y ST PRES
-Z STAR PRESENT	X	Z ST PRES
-Z STAR ID	X	
-Y STAR MAG	X	
-Z STAR MAG	X	
-Y STR TRKR HORIZ POS	X	
-Z STR TRKR HORIZ POS	X	
-Y STR TRKR VERT POS	X	
-Z STR TRKR VERT POS	X	
-Y SHUTTER CLOSED	X	
-Z SHUTTER CLOSED	X	Y STR TRK SHTR CLSD
-Y STR TRKR STATUS	X	Z STR TRK SHTR CLSD
-Z STR TRKR STATUS	X	
-Z STR TRKR CMD WORD	X	
-Y STR TRKR CMD WORD	X	
-Y STR TRKR STATUS	X	
-Z STR TRKR STATUS	X	
STAR TABLE TRK ID 1	X	
STAR TABLE TRK ID 2	X	
STAR TABLE TRK ID 3	X	

APPENDIX C
MCC STAR TRACKER DOWNLIST DATA (Cont'd)

TITLE	CRT	EVENT LIGHT
STAR TABLE Δ MIN 1	X	
STAR TABLE Δ MIN 2	X	
STAR TABLE Δ MIN 3	X	
STAR ANG DIFF 1-2	X	
STAR ANG DIFF 2/3	X	
STAR ANG DIFF 1/3	X	
COAS SIGHT		COAS SITE
COAS CAL		COAS CAL
+X COAS BIAS	X	
-Z COAS BIAS	X	
+X COAS Δ BIAS	X	
-Z COAS Δ BIAS	X	
ALIGNMENT EXECUTE		ALIGN EXCC
COAS X LOCATION		COAS POS +X
COAS -Z LOCATION		COAS POS -Z
COAS ACCEPT		COAS ACPT
-Z S TRK PWR ON CMD		ST Z PWR ON
-Y S TRK PWR ON CMD		ST Y PWR ON
TABLE 1 ALIGN SEL	X	
TABLE 2 ALIGN SEL	X	
TABLE 3 ALIGN SEL	X	
TABLE 1/2 ANG ERR	X	
TABLE 1/3 ANG ERR	X	
TABLE 2/3 ANG ERR	X	
-Y ST TRK SHUT CMD	X	
-Z ST TRK SHUT CMD	X	

