

ELECTRONICS DEPARTMENT  
SAN JOSE CITY COLLEGE

# Attitude and Pointing Flight Procedures Handbook

Crew Training and Procedures Division  
Flight Activities Branch

Final  
January 1982



National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
Houston, Texas

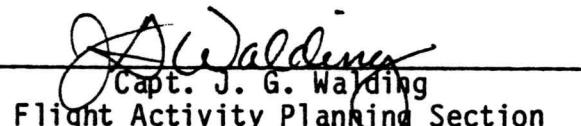
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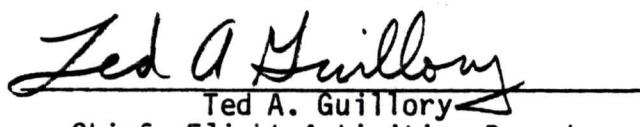
ATTITUDE AND POINTING FLIGHT PROCEDURES HANDBOOK

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## FLIGHT PROCEDURES HANDBOOK PUBLICATIONS

The following is a list of the Flight Procedures Handbooks of which this document is a part. These handbooks document integrated and/or flight procedural sequences covering major STS crew activity plan phases.

TITLE	JSC/FOD DOCUMENT NO.
o ASCENT/ABORTS	10559/LA-B-11180-4A
o ENTRY	11542/LA-B-11180-4B
o RENDEZVOUS/ORB NAV	10589/LA-B-11180-4C
o ORB TRANSLATION/IMU ALIGN	10588/LA-B-11180-4D
o FORMATION FLYING, DOCKING, FLY-AROUND, STANDOFF	10566/LA-B-11180-4E
o PAYLOAD DEPLOYMENT/RETRIEVAL	/LA-B-11180-4F
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o ATTITUDE & POINTING	10511/LA-B-11180-4G
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o STS WORKDAY	10541/LA-B-11180-4H
o SPACELAB ACTIVATION	10545/LA-B-11180-4J
o SPACELAB DEACTIVATION	/LA-B-11180-4K
o OFT PAYLOADS PROCEDURES	10590/LA-B-11180-4L
o CREW DATA MANAGEMENT	12985/LA-B-11180-4M

## FOREWORD

The Attitude and Pointing Flight Procedures Handbook is intended to be a generic document. Because of the nature of the material and the requirements for specific flights, some information will not agree. The purpose is to show what and how the information, display, or hardware is used (not necessarily to show specific constraints that can change from flight to flight). For future flights, updates will be made to reflect software/hardware changes that occur.

The author wishes to express appreciation to R. Hieb, M. Griffin, R. Rolwes, E. Tippert, and M. Brown for their contributions in the preparation of this document.

Comments and suggestions concerning this document are welcomed. Contact Capt. J. G. Walding, Flight Activity Planning Section (CH4), NASA JSC, Houston, Texas 77058, or telephone (713) 483-2201.

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## SECTION 1 DEFINITIONS/CONCEPTS

### 1.1 BODY VECTOR

A body vector is a unit vector that is defined in the Orbiter body axis coordinate system. It is defined as a pitch/yaw sequence in this system.

### 1.2 TARGET VECTOR

A target vector is a unit vector that is defined in the M50 inertial coordinate frame (sec. 1.6).

### 1.3 POINTING

Pointing means that a body vector is pointed in a desired direction. Pointing is accomplished by orienting the Orbiter to a specific attitude such that the body vector or line-of-sight (LOS) points at the target.

### 1.4 $\beta$ ANGLE

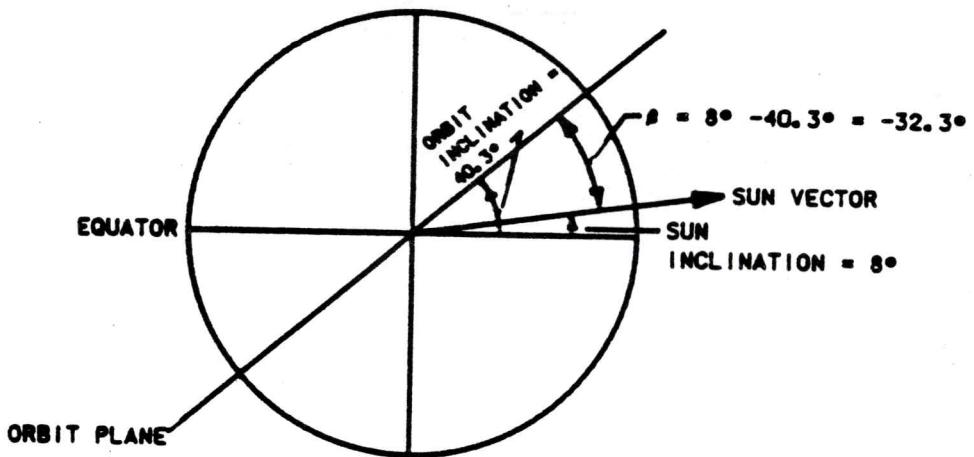
$\beta$  angle is the angle between the orbit plane and the Sun vector (fig. 1-1). Mathematically,  $\beta$  angle is defined as

$$\beta = \sin^{-1} (R \times V) \cdot \text{Sun vector}$$

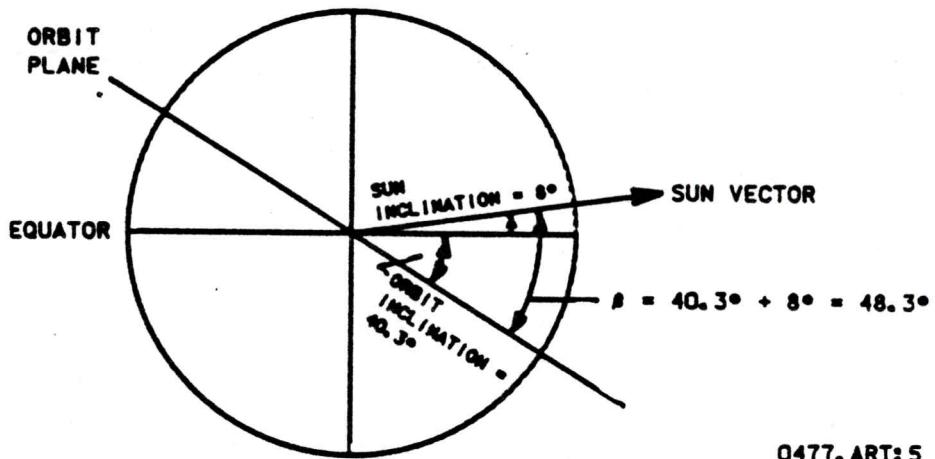
### 1.5 BODY AXES COORDINATE SYSTEM

The body axes have the center of mass of the Orbiter as the origin. The coordinate system (fig. 1-2) is then defined such that

- a. X body (BY) axis is parallel to the Orbiter structural body axis. The positive X-axis is from the c.g. of the Orbiter through the nose of the vehicle. The negative X-axis is from the c.g. through the aft end of the vehicle.
- b. Z body axis is parallel to the Orbiter plane of symmetry and is perpendicular to the X axis. The Z body axis is positive down with respect to the Orbiter fuselage.
- c. Y body axis completes the right-hand orthogonal system.

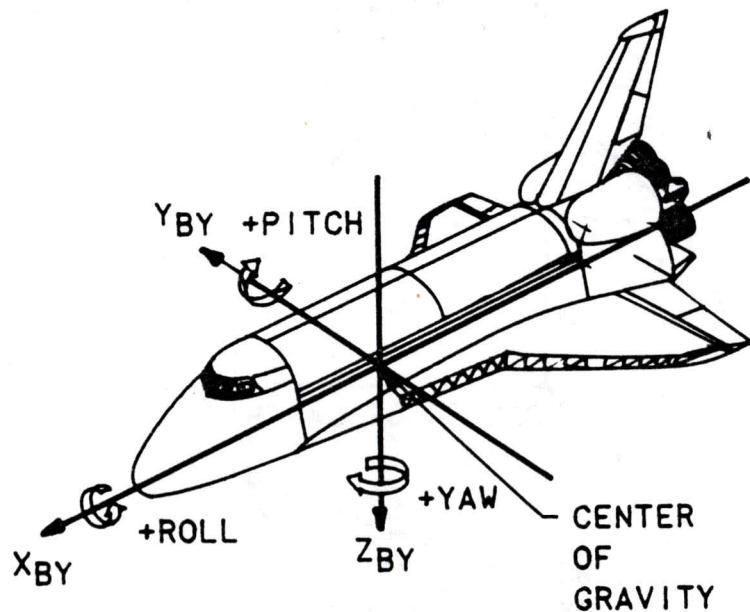


(a) Maximum negative  $\beta$  angle condition for a given orbit plane (ascending/descending nodes perpendicular to the Sun vector).



(b) Maximum positive  $\beta$  angle condition (nodes perpendicular to the Sun vector for a given orbit plane).

Figure 1-1.-  $\beta$  angle.



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Figure 1-2.- Body axes coordinate system. Maneuver sequence for the Orbiter is pitch, yaw, roll.

### 1.6 M50 INERTIAL REFERENCE FRAME

This coordinate system has its origin at the center of the Earth and its axes are fixed relative to the stars. The inertial Earth center coordinate frame (fig.1-3) has its axes defined as follows:

- +Z axes is directed towards the Earth's North Pole at epoch (the Earth's mean rotational pole at epoch).
- +X axis is pointed at the first point of Aries (the Earth's mean vernal equinox at epoch).
- +Y axis completes the right-hand system.

Because the epoch of this system is the beginning of the Besselian year, 1950, and the +X axis points toward the first point of Aries, this reference frame is often referred to as the Mean of 50 (M50) frame.

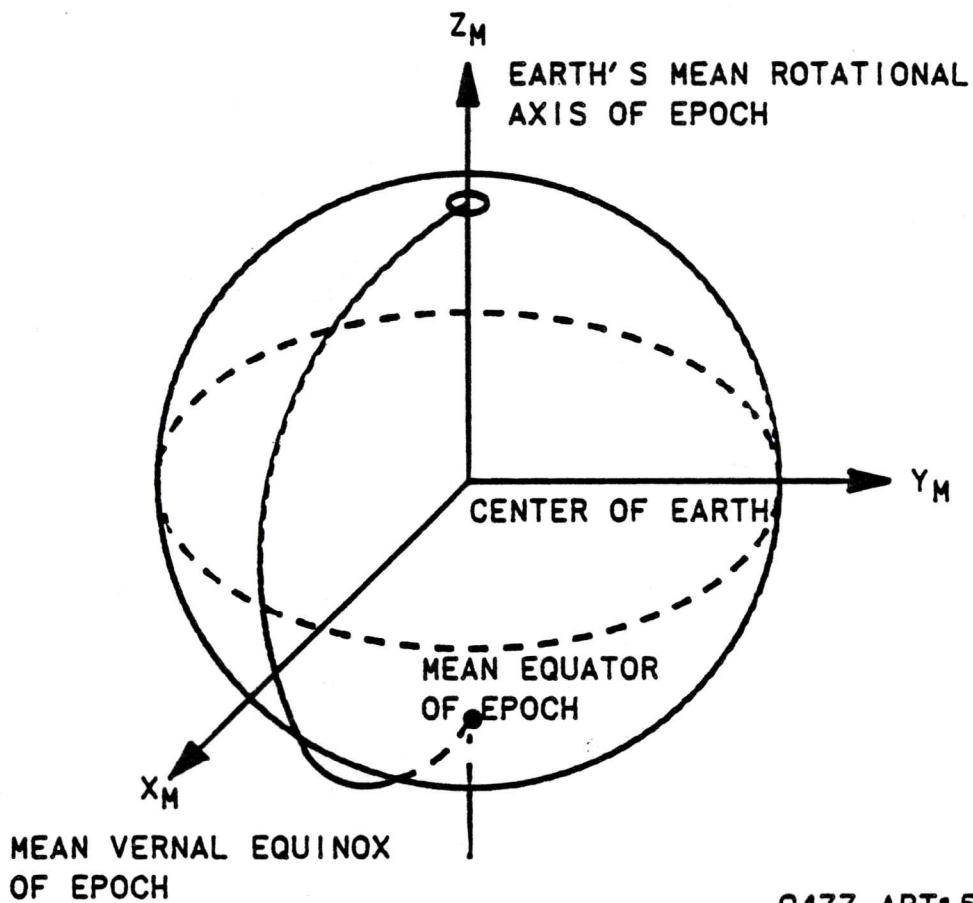
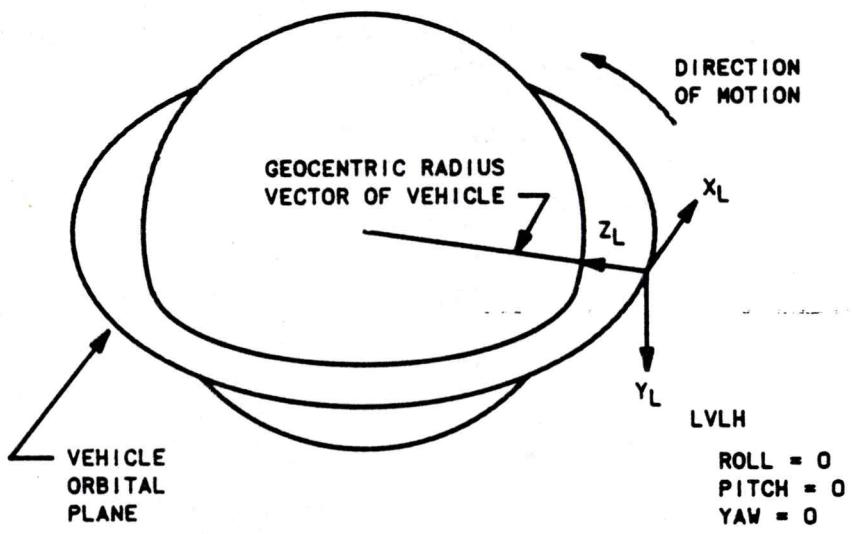


Figure 1-3.- M50 inertial reference frame.

### 1.7 LVLH REFERENCE FRAME

The local vertical local horizontal (LVLH) reference frame (fig. 1-4) is a rotating reference coordinate system that instantaneously (referenced with respect to time) defines the attitude of the Orbiter. These coordinate system axes are defined as follows:

- +Z axis is pointed at the center of the Earth.
- +Y axis is pointed opposite to the momentum vector ( $\vec{H}$ ).
- +X axis is positioned to complete the right-hand system.



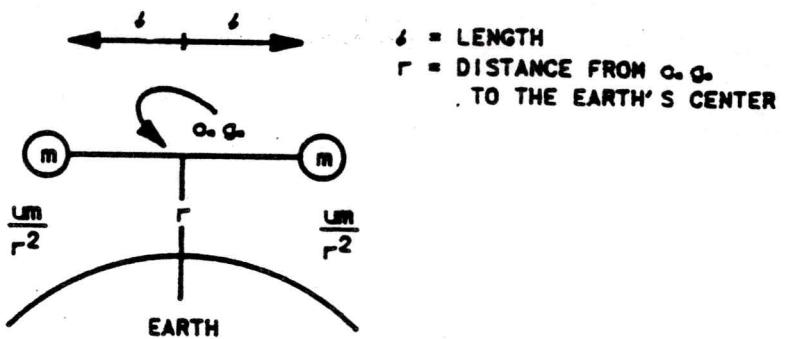
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Figure 1-4.- LVLH reference frame.

### 1.8 GRAVITY GRADIENT

Satellites are regularly required to point either toward the Earth or to some fixed point in inertial space. This can be accomplished by active control (thrusters, momentum wheels, etc.) or by passive means. Passive attitude control is provided either by gravitational torques or by spinning the satellite like a top. These two methods of stabilization are referred to as gravity gradient and spin stabilization. Spin stabilization is a technique more commonly used for unmanned satellites. Gravity gradient is more acceptable for manned vehicles.