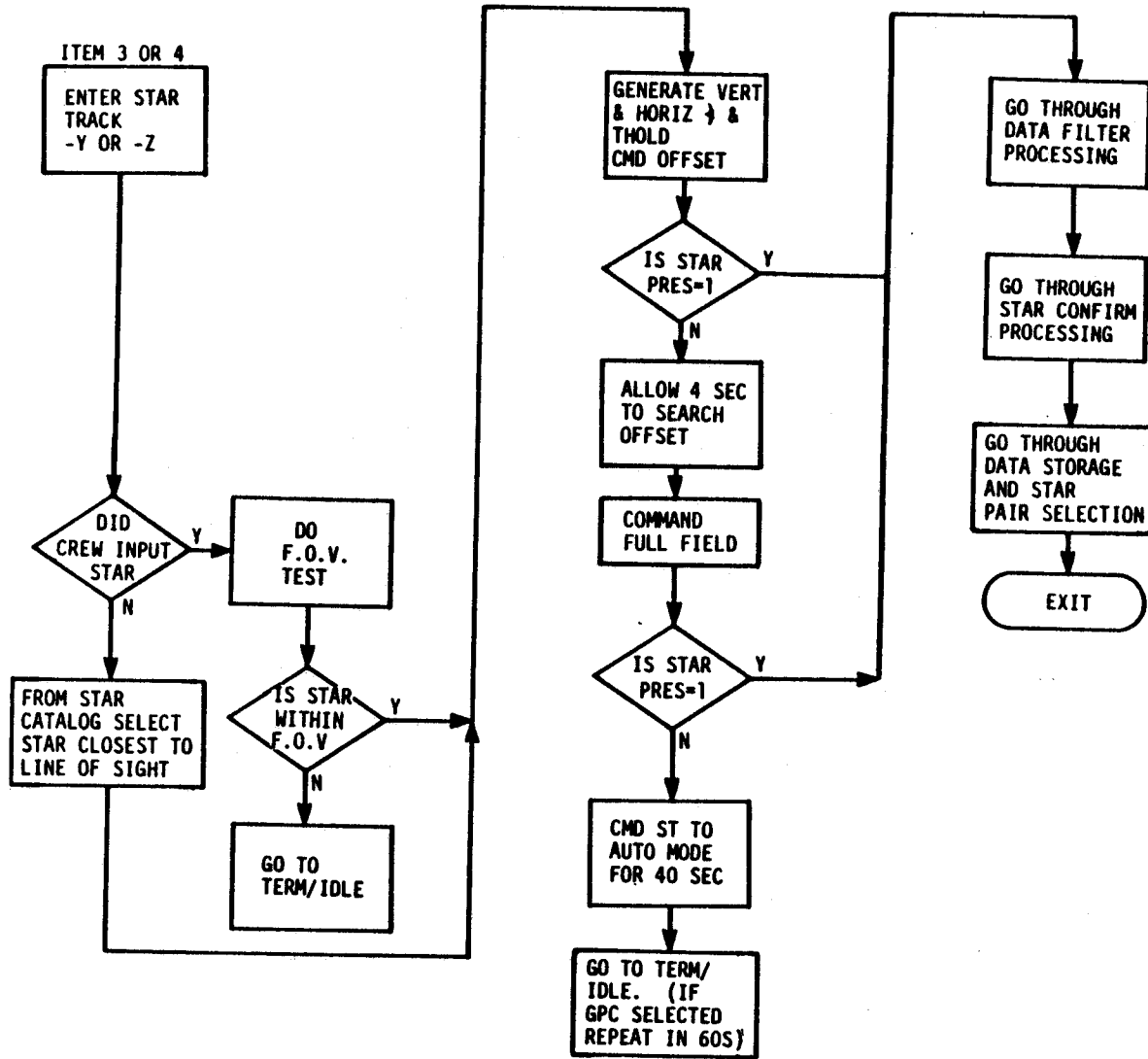


Figure D-1. Star Track Overview

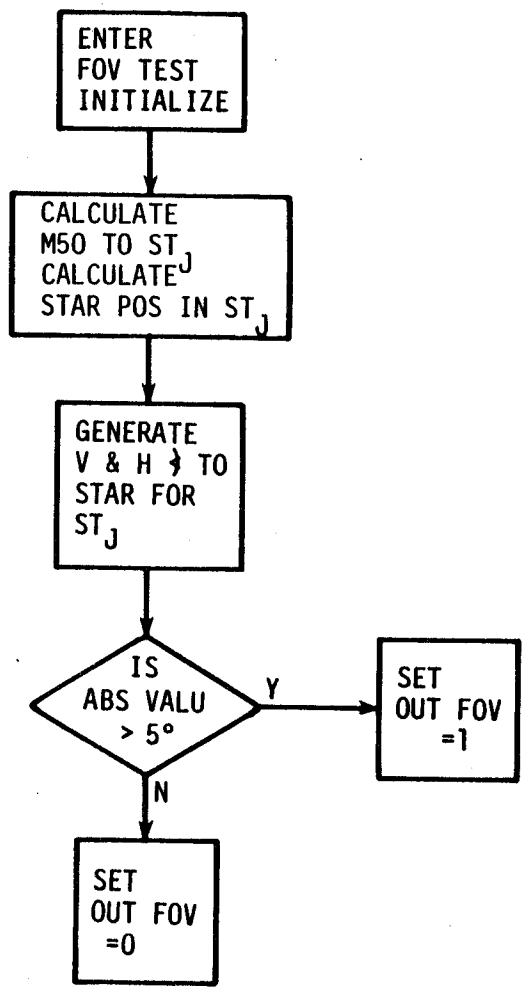


Figure D-2. Field of View

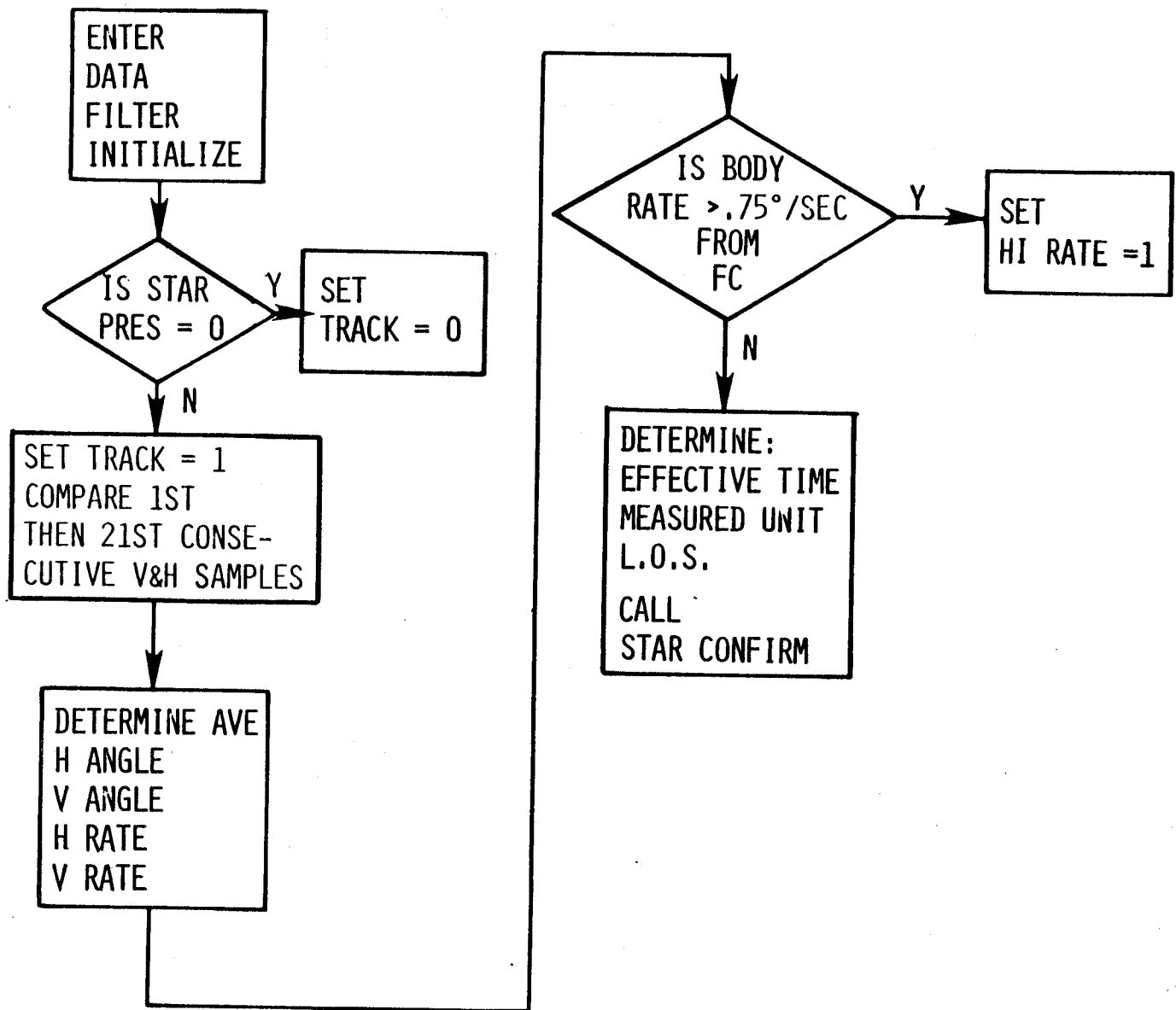
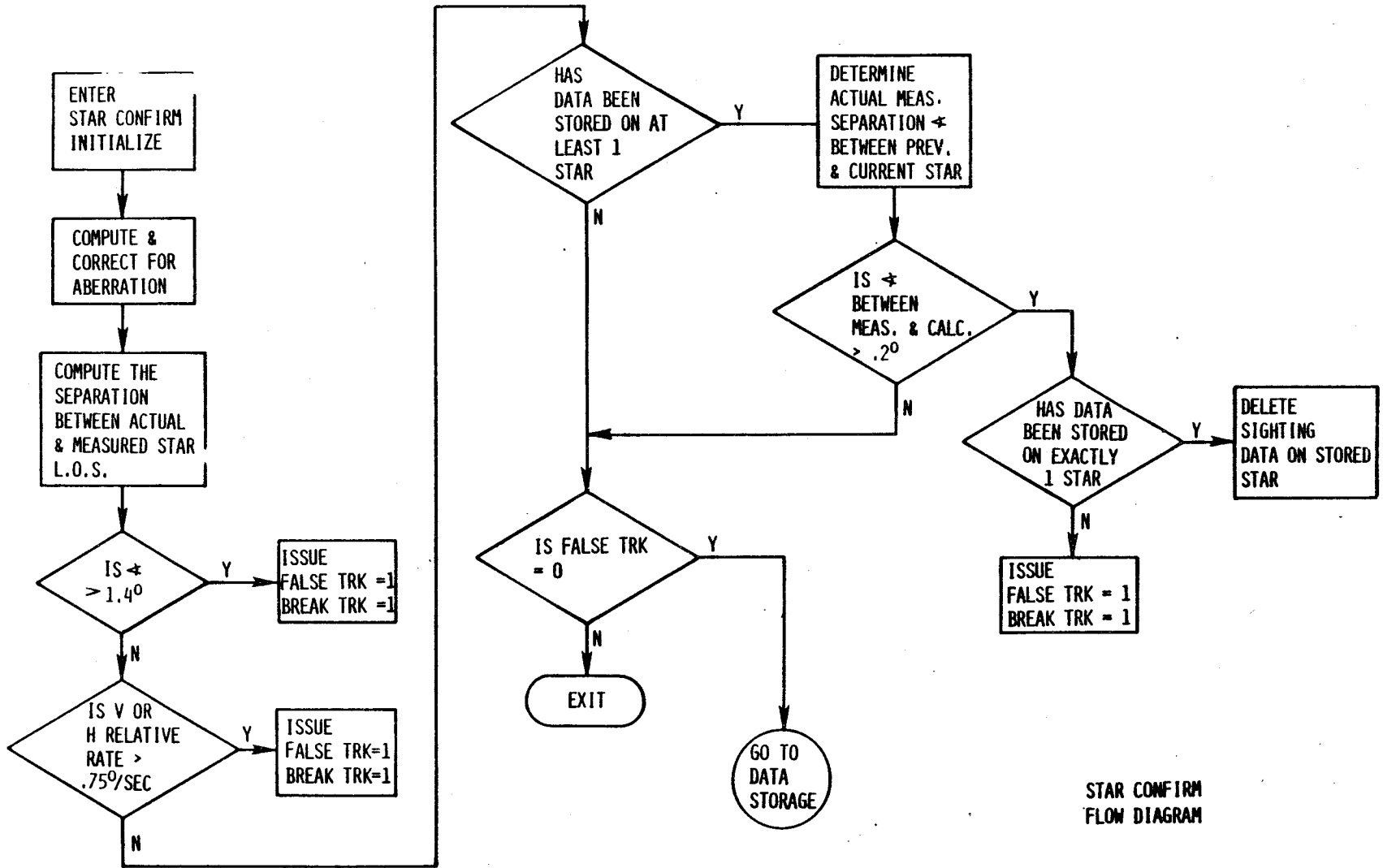