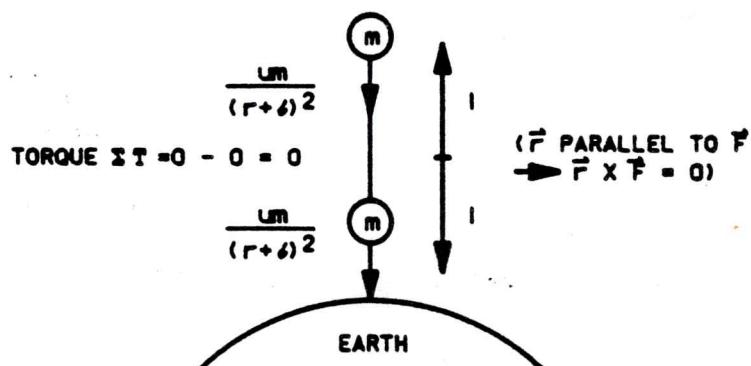
To simplify the concept of gravity gradient, consider the two masses (fig. 5-1(a)) connected by the rigid rod of length  $2\ell$ . Consider this an integral body.



$$\Sigma T \text{ (TORQUE)} = \frac{\delta U m}{r^2} - \frac{\delta U m}{r^2} = 0$$

(a)

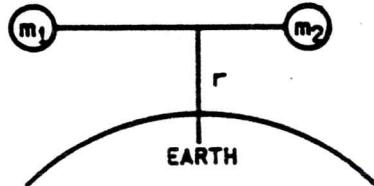
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(b)

$$\delta_1 \quad \delta_2 \quad \delta_1 m_1 = \delta_2 m_2$$



$$\Sigma T = \frac{\delta_1 U m_1}{r^2} - \frac{\delta_2 U m_2}{r^2} = 0$$

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(c)

Figure 1-5.- Gravity gradient.

Masses  $m$  are equal and spherical; therefore, these masses are concentrated at their centers.

Note that torques on the body are about the c.g. The body can be seen to be in an equilibrium position; the sum of the torques is zero, since the forces are equal and the moment arms are equal and opposite. This position, however, is an unstable equilibrium because any displacement or perturbation will tend to cause the body not to return, i.e., the force on the closer mass increases as the  $r$  in the denominator decreases, and the force on the farther mass decreases as  $r$  increases. This change in force results in a net torque, causing the body to swing toward a vertical position and, subsequently, around toward the other horizontal position. The maximum rate is reached as the body passes through the vertical position. In general, this oscillation will continue indefinitely as stabilizing effects due to aerodrag are negligible for an orbiting body.

In the position shown in figure 1-5(b), the forces are not equal, but each term contributes zero torque since the forces are parallel to the moment arms. This position is a somewhat stable equilibrium because a perturbation will result in a net torque returning the body to a vertical position.

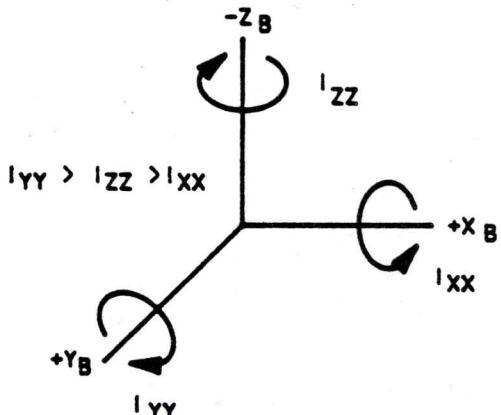
If the masses are unequal (nonsymmetrical body) (fig. 1-5(c)), there is no appreciable difference. The length of the moment arms are in an inverse ratio to the masses (meaning that the c.g. moves closer to the larger mass, reducing its moment arm). Thus, the only difference in the torques results once again from the change in the  $r$  term in the denominators as the body rotates.

The position shown in figure 1-5(c) is not stable; however, the vertical position would tend to be stable.

The Space Shuttle is a nonsymmetrical object with different moments of inertia about each axis and mass not evenly distributed. A yardstick to show how easily the Orbiter can be rotated can be seen when each moment of inertia is divided by the inertia about  $I_{yy}$ .

As the Orbiter orbits the Earth, gravity generates torques about the Orbiter center of mass for each axis in the same way that lift and drag generate torques on the Orbiter in the atmosphere. The magnitude of these torques about each axis is uniquely determined by the orbit of the Shuttle, the current position and attitude, and the moments of inertia of the vehicle itself. Therefore, the central idea of gravity gradient is to find attitudes where the destabilizing torques go to zero just as described for the symmetrical rigid body (fig. 1-6).

$$\begin{aligned} I_{xx} &= 0.125 \\ I_{yy} &= 1.0 \\ I_{zz} &= 0.945 \end{aligned}$$



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Figure 1-6.- Orbiter rotation.

A total of 12 equilibrium solutions that are variations of the 3 general types are described in table 1-I. Only 8 of the equilibrium solutions are dynamically stable and the addition of aeroeffects reduces this number to 6 stable attitudes.

These attitudes will not result in zero angular rates. In reality, there are no perfect solutions. Instead, the attitudes (table I) represent solutions that minimize the angular rates and tend to be stable points. In any one of these attitudes, the vehicle will oscillate about the attitudes at rates less than 0.1 deg/sec.

These solutions should vary only a few degrees from mission to mission. Note that the solutions are not good in all cases. Changes of the mass properties of the vehicle (water tanks, fuel, payloads) affects the moments of inertia. Any change in orbital altitude or in inclination changes the gravitational torques. Also, any change in the orbital atmosphere (solar flares, orbital altitude) alters the torques.

Finally, gravity gradient is a passive means of vehicle control; i.e., no primary reaction control system/vernier reaction control system (PRCS/VRCS) firings. Applications and characteristics of this stabilization method include the following: excellent for fuel conservation; good for attitude control with loss of VRCS; excellent for payload/rendezvous activity that requires no perturbations from reaction control system (RCS) jet plume; and excellent during crew sleep periods.

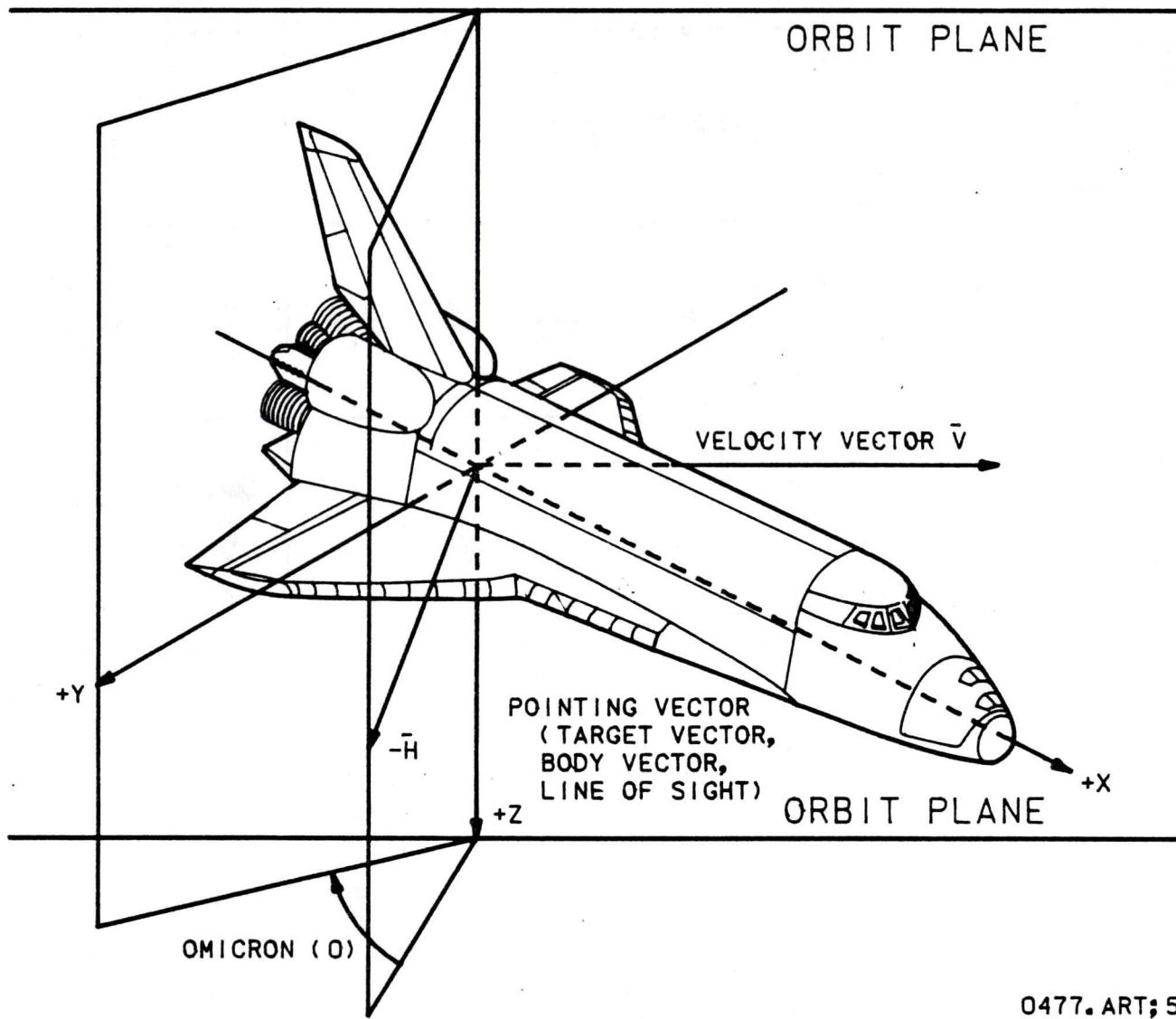
attitude	position	Roll	Pitch	Yaw
<u>Nose</u>	<u>Payload bay</u>	<u>LVLH, deg</u>		

General				
outward signs out to emission out of body nothing as to not reflect the out				
out bns (R-) rotev mutismom uslups 180deg evitpns out of hemint emis				
tbody) 20J out bns axis Y+ out yd bennot emisq out bns (rotev degres) 20J				
<del>Away from Earth from Along velocity plus out 180 deg 90 deg (rotev axis radially bennot emis vector of rotev degres out bns R- out yd bennot</del>				
Away from Earth	North	270	90	0
radially				
South	Along velocity vector	270	0	90
<b>Stable attitude</b>				
Radially toward center of Earth	North	256	267	358
Radially toward center of Earth	South	105	267	2
Radially toward center of Earth	In plane	358	2	0
Radially toward center of Earth	North	285	93	358
Radially away from center of Earth	South	75	93	2
Radially away from center of Earth	In plane	179	90	0

## 1.9 OMICRON

An omicron is an angle that fixes the rotation of a space vehicle about a line-of-sight or body vector pointed to a target. If only one LOS is pointed to a target, a space vehicle can assume any orientation about that LOS and still meet any pointing requirements. If, however, an omicron angle is specified, then there is only one unique attitude for the space vehicle to assume.

The definition of an omicron then is the measure of the angle between the plane formed by the negative orbital angular momentum vector ( $-\vec{h}$ ) and the LOS (target vector) and the plane formed by the  $+Y$  axis and the LOS (body vector). See figure 1-7. The angle is measured positively from the plane formed by the  $-\vec{h}$  and the target vector to the plane formed by the  $+Y$  axis and the body vector.



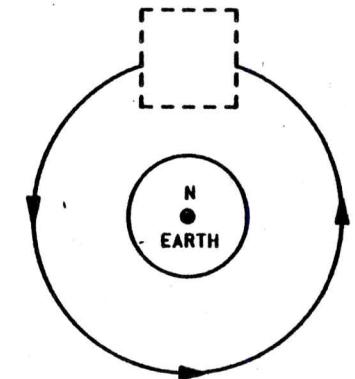
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Figure 1-7.- Omicron measurement.

Omicron is measured clockwise about the pointing vector looking in the direction of the pointing vector. Omicron is taken from the  $-H$ -pointing vector plane to the  $+Y$ -pointing vector plane. Singularity points: (a) when Orbiter  $+Y$  axis is the pointing vector, the plane with  $+Y$  axis in it is redefined to include  $-Z$  axis; (b) when  $+H$  is the pointing vector, the plane with  $-H$  vector in it is redefined to include the descending node of the (each) orbit concerned. Examples of omicron measures are shown in figure 1-8.

INSTRUCTIONS

- SELECT ORIENTATION.
- REFERENCE CORRESPONDING OMICRON BLOCK FOR THE BODY POINTING VECTOR (BPV).
- OR
- CHOOSE DESIRED BPV.
- SELECT OMICRON.
- THEN
- PLACE PICTURE IN DOTTED SQUARE. (DO NOT ROTATE.)



1-12

BLOCK	ORIENTATION	LVLH ATTITUDE, DEG (P, Y, R EULER SEQUENCE)			BPV SEQUENCE P, Y	OMICRON					
		ROLL,	PITCH,	YAW,		1	0°	2	90°	3	180°
1	+XLV Y-POP (PLBD FWD)	0°	270°	0°	+X P=0, Y=0						
2	+XLV Z-POP (PLBD SOUTH)	90°	270°	0°	+X P=0, Y=0						
3	+XLV Y-POP (PLBD AFT)	180°	270°	0°	+X P=0, Y=0						
4	+XLV Z-POP (PLBD NORTH)	270°	270°	0°	+X P=0, Y=0						
1	-XLV Y-POP (PLBD AFT)	0°	90°	0°	-X P=180, Y=0						
2	-XLV Z-POP (PLBD NORTH)	270°	90°	0°	-X P=180, Y=0						
3	-XLV Y-POP (PLBD FWD)	180°	90°	0°	-X P=180, Y=0						
4	-XLV Z-POP (PLBD SOUTH)	90°	90°	0°	-X P=180, Y=0						
1	+ZLV Y-POP (NOSE FWD)	0°	0°	0°	+Z P=270, Y=0						
2	+ZLV X-POP (NOSE SOUTH)	0°	0°	90°	+Z P=270, Y=0						
3	+ZLV Y-POP (NOSE AFT)	180°	180°	0°	+Z P=270, Y=0						
4	+ZLV X-POP (NOSE NORTH)	0°	0°	270°	+Z P=270, Y=0						
1	-ZLV Y-POP (NOSE AFT)	0°	180°	0°	-Z P=90, Y=0						
2	-ZLV X-POP (NOSE NORTH)	0°	180°	270°	-Z P=90, Y=0						
3	-ZLV Y-POP (NOSE FWD)	180°	0°	0°	-Z P=90, Y=0						
4	-ZLV X-POP (NOSE SOUTH)	0°	180°	90°	-Z P=90, Y=0						
1	+YLV Z-POP (PLBD SOUTH)	90°	0°	0°	+Y P=0, Y=90						
2	+YLV X-POP (NOSE SOUTH)	0°	90°	90°	+Y P=0, Y=90						
3	+YLV Z-POP (PLBD NORTH)	270°	180°	0°	+Y P=0, Y=90						
4	+YLV X-POP (NOSE NORTH)	0°	270°	270°	+Y P=0, Y=90						
1	-YLV Z-POP (PLBD SOUTH)	90°	180°	0°	-Y P=0, Y=270						
2	-YLV X-POP (NOSE NORTH)	0°	90°	270°	-Y P=0, Y=270						
3	-YLV Z-POP (PLBD NORTH)	270°	0°	0°	-Y P=0, Y=270						
4	-YLV X-POP (NOSE SOUTH)	0°	270°	90°	-Y P=0, Y=270						

Figure 1-8.- Omicron examples.

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## 1.10 PTC ORIENTATION

Passive thermal conditioning (PTC) is an inertial orientation that a space vehicle can assume where the X-body axis of rotation is perpendicular to the Sun pointing vector (fig. 1-9). This pointing vector is within the Y - Z body plane and the body X axis is the axis of rotation.

The PTC orientation necessitates a maneuver to an inertial attitude that places the Sun pointing vector in the Y - Z plane before rotation starts about the X axis.

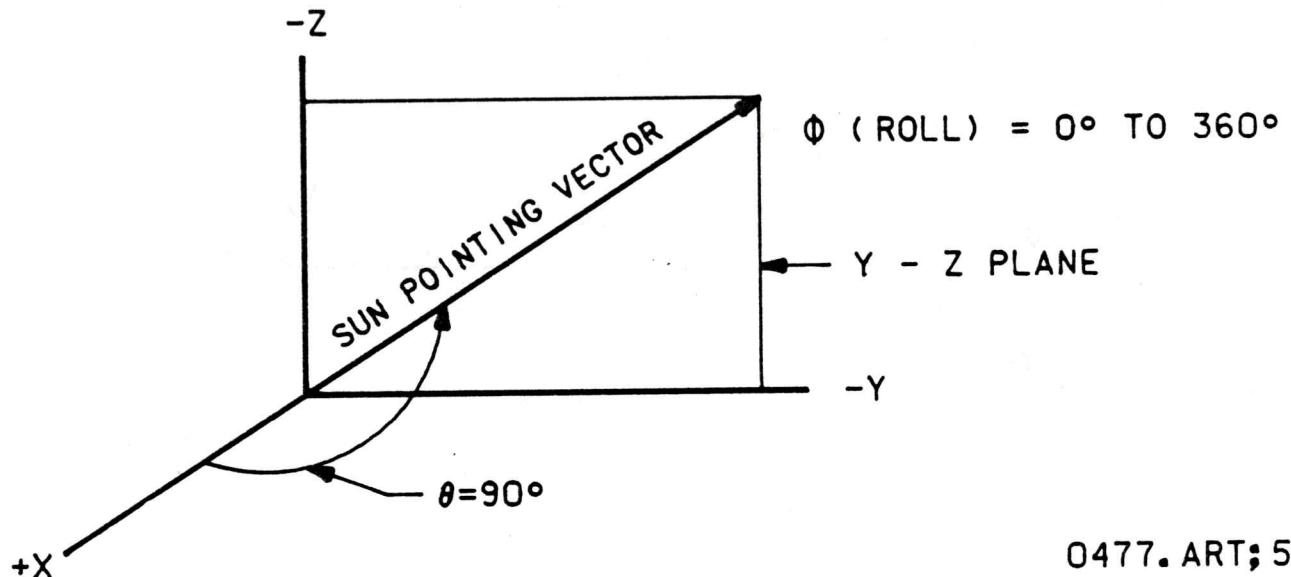


Figure 1-9.- PTC orientation.