Figure D-3. Data Filter Diagram



STAR CONFIRM FLOW DIAGRAM

Figure D-4. Star Confirm Diagram

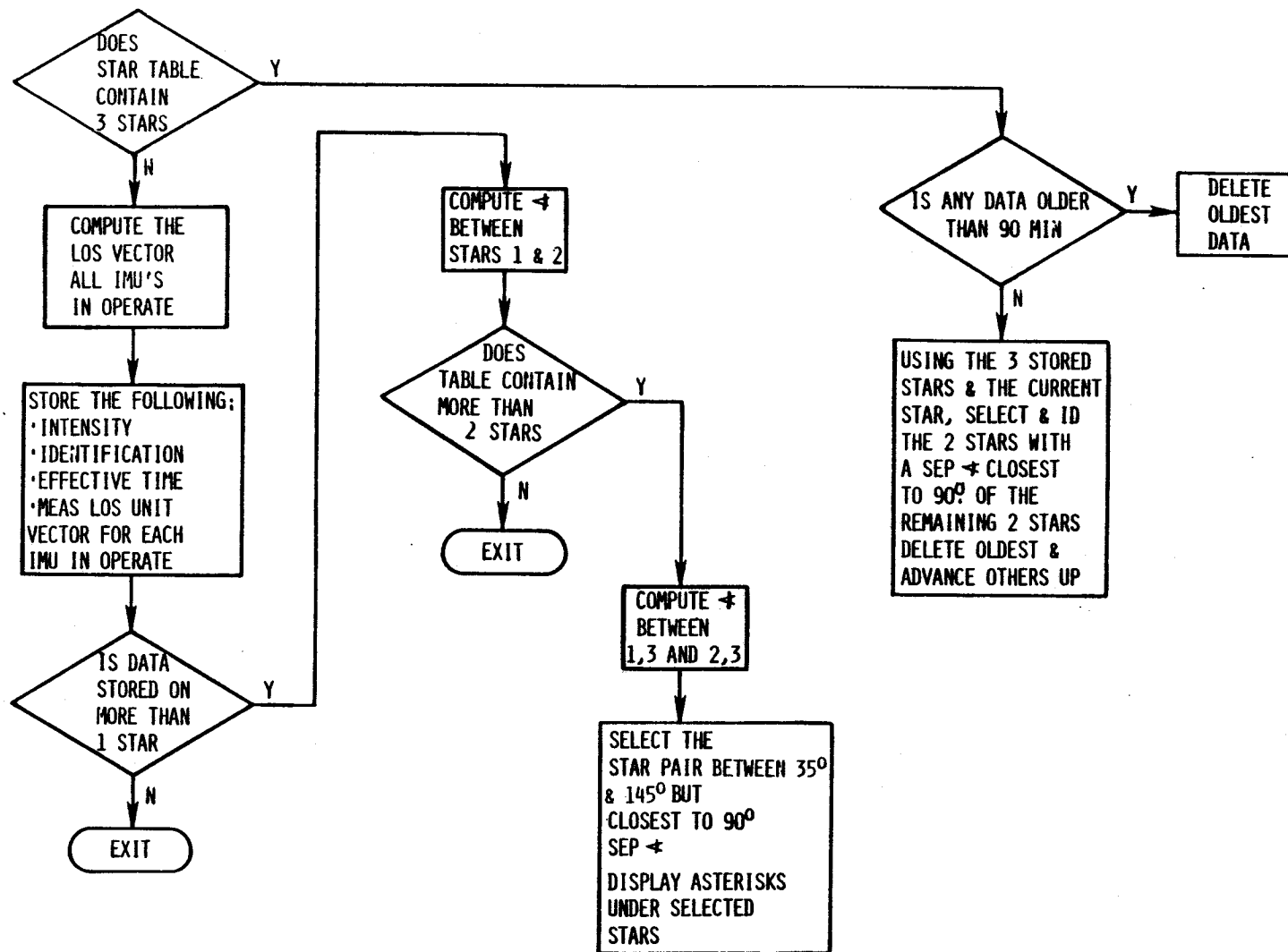


Figure D-5. Data Storage and Star Selection

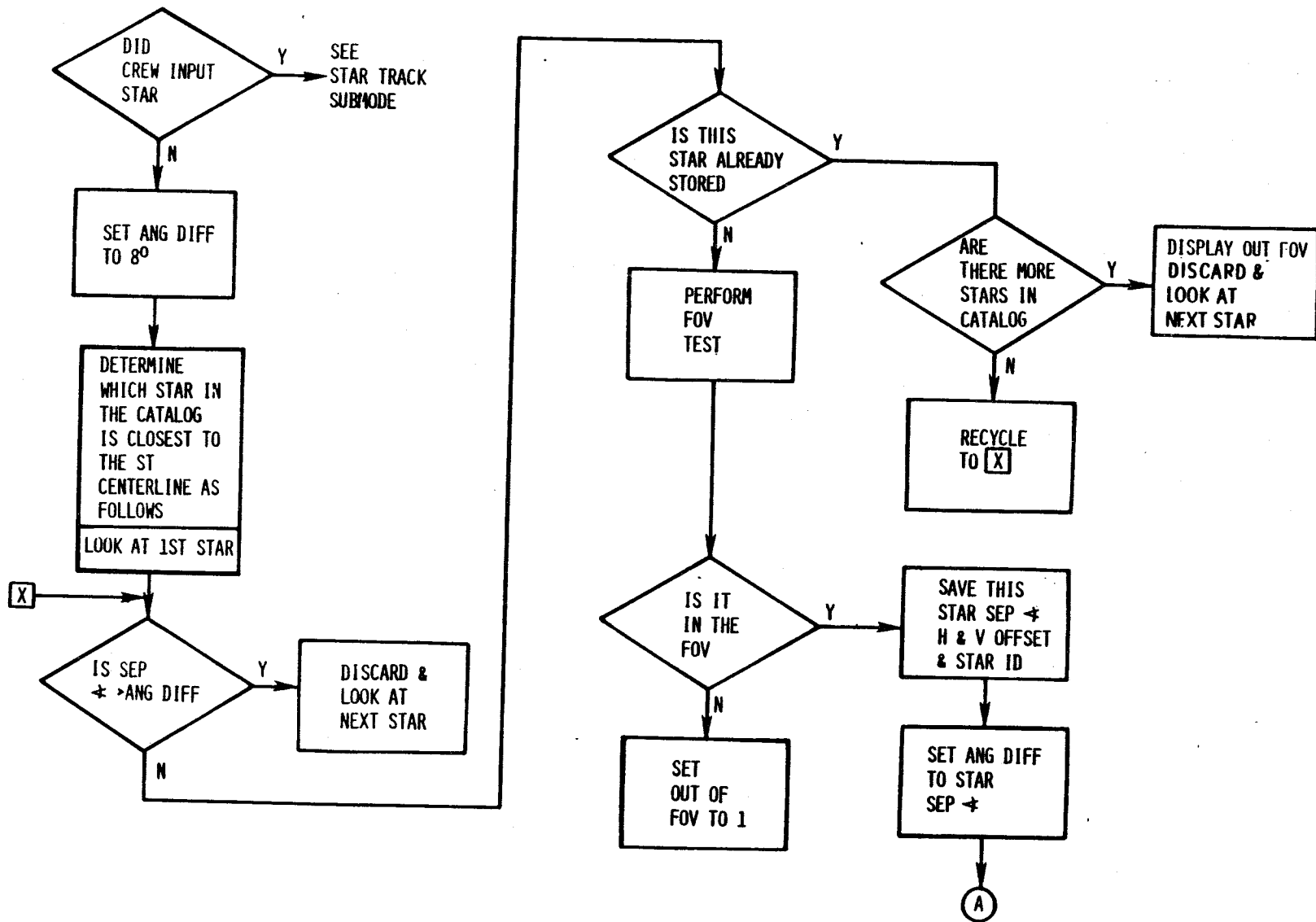


Figure D-6. GPC Star Selection, Part 1

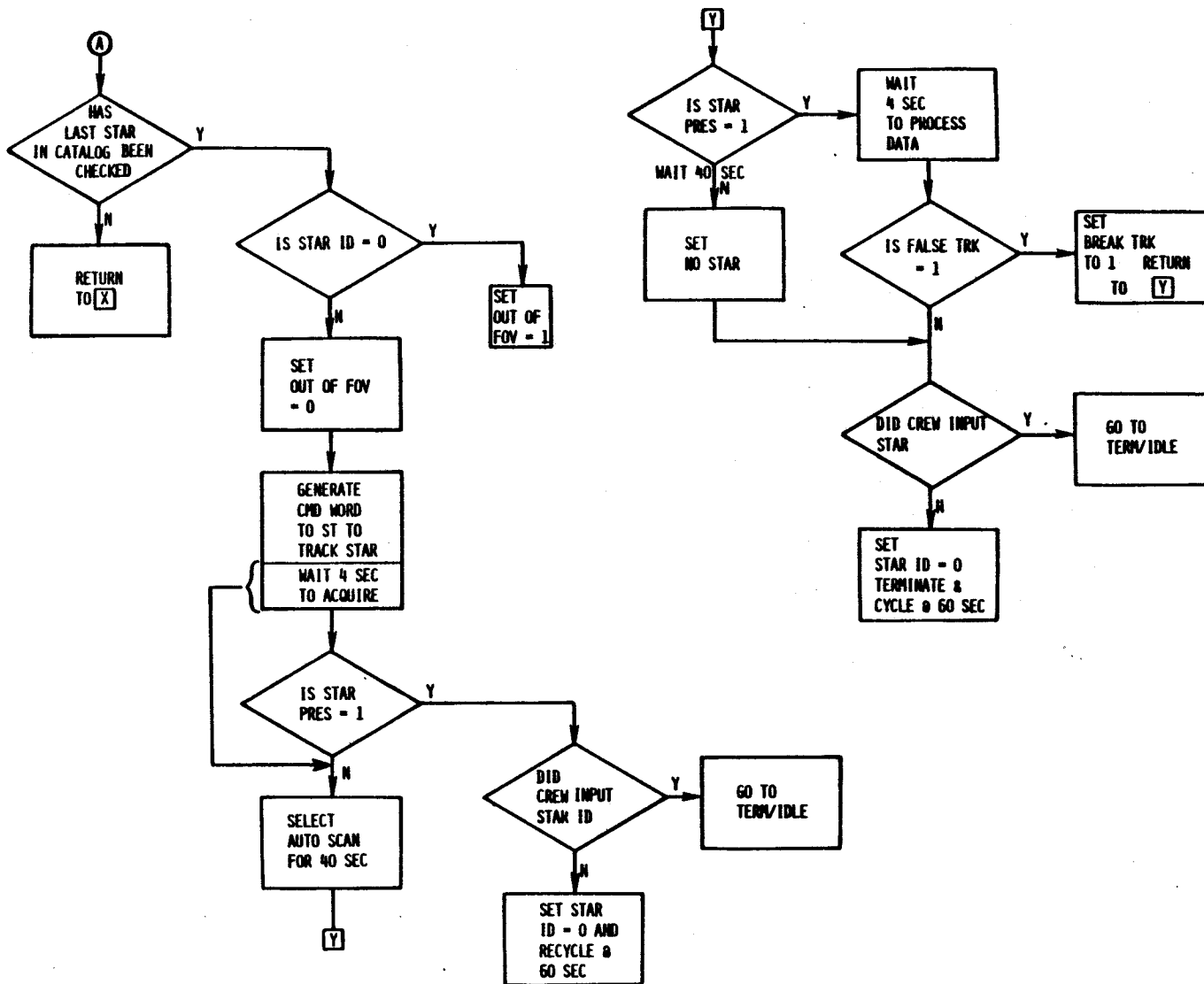


Figure D-7. GPC Star Selection, Part 2

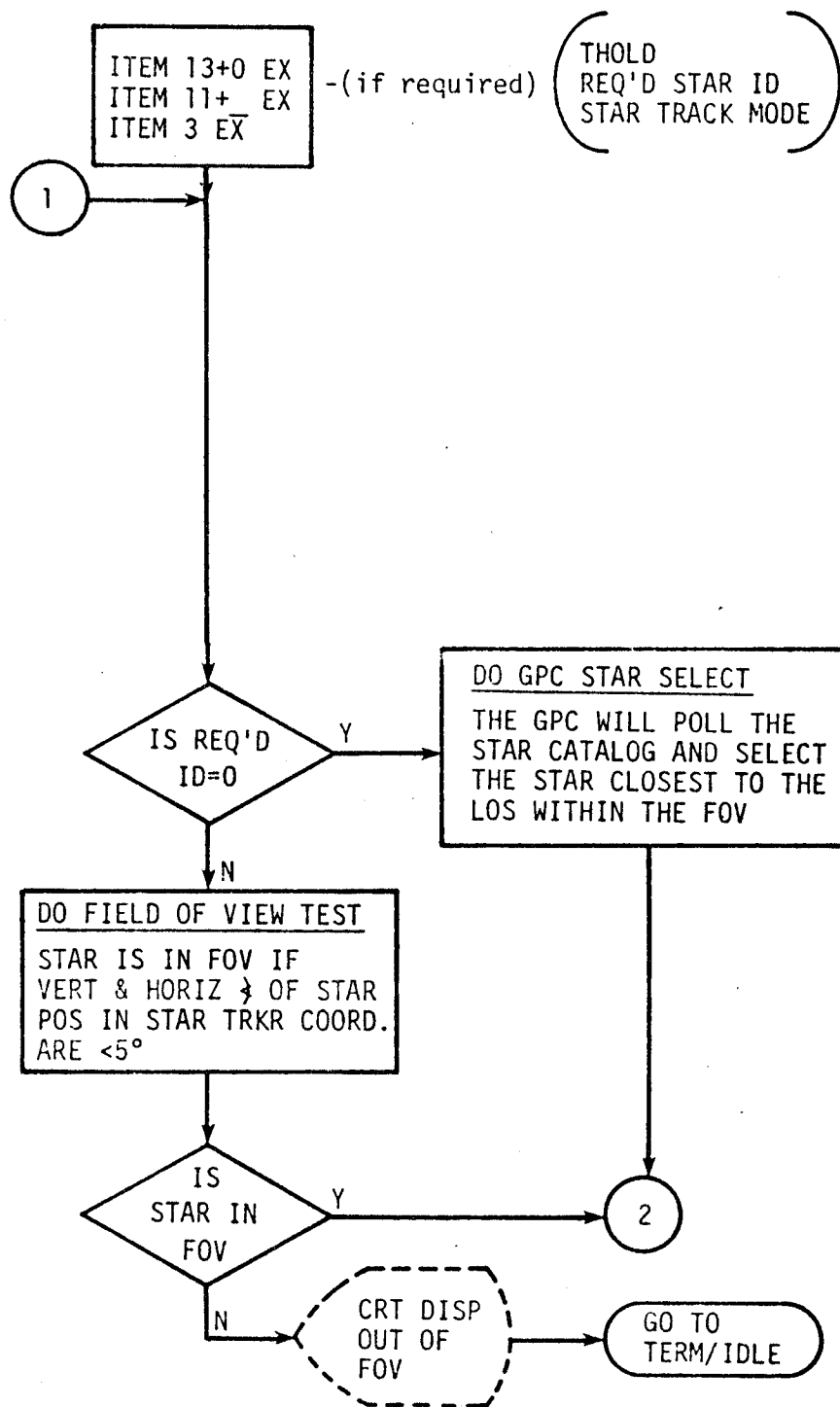


Figure D-8. Star Track Submode, Part 1

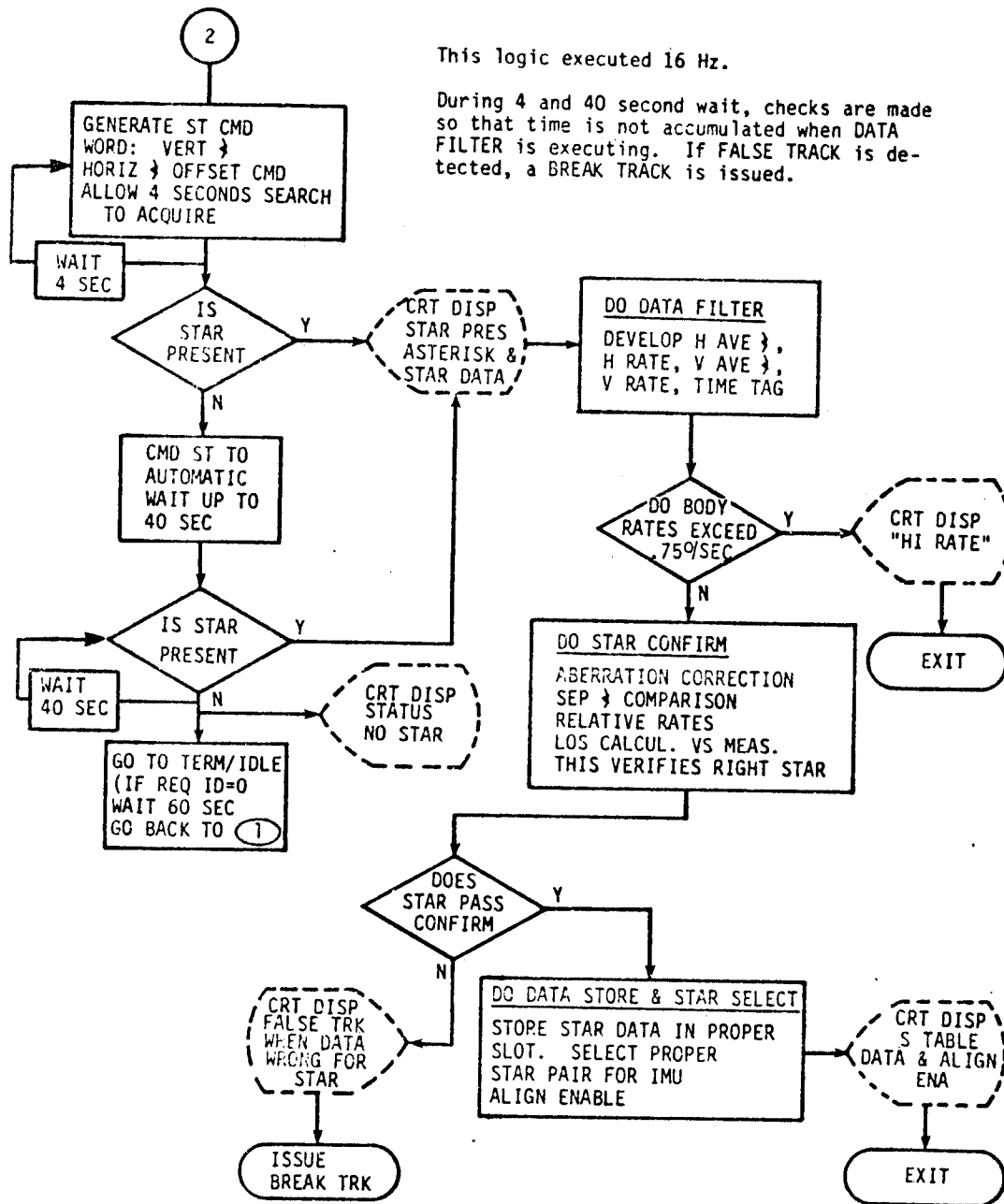


Figure D-9. Star Track Submode, Part 2

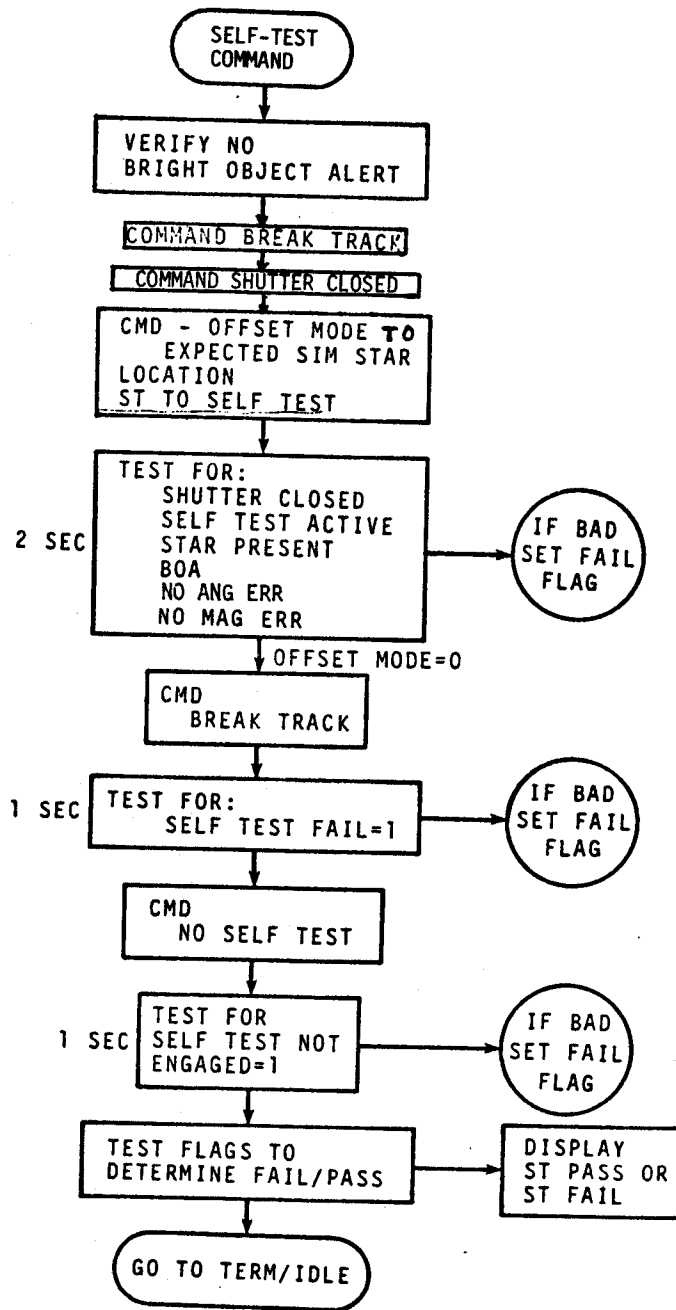


Figure D-10. ST Self Test

STAR TRACKER BLOCK DIAGRAM

Refer to figure E-1 for Star Tracker block diagram.

- (1) GPC commands Star Tracker to either full field or offset scan mode. Provides offset angles when offset scan mode is selected.
- (2) Scan circuits generate deflection currents applied to image dissector tube deflection coils.
- (3) Image dissector tube converts target image into a video signal.
- (4) Threshold detector filters video signal and compares signal amplitude against selected threshold level. Signals with amplitudes above threshold level are routed to sample and hold peak detector circuits.
- (5) Sample and hold peak detector provides control signals to scan circuits and measures intensity of target being tracked.
- (6) Horizontal and vertical sample circuits determine angular offset from boresight of target by measuring deflection current at point of maximum target intensity.
- (7) Interface circuits provide analog-to-digital conversion and data formatting of angular data and target intensity for routing to the GPC.

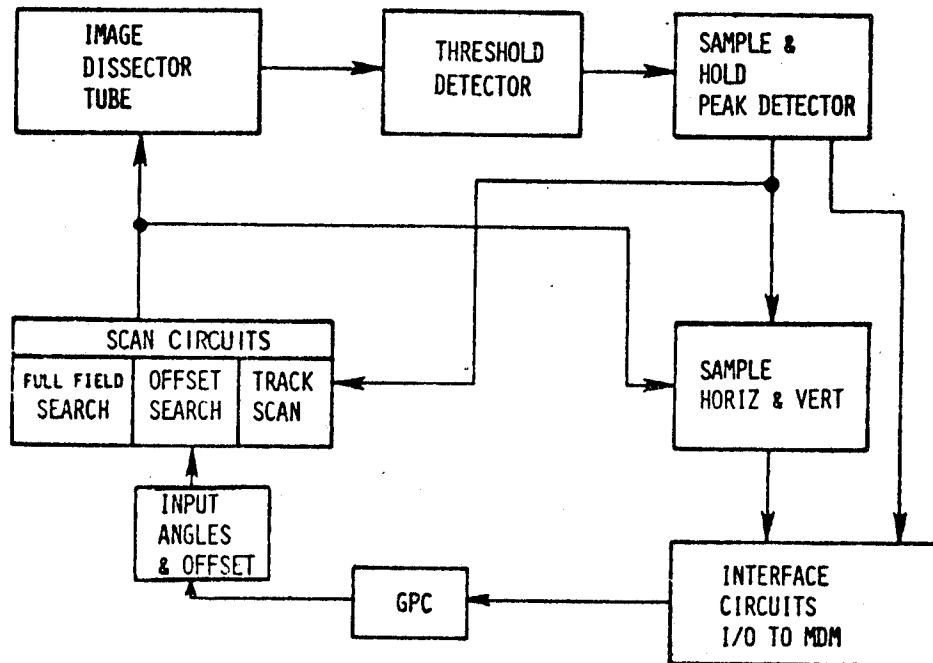


Figure E-1. Star Tracker Electronics Block Diagram

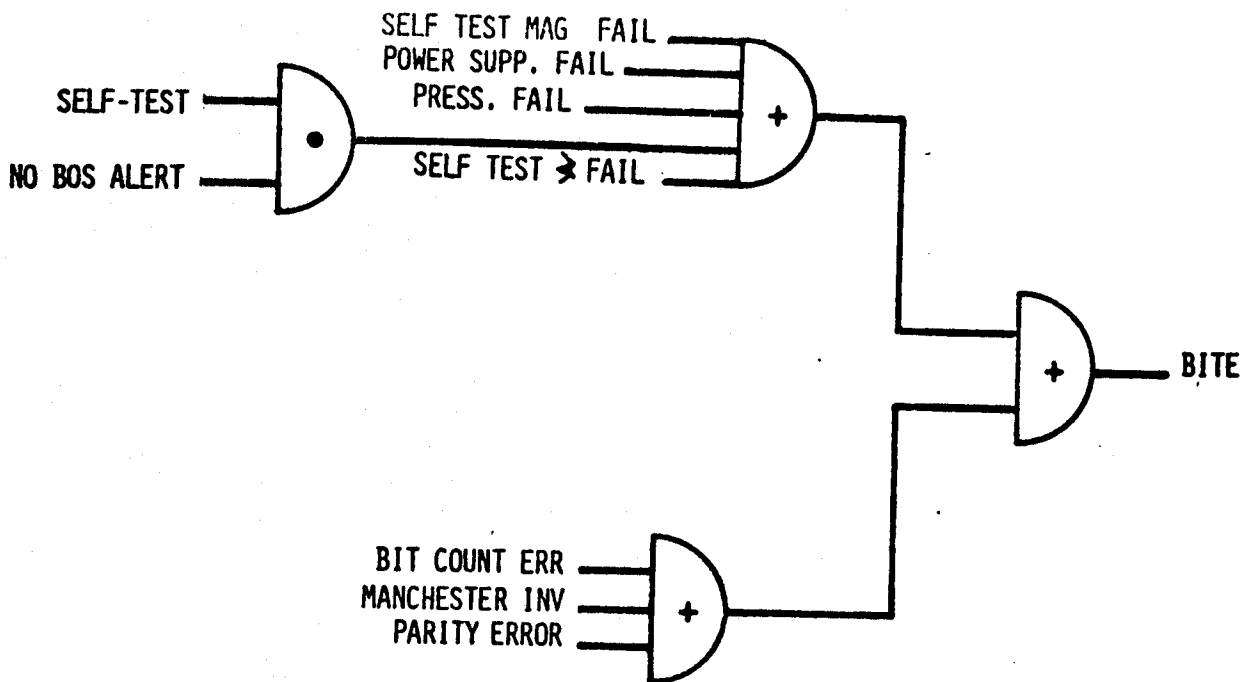


Figure E-2. BITE Logic

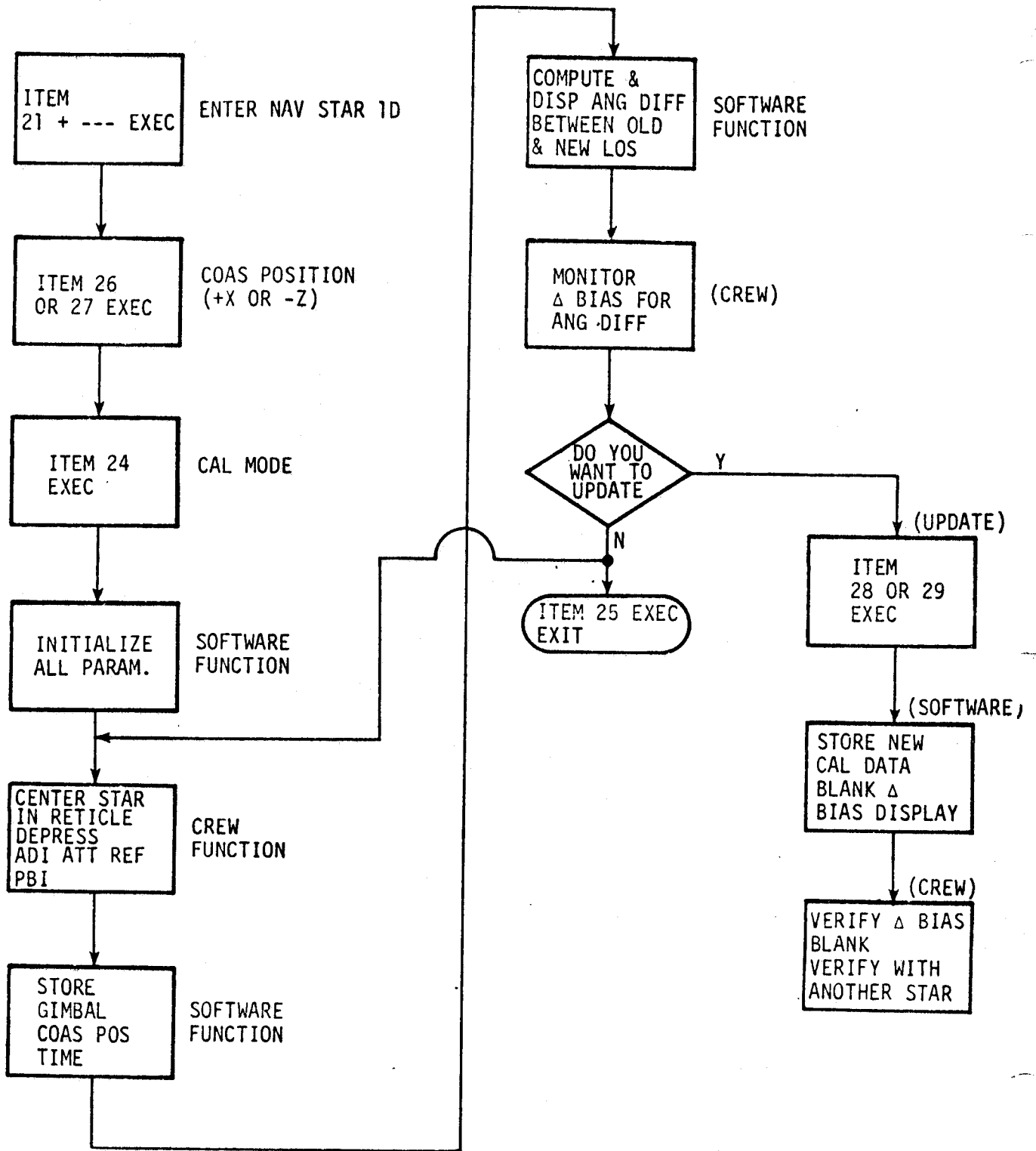


Figure F-1. COAS Calibration Flow Diagram

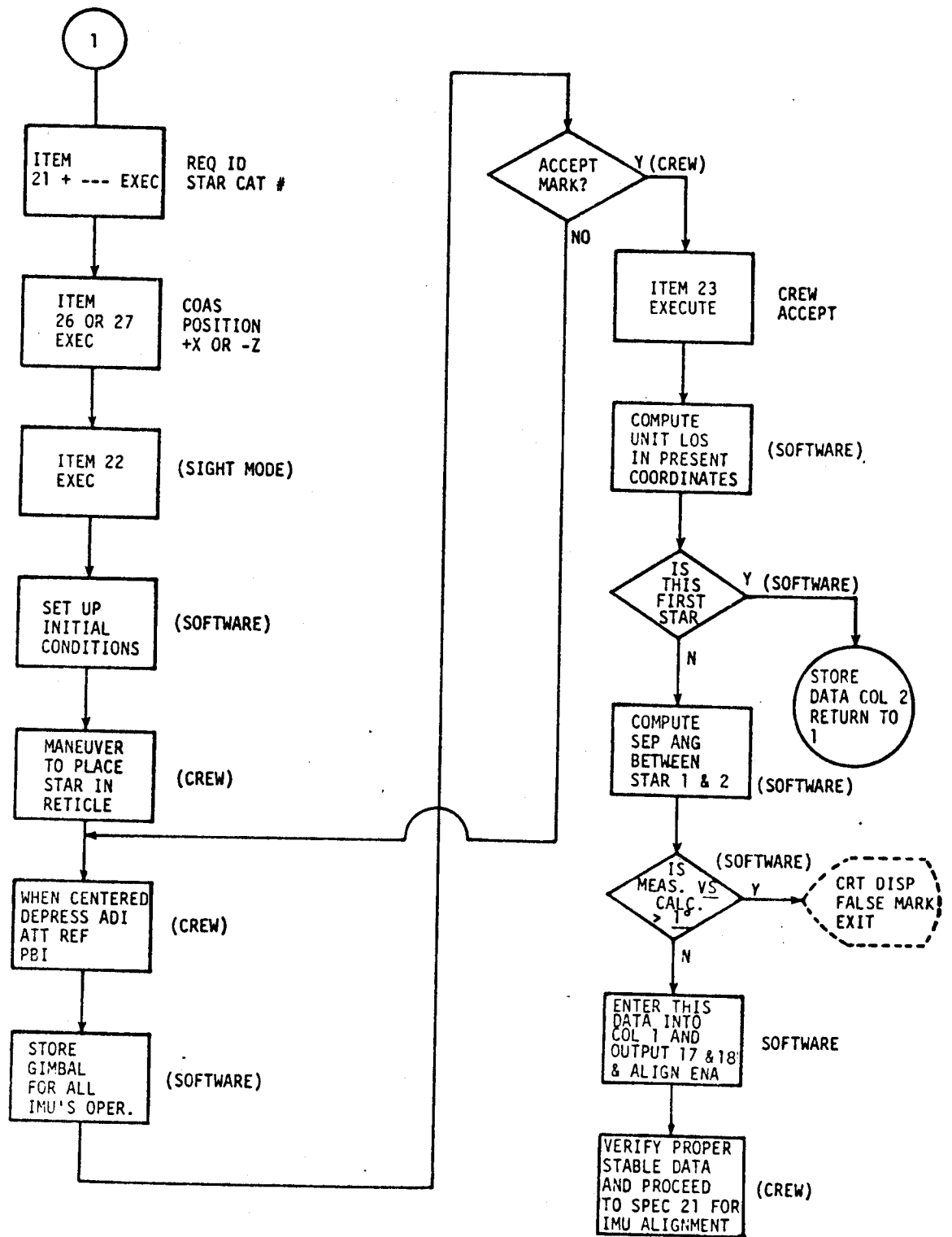


Figure F-2. COAS Sight Mode Flow Diagram

2011/021/
IMU

IMU ALIGN

1 273/17:20:59
000/00:00:00

STAT						ALIGN ENA		
TEMP	OK	OK	OK	IMU	1	10*	STAR ALIGN	13*
STBY	1	2	3		2	11*	14 IMU/IMU	
OPER	4*	5*	6*		3	12	MATRIX	15
DES	7	8	9					