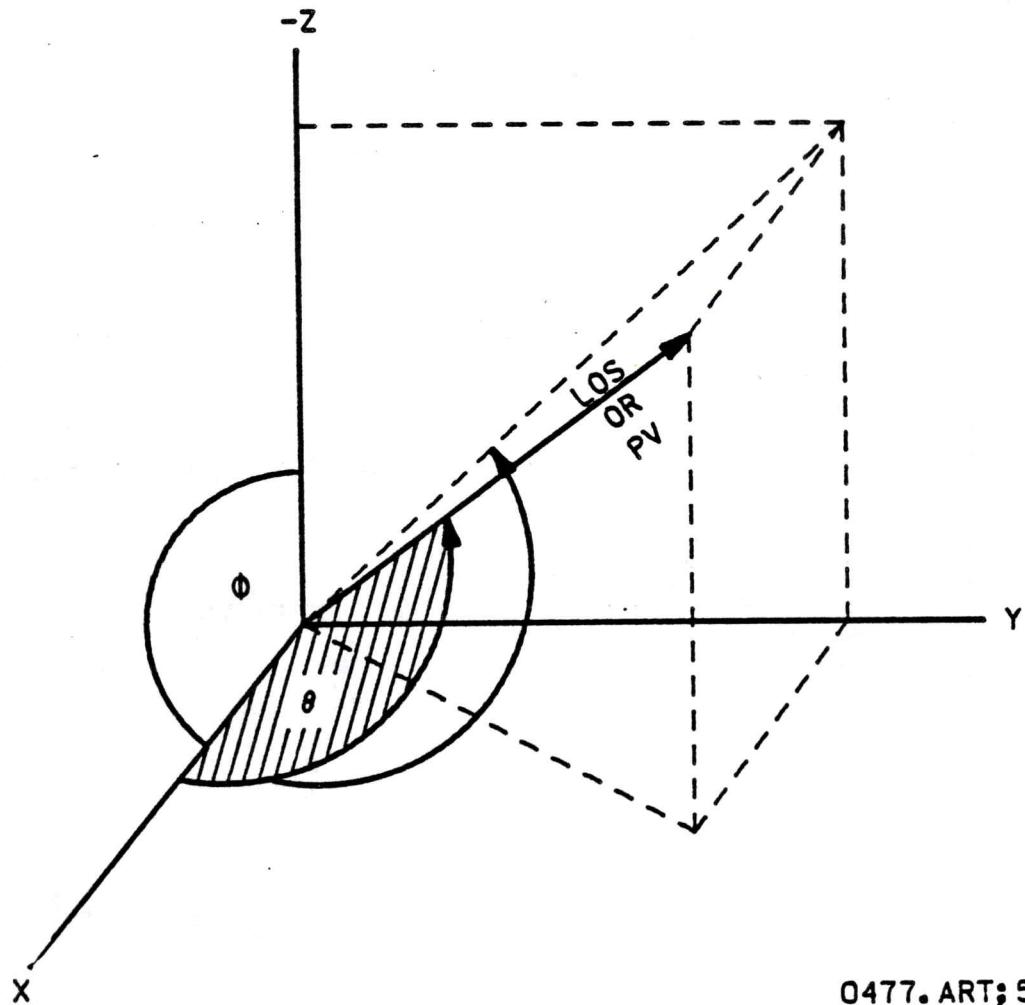
Note: Reference discussion concerning the Universal Pointing display (sec. 2.4) body vector input for more information on PTC.

The objective of the vehicle maneuver is to place the Sun pointing vector in a position where  $\phi = 0^\circ$  to  $360^\circ$  and  $\theta = 90^\circ$ . This position allows maximum vehicle body exposure to the Sun. This equates to a "barbeque" effect and, thus, more even heating of the space vehicle body.

The common PTC orientation involves an initial maneuver to an attitude where the +X axis is along the angular momentum vector ( $\mathbf{h}$ ) with the -Z axis coincident with the Sun pointing vector. After this attitude is achieved, rotation is initiated about the X axis. This orientation of the X axis is to allow better antenna ground coverage.

## 1.11 LOOK ANGLES $\theta$ AND $\phi$

One common way of describing an LOS within a reference frame is through the defining of the look angles  $\theta$  and  $\phi$  (fig. 1-10).

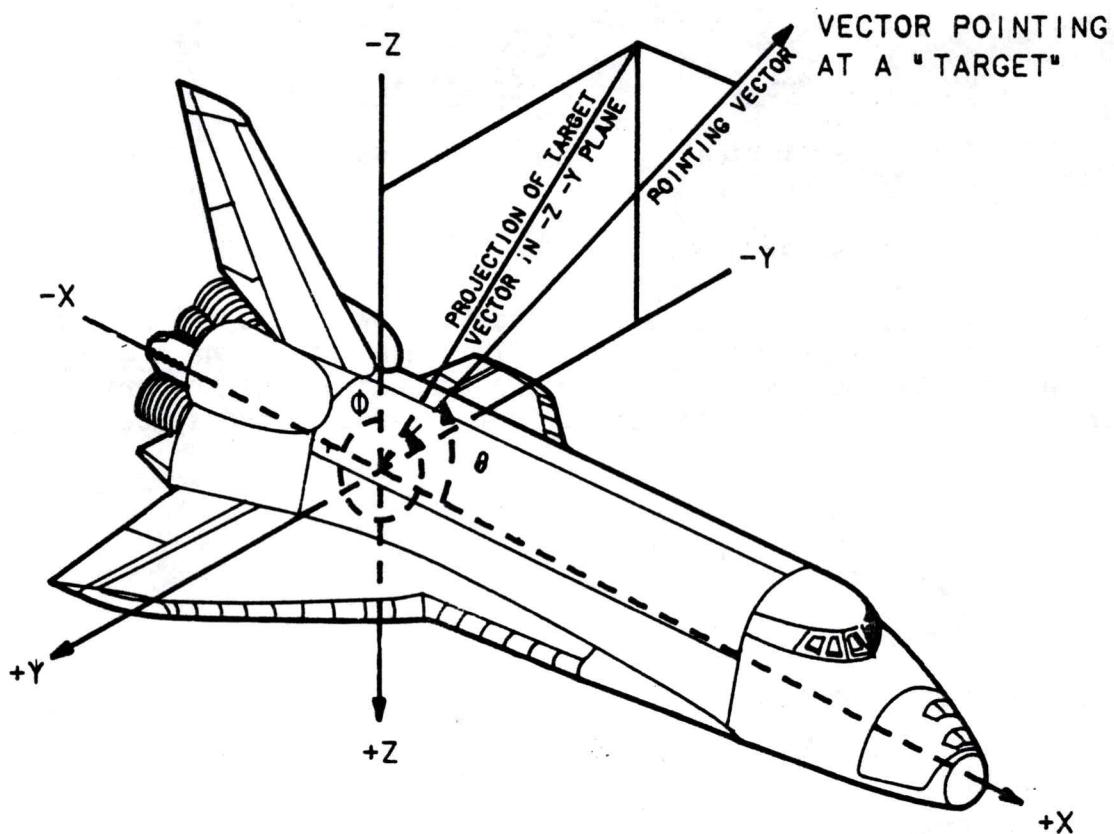


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Figure 1-10.- Look angles  $\theta$  and  $\phi$ .

$\theta$  is measured from the +X axis (positive direction) to the LOS.  $\phi$  is measured from the -Z axis to the projection of the LOS in the Y Z plane. These measurements describe the LOS.