EXEC 16
TERM 17

ACC

	1	2	3
X	-0.01	+0.00	-0.02
Y	+0.01	+0.00	+0.01
Z	-0.00	-0.03	+0.02

ANG

	1	1	1
X	155.75	155.65	155.50
Y	343.35	343.33	343.31
Z	256.03	256.05	255.94
ΔX	- 0.07	- 0.21	+ 0.03
ΔY	- 0.20	+ 0.06	+ 0.01
ΔZ	- 0.06	- 0.06	+ 0.05

NAV ΔV THRESH
18 ___3840

MM READ 19

2011/022/

S TRK/COAS CNTL

1 273/17:20:59
000/00:00:00

S TRK CNTL	-Y	-Z	S TABLE	1	2	3
SELF-TEST	1	2	TRK ID	51	46	0
STAR TRK	3*	4	Δ MIN	14	30	0
TGT TRK	5	6	ANG DIF	90.2	0.0	0.0
BREAK TRK	7	8	ERR	0.01	0.00	0.00
TERM/IDLE	9	10*	SEL	17*	18*	19

S TABLE CLR 20

S TRK	-Y	-Z	COAS	
RECD ID	11	12	REQD ID	21
TRK ID	0	0	ΔDEG X	11
S PRES	*		Y	+0.0
ΔANG	+0.07	-0.00	SIGHT MODE	-0.0
THOLD	13	14	ACCEPT	22
SHUTTER	OP	CL	CAL MODE	23
MAN OP	15	16	DES	24
STATUS	OUT	FOV	POS	25*
			+X	26
			-Z	27*
			ΔBIAS	0.00
			UPDATE	0.00
				28
				29

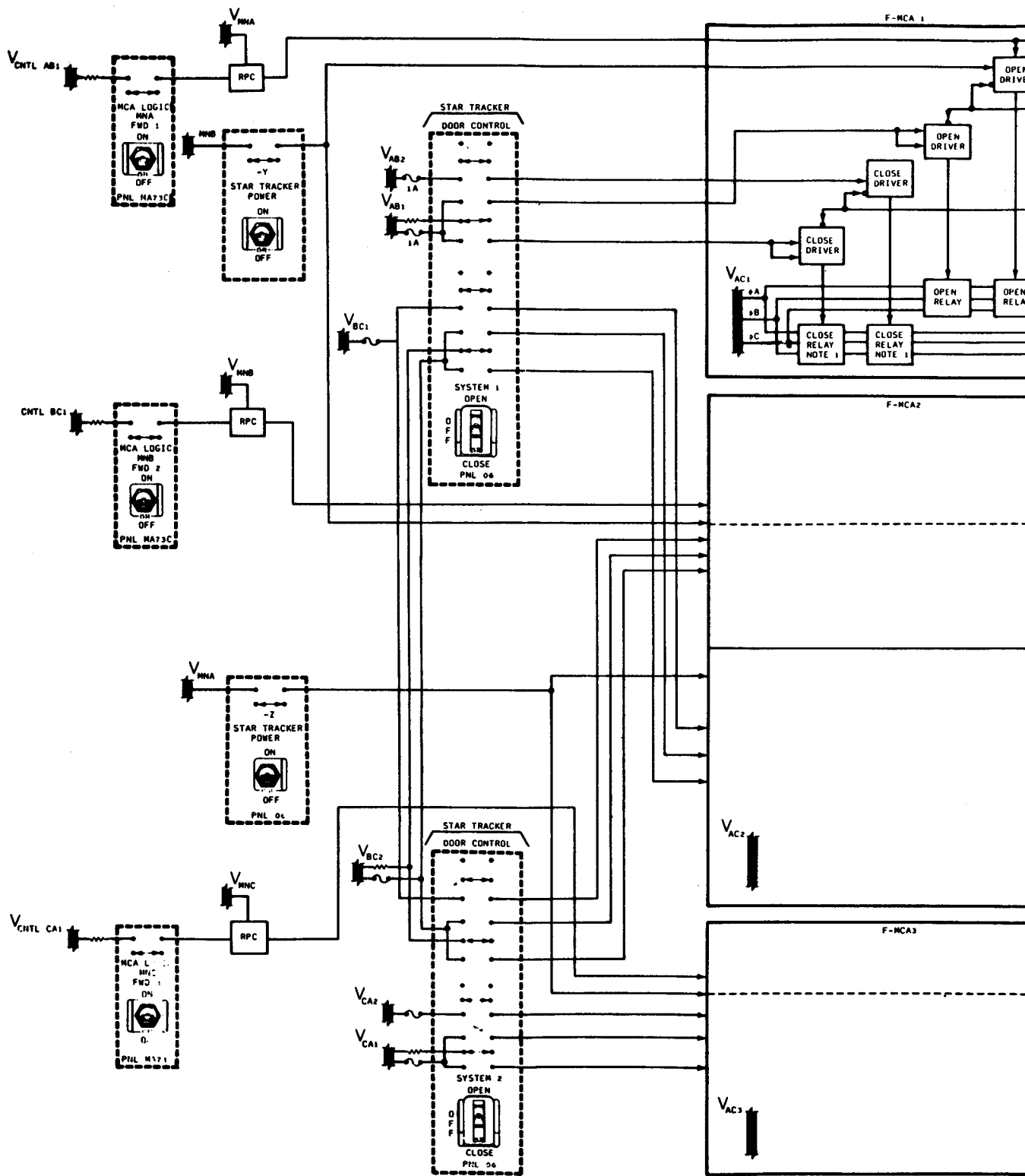
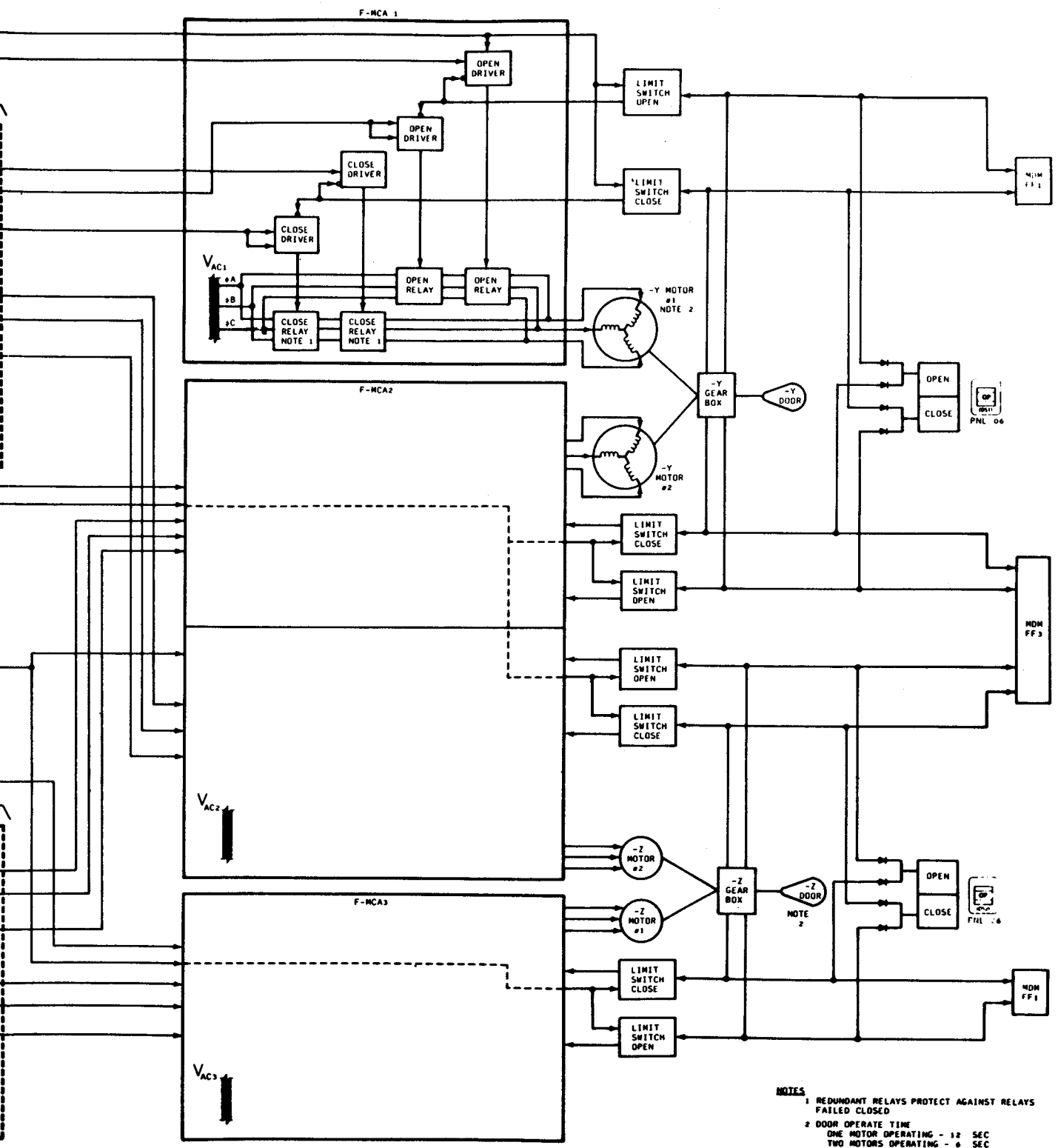