Figure 1-11 shows  $\phi$  and  $\theta$  with an Orbiter body axis reference.



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Figure 1-11.- Angles  $\theta$  and  $\phi$  with an Orbiter body axis reference.

### 1.12 CLASSICAL ORBITAL ELEMENTS

The following six quantities are generally accepted to describe the orbit of a vehicle in space (fig. 1-12).

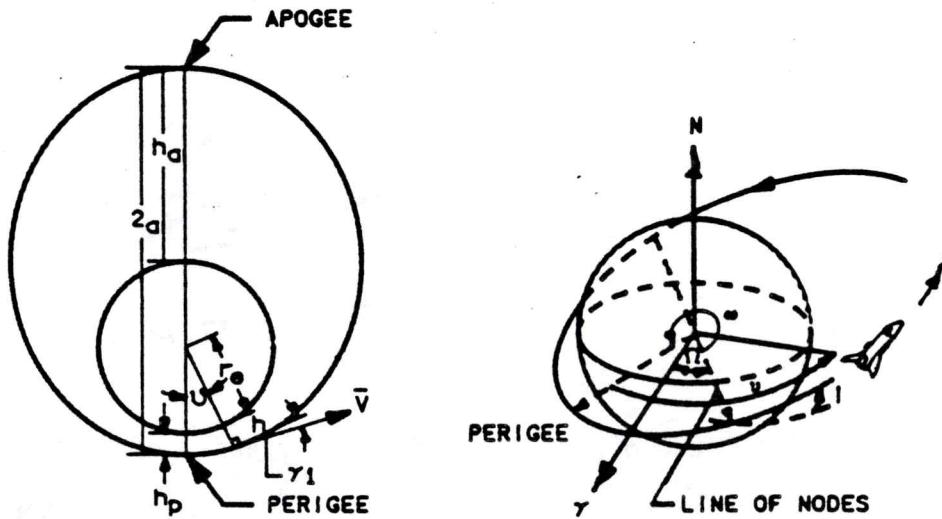
Two elements are needed to locate the plane of the orbit relative to some fixed direction in space and to the Earth. The longitude of the node, or the right ascension, is the angle measured to the ascending node from the first point of Aries (a reference point on the celestial sphere) as seen from the center of the Earth. The node locates the line of nodes in the equatorial plane. Sidereal time, with respect to the Earth's orbit around the Sun, also uses the line from the Earth's center to the first point of Aries as a reference. The time reference, when the Earth and the Sun are in alignment with this point, is the equinox.

Orbit inclination is another element that locates the orbital plane of a space vehicle. Orbital inclination is the angle between the orbit plane and the equatorial plane.

Two elements describe the size and shape of an orbit: the semimajor axis describes the length of the major axis and eccentricity describes the shape. Eccentricity is a measure of how much the orbit deviates from circular.

<u>Orbit</u>	<u>Eccentricity</u>
Elliptical	>0 to <1
Circular	0
Parabolic	1
Hyperbolic	>1

One element is required to locate the direction of the major axis of the trajectory within the trajectory plane. This element is the argument of perigee and is the angle measured from the ascending node to perigee in the direction of the space vehicle and in the plane of the space vehicle.



$h$ = ALTITUDE	$r_e$ = EARTH RADIUS	$\omega$ = ARGUMENT OF PERIGEE
$h_a$ = APOGEE ALTITUDE	$\gamma_1$ = FLIGHT PATH ANGLE	$v$ = TRUE ANOMALY AT EPOCH
$h_p$ = PERIGEE ALTITUDE	$v$ = VELOCITY VECTOR	$\gamma$ = FIRST POINT OF ARIES
$a$ = SEMIMAJOR AXIS	$\Omega$ = ANGLE OF THE NODE	$i$ = INCLINATION
$u$ = TRUE ANOMALY		

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Figure 1-12.- Orbital elements.

The final element of the required six is used to locate the space vehicle on its orbit at some specific time so that future positions can be predicted as a function of time. This element is the true anomaly at epoch and is the angle from perigee to the object measured in the direction of motion at some specific time.

### 1.13 REFSMMAT

The Reference Stable Member Matrix (REFSMMAT) is a transformation matrix that defines an orientation of the vehicle Inertial Measurement Unit (IMU) stable platform relative to the Aries Mean of 1950 inertial reference frame.

The IMU's are used in conjunction with the Shuttle computers to obtain such parameters as position, velocity, and attitude. To ensure reliability, there are three IMU's. Each unit contains gyros that, when released, remain inertially fixed in space. The platform on which the gyros are mounted, therefore, also remains stable.

While the Shuttle is on the launch pad, the orientation of the stable platform must be known in M50 space to a high degree of accuracy. To accomplish this, an Earth-fixed reference system is used with the origin being the vehicle stable platform. If the IMU stable platform is aligned with the Earth reference, the exact orientation of the IMU stable platform is known in the M50 system.

A routine called gyrocompassing forces the gyros to remain fixed with respect to the Earth-fixed system. Once the axes have stabilized, gyrocompassing keeps them in position (compensates for the Earth's rotation while on the launch pad). At approximately T - 20 minutes to launch, the orientation of the IMU stable platforms is recorded in a 3 by 3 transformation matrix, REFSMMAT (the angular difference between the Earth-fixed system and the M50 system are loaded into the arguments of a direction cosine matrix). At this instant, the gyros stop rotating with the Earth and become inertial. This REFSMMAT is called the desired REFSMMAT.

The desired REFSMMAT is maintained in the IMU alignment module of the general purpose computer (GPC) to define the preferred position of the IMU platform. This REFSMMAT provides the IMU's with the most favorable mechanical positions. During an IMU alignment, the orientation of the gyros are checked to see how far they have drifted from the desired. If drift has occurred, position, velocity, and attitude data are inaccurate. To correct this situation, the gyros are forced (torqued) to the true orientation defined by the desired REFSMMAT.

Note that there are three REFSMMAT's for each of the three IMU's: desired, current, and present. Only the desired and current are constantly available during IMU operations. The present REFSMMAT is computed when needed to support IMU alignments and is available only during alignment activities.

The current REFSMMAT resides in the GPC common data pool (COMPOOL). This REFSMMAT is used to determine attitude, velocity, instrument LOS, and other pointing computations. This transformation does not change between

alignments even though the IMU platforms may have drifted. The current REFSMMAT is either confirmed or changed as the result of each IMU alignment. On-orbit, the current REFSMMAT is normally the same as the desired since the goal of most alignments is to force the platform back to the desired position. The crew can, however, make the current REFSMMAT equal to the present REFSMMAT.

The present REFSMMAT is computed when any of the three IMU alignment options is selected. This transformation matrix defines the actual platform position at the time of computation. It is based on either star data or a specified IMU's current REFSMMAT selected as a reference. If the IMU being aligned is also the reference, the present REFSMMAT is set equal to the current REFSMMAT.

#### 1.14 RELMAT (STARBALL)

The Relative Matrix (RELMAT) is a transformation matrix that relates the attitude direction indicator (ADI) inertial reference frame to the M50 reference frame.