Figure 3-5. Star Tracker Door Mot



NOTES
 1 REDUNDANT RELAYS PROTECT AGAINST RELAYS FAILED CLOSED
 2 DOOR OPERATE TIME
 ONE MOTOR OPERATING - 12 SEC
 TWO MOTORS OPERATING - 6 SEC

Figure 3-5. Star Tracker Door Motor Logic

7.5 ATT REF PUSHBUTTON

In order to establish a line of sight vector to a COAS-sighted star, the crewmember needs some method of informing the GPC software when he has a star correctly sighted. Located on Panels A6 and F6 (see figure 7-14 and 7-15) is an attitude reference pushbutton. One of its functions is to send a discrete to the GPC telling it to snapshot a LOS vector at the current vehicle attitude. These buttons are the ATT REF pushbuttons. A COAS mode must be selected on SPEC 22 for the ATT REF pushbutton to have this function. Otherwise, its function is ADI reference definition.

Each ATT REF pushbutton is within easy reach of a crewmember sighting through a COAS in the +X or -Z position. Each is positioned such that it can be depressed with the left hand while the crewmember sights through the COAS as he maneuvers the Shuttle using the RHC with the right hand. The ATT REF pushbutton on Panel F8 can also be used through coordination with another crewmember. While in a COAS mode, the ATT REF pushbutton does not control the ADI.

The action of sighting on a star and depressing the ATT REF pushbutton is often referred to as "marking on a star".