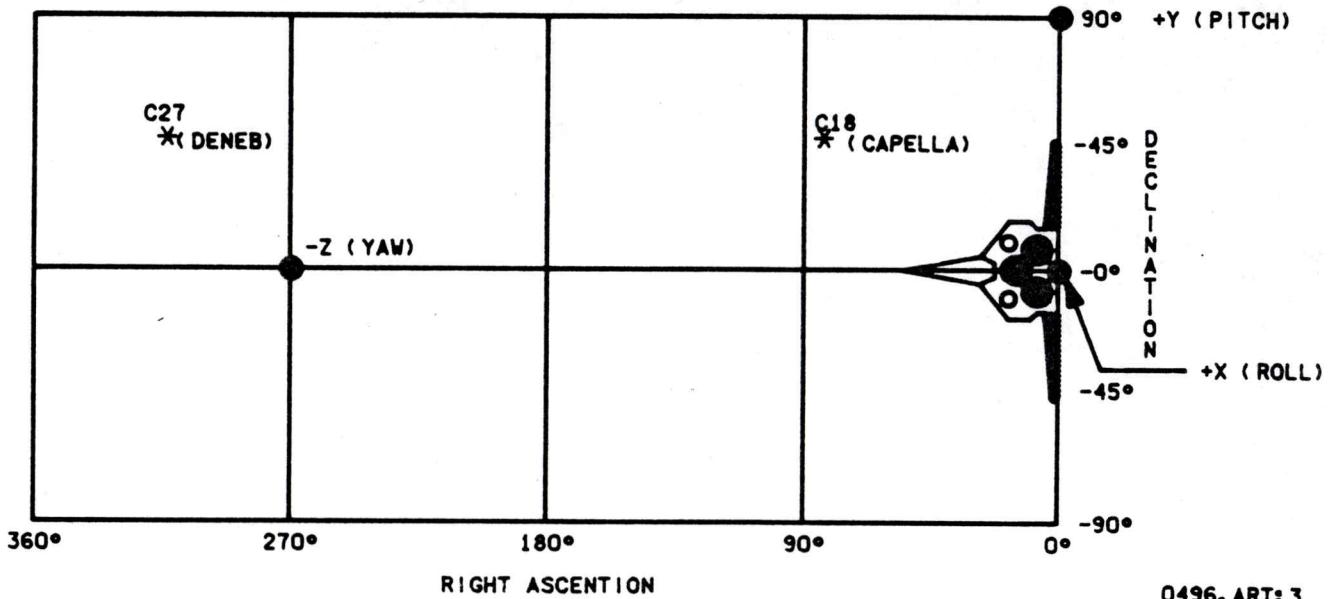
Three ADI's onboard the Shuttle are used to display vehicle attitude in either an inertial, a reference, or an LVLH coordinate frame. The inertial attitude information depicted on the ADI is data derived by a RELMAT called the starball RELMAT. A RELMAT is similar in structure to a REFSMMAT; however, the transformation in this case relates the inertial ADI attitude data to an M50 reference frame.

With the ADI source switch set to inertial, the ADI angles correspond to vehicle orientation in inertial coordinates. By design of the RELMAT, the Shuttle can also be oriented to place an LOS to any navigation star or target if the right ascension (RA) and declination (DEC) is known. Further, a crewmember can determine his relative orientation in the inertial sphere in the same manner. This capability is of particular value when determining locations of stars for Crew Optical Alignment Sight (COAS) sightings.

As an example of this method, a RELMAT was chosen where the M50 reference for the +X and +Y body axes corresponds to RA and DEC in the celestial sphere as read on the ADI (thus the name starball RELMAT). The starball RELMAT ADI orientation places the +X axis at  $0^\circ$  RA and DEC; +Y at  $0^\circ$  RA and  $90^\circ$  DEC; and -Z at  $270^\circ$  RA and  $0^\circ$  DEC (orthogonal). This orientation completes the body reference frame in M50 (fig. 1-13).

Given this reference, the vehicle can be oriented to point a LOS to an object directly by knowing its RA and DEC. For example, to point the +X body LOS to star 18, an ADI pitch of  $79^\circ$  and a yaw of  $45^\circ$  is used where

$$\begin{aligned} \text{Pitch} &= \text{RA} \\ \text{Yaw} &= \text{DEC} \end{aligned} \quad ] +X \text{ LOS}$$



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Figure 1-13.- Mercator projection of celestial sphere.  
Star 18, RA 79° DEC 45°; star 27 RA 310° DEC 45°.

For a -Z LOS pointed to a target, the process is similar. For example, for the -Z LOS pointed to star 27, the ADI used is

$$\begin{aligned} \text{Pitch} &= \text{RA} - 90^\circ = 220^\circ \\ \text{Roll} &= \text{DEC} = 45^\circ \\ \text{Yaw} &= 0^\circ \end{aligned}$$

Several other conventions can be made for the other body axis LOS's. These two examples give a good idea of the utility of the inertial starball RELMAT.

One final note, an infinite number of possible RELMAT's that will give the ADI an inertial reference are available for use. The starball RELMAT, however, was selected as the I-load RELMAT because of its unique characteristics and base reference.

## SECTION 2

### VEHICLE POINTING: HARDWARE/SOFTWARE

## 2.1 ATTITUDE DIRECTION INDICATOR

The attitude direction indicator (ADI) is a crew-observed hardware instrument that provides indications of the Orbiter pitch, yaw, and roll attitude via a gimballed ball (fig. 2-1).

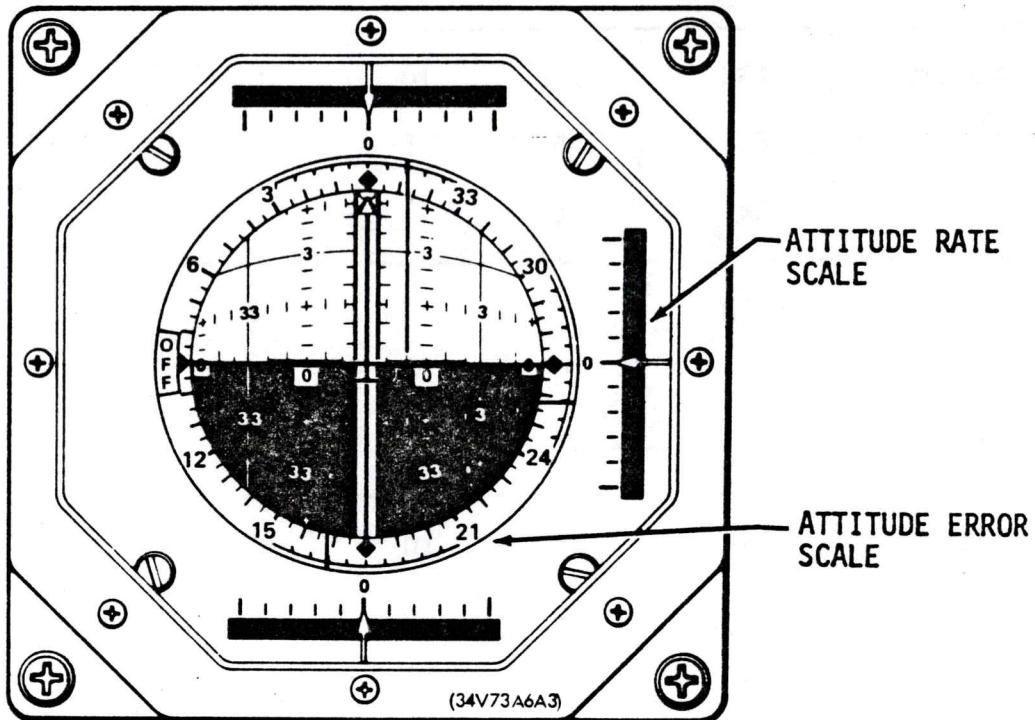


Figure 2-1.- Attitude direction indicator.

Note: Starting from the top, rate/error scales are roll, pitch and yaw, respectively.

Attitude errors are shown by three metered position needles; attitude rates are indicated by three metered position pointers. The scale for each of the three ADI's are controlled by the ADI scale switches (fig. 2-2) located on panels F6, F8, and A6U. Each ADI can be set to an error level of high, medium, or low. The scales for the switch positions are shown in table 2-I.

The ADI attitude switch (fig. 2-3) selects the ADI reference frame desired for display on the ADI. The switch selections are INRTL, LVLH, and REF. The three positions for ADI display relate to a specific Relative Matrix (RELMAT) that has as a reference the transformation from M50 inertial reference to the desired reference frame. The INRTL and REF reference frames are defined by I-Loaded RELMATS. The crew can also set up their present attitude as the REF reference frame for future reference by pressing the ATT REF push-button on F6, F8, or A6U.

TABLE 2-I.- SWITCH POSITIONS FOR THE ADI

Mode	Switch position	Full-scale value					
		Attitude rate, deg/sec			Attitude error, deg		
		Roll	Pitch	Yaw	Roll	Pitch	Yaw
Ascent	HIGH	10	10	10	10	10	10
	MED	5	5	5	5	5	5
	LOW	1	1	1	1	1	1
On-orbit	HIGH	10	10	10	10	10	10
	MED	5	5	5	5	5	5
	LOW	1	1	1	1	1	1
Entry	HIGH	10	10	10	20	10	2.5
	MED	5	5	5	5	5	2.5
	LOW	1	1	1	1	1	2.5
Terminal Area Energy Management (TAEM)	(a)						
	HIGH	10	10	10	20	1.25	2.5
	MED	5	5	5	5	1.25	2.5
	LOW	1	1	1	1	.50	2.5
Approach and landing (A/L)	(b)						
	HIGH	10	10	10	20	10	2.5
	MED	5	5	5	5	5	2.5
	LOW	1	1	1	1	1	2.5

<sup>a</sup>Worst-on-worst longitude (WOWLON) = 0.<sup>b</sup>WOWLON = 1.