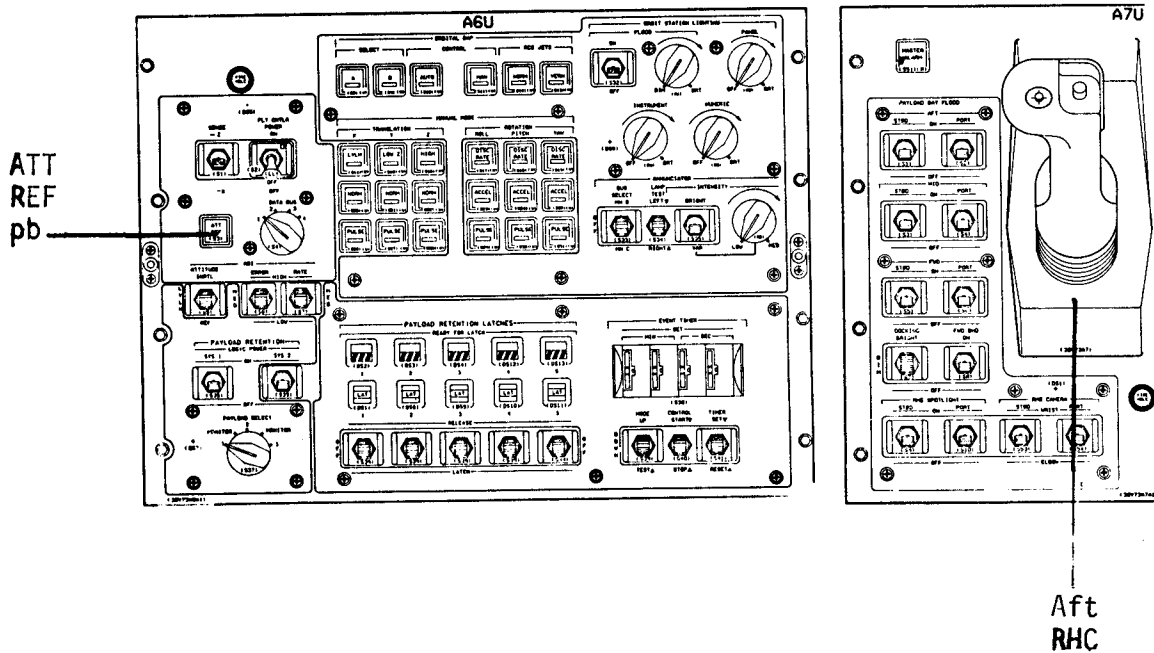


Figure 7-14. Aft ATT REF Button on Panel A6

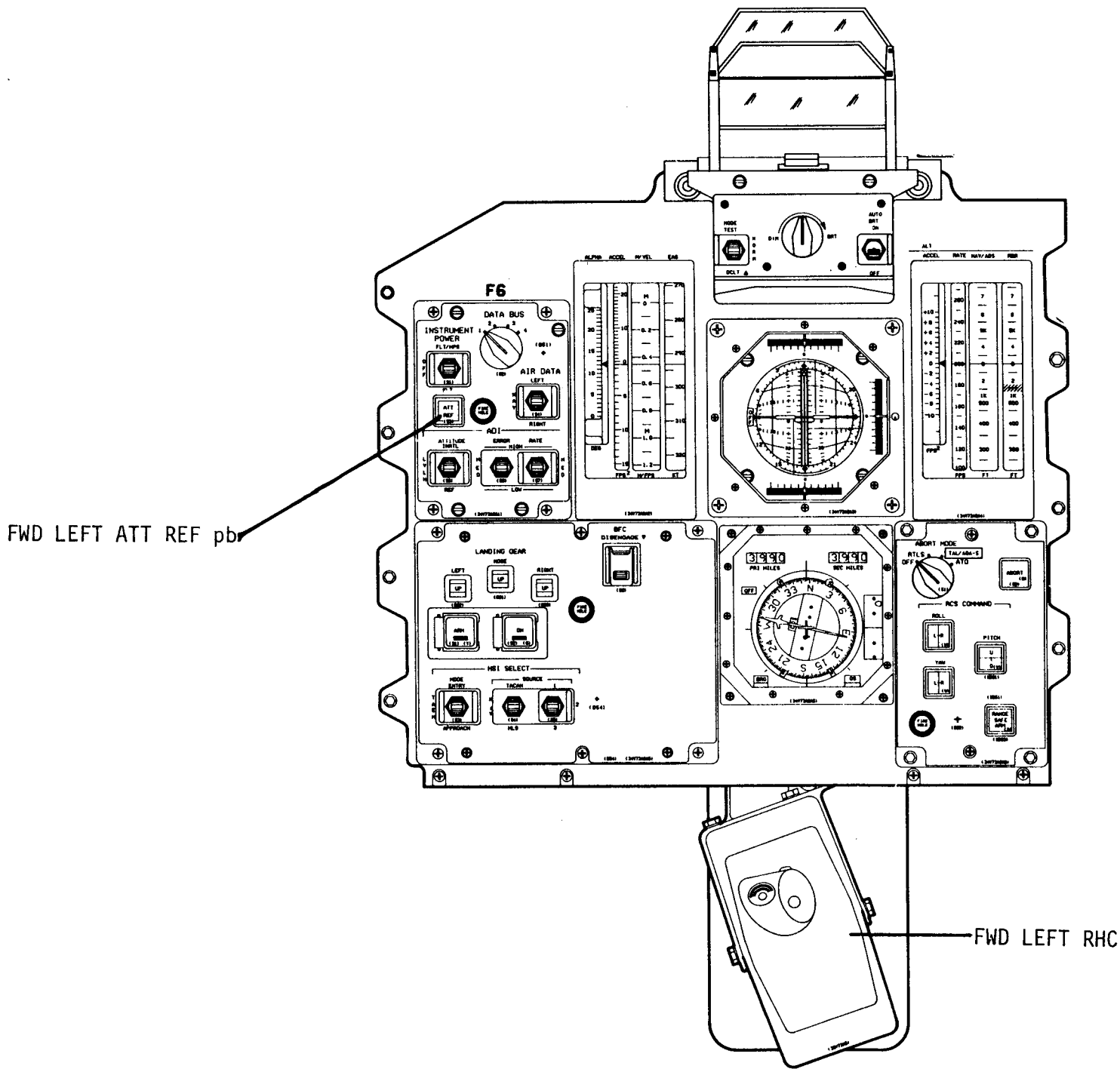
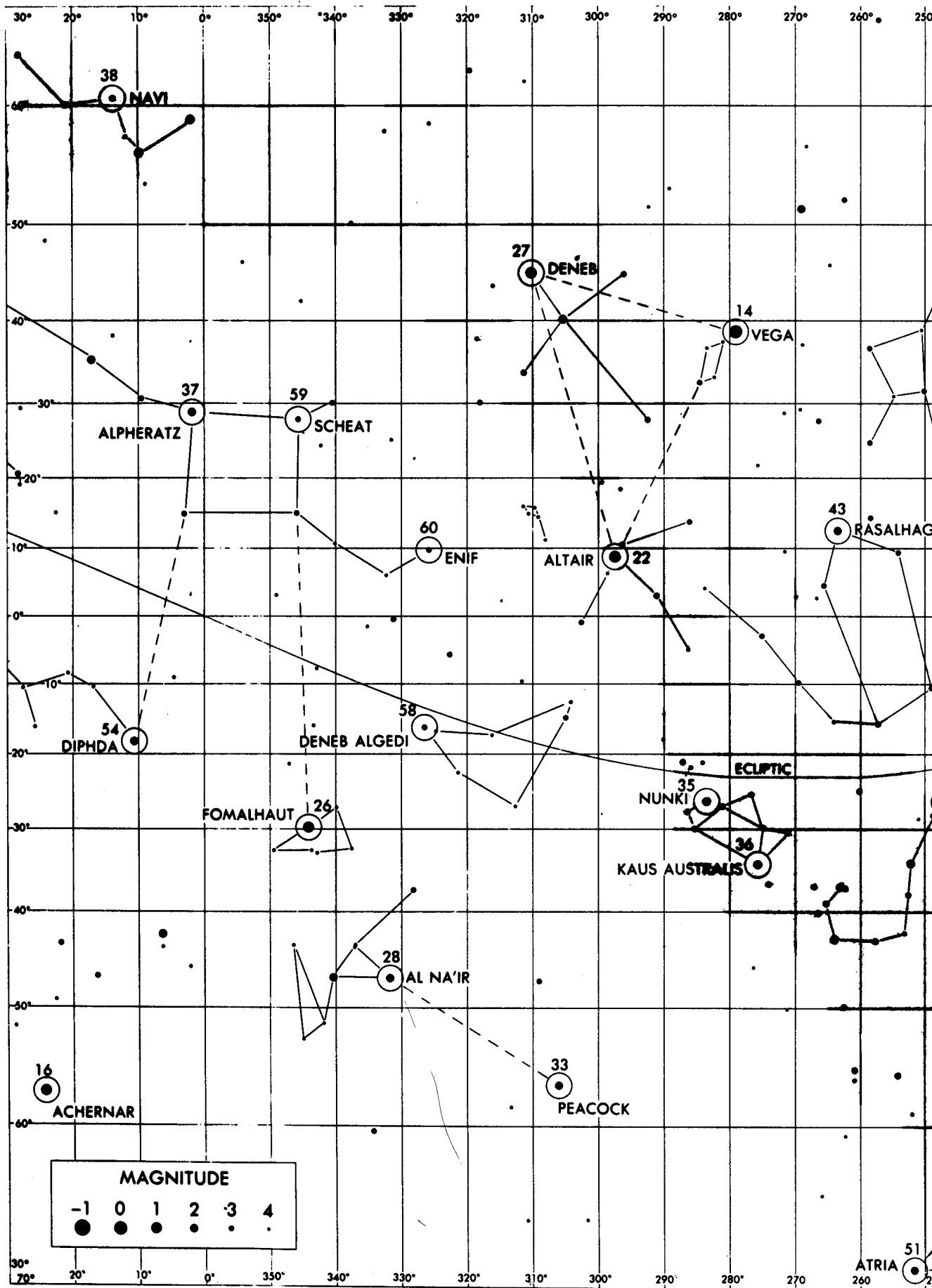
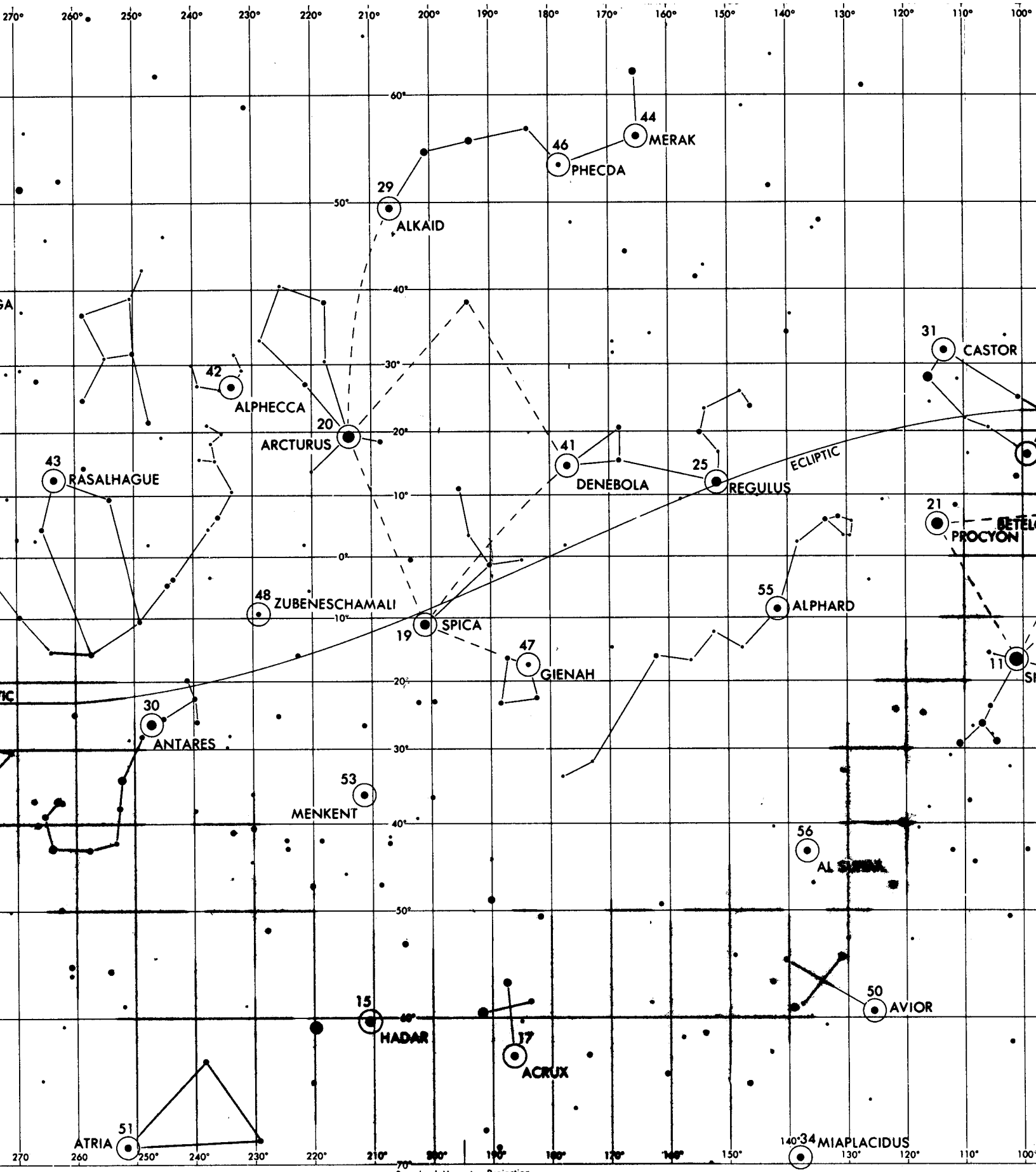


Figure 7-15. Forward ATT REF Button on Panel F6

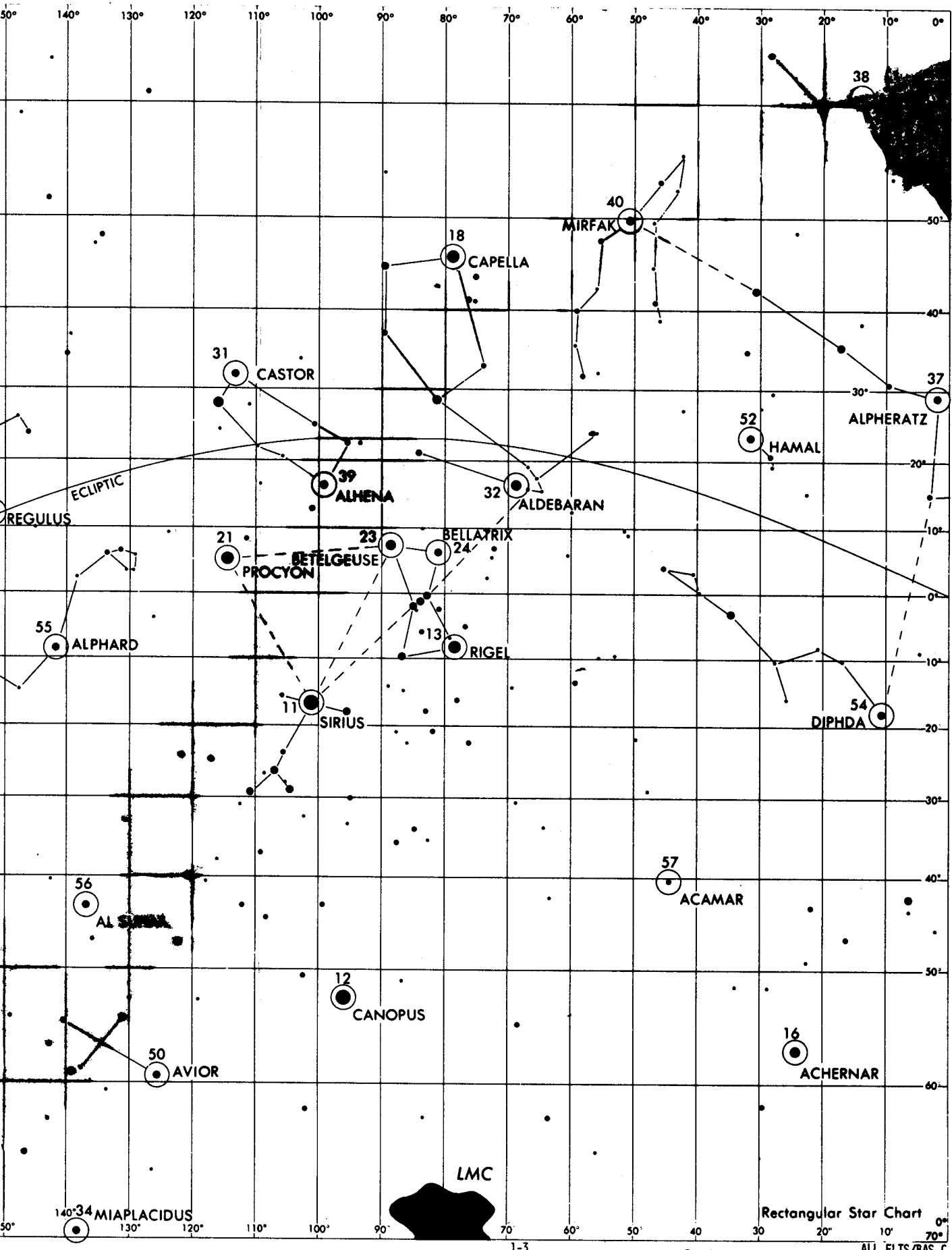


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STAR CHART



65A