HIGH  
MED  
LOW

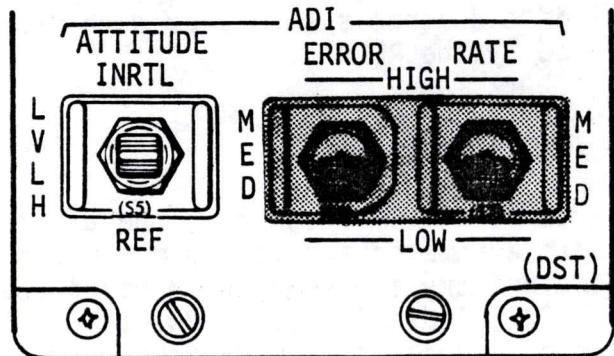


Figure 2-2.- ADI scale switch.

INRTL  
LVLH  
REF

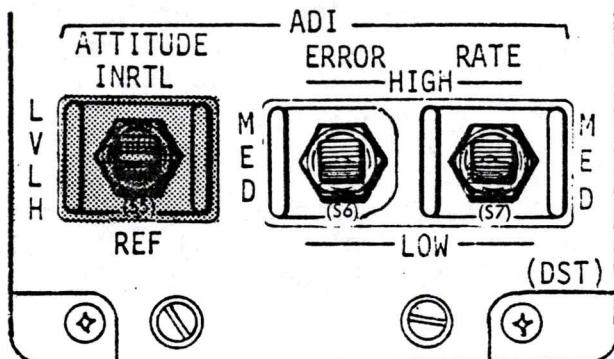


Figure 2-3.- ADI attitude switch.

Whenever the TRANS DAP is initialized or when the MAN/AUTO mode is changed, the attitude is snapshotted and errors are displayed relative to that attitude. When there is an attitude in the BURN ATT R, P, Y (items 24, 25, 26) slots on the MNVR display, the errors are displayed relative to the BURN ATT as "total" errors. When an attitude is loaded on the Universal Pointing display that is executed as a future maneuver, the ADI attitude error remains referenced to present attitude until the maneuver becomes current. There is an exception. When the STOP option has been exercised prior to executing the maneuver, whether current or future, the ADI attitude errors will immediately reference the loaded attitude. DAP errors are displayed during guided  $\Delta V$  burns (orbital maneuvering system (OMS) or reaction control system (RCS)).

The last hardware function is the ADI SENSE switch located in the aft station. This switch allows the ADI angles to indicate the orientation of either a -X sense axis system or a -Z sense axis system (forward ADI's use +X only), depending on whether the crewmember is viewing through the pay-

load bay (-X) windows or the overhead (-Z) window. These sense axes systems (+X, -X, -Z) are fixed in the body; and the ADI displays the pitch, yaw, and roll of the sense system axes with respect to the ADI reference frame as defined by the RELMAT.

## 2.2 DIGITAL AUTO PILOT

The digital auto pilot (DAP) controls the attitude and translation of the Orbiter for both automatic and manned maneuvers by sending the appropriate commands to the primary and vernier reaction control system (PRCS/VRCS) jets. The DAP CONFIG display (SPEC 20) allows the crew to control the DAP through inputs or changes to the various parameters that the DAP uses.

A description of the item entries for the DAP CONFIG display (fig. 2-4) is given in table 2-II.

The crew uses the DAP panel located on panel C3 or A6 to exercise vehicle control. The DAP panel consists of hardware pushbuttons that allow the crew to select the translation DAP (or TRANS DAP) auto/manual control operations sequence (OPS) 1 and 3; to determine whether A or B DAP configuration values will be used with auto/manual control (OPS 2); to select translational control; and to determine if primary or vernier jets will be commanded to fire (OPS 2).

Sections 2.2.1 and 2.2.2 describe the functions of the DAP control panel, the translation hand controller (THC) and rotation hand controller (RHC) interface for the TRANS DAP and On-Orbit DAP.

### 2.2.1 Translation DAP - OPS 1 and 3 (fig. 2-5)

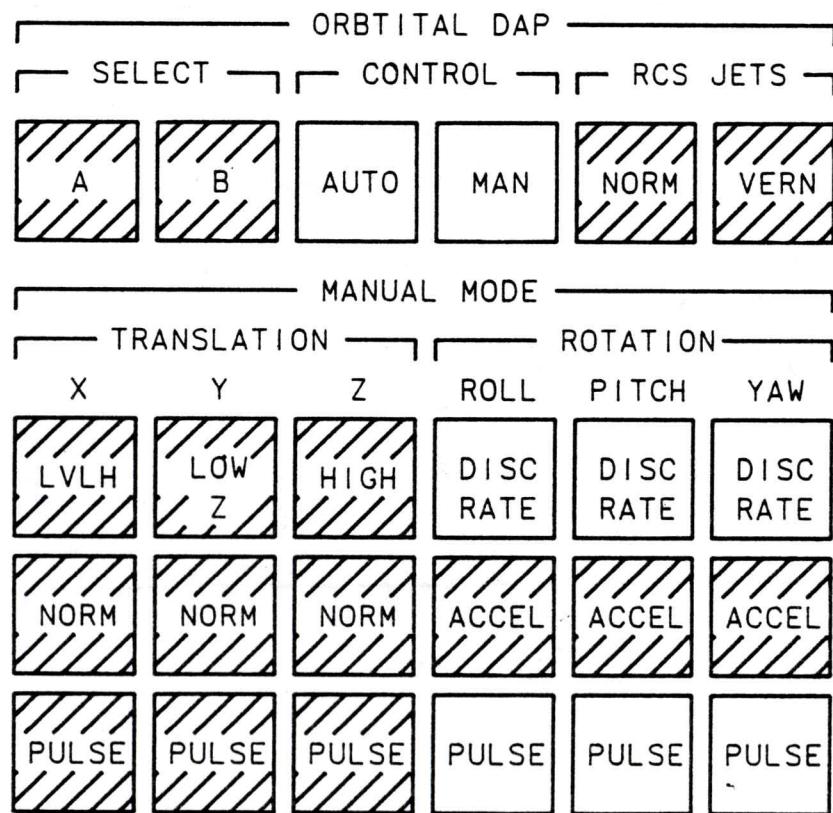
#### 2.2.1.1 AUTO/MAN Selection (RCS)

- a. AUTO provides for an automatic eigen axis (a specified axis of rotation) maneuver at  $0.2^{\circ}/\text{sec}$  to the attitude indicated on MNVR display. Auto control is not available in the backup flight system (BFS).
- b. MAN provides for manual maneuvers
  - (1) DISC RATE provides  $1.0^{\circ}/\text{sec}$  selectable by axis in the PASS; all axes or none in the BFS.
  - (2) PULSE provides for a minimum impulse firing selectable by axis in PASS; all axes or none in BFS. PULSE is a "free" mode.

XXXX/020/XXX	DAP CONFIG	XX X	DDD/HH:MM:SS
TRANSLATION		A	B
PULSE		1 0.10	15 0.02
ROTATION			
DISC RATE	NORM	2 0.200	16 0.500
	VERN	3 0.200	17 0.200
PULSE	NORM	4 0.10	18 0.04
	VERN	5 0.010	19 0.002
COMP	NORM	6 .00	20 .00
	VERN	7 .000	21 .000
DEADBAND			
ATT	NORM	8 10.00	22 10.00
	VERN	9 1.000	23 1.000
	NORM	10 0.20	24 0.20
	VERN	11 .020	25 .020
JET OPT	P	12 1	26 1
	Y	13 1	27 1
CNTL ACCEL		14 0	28 0

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Figure 2.4.- DAP CONFIG display. (See table 2-II.)



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Figure 2-5.- DAP control panel - TRANS DAP - OPS 1 and 3.

TABLE 2-II.- DESCRIPTION OF DAP CONFIG DISPLAY  
(See figure 2-4.)

ITEM	Description	Units	Limits
1,15	Specifies desired $\Delta V$ resulting from single translation hand controller (THC) command	ft/sec	0.01 +5.00
2,3,16,17	Specifies desired rotation rate achieved in a DISC RATE MAN mnvr or AUTO mnvr	deg/sec	N: .05 +2 V: .002 +1
4,5,18,19	Specifies desired rotation rate achieved by a single rotation hand controller (RHC) pulse command	deg/sec	N: .04 +1 V: .001 +.5
6,7,20,21	Specifies allowable rate for a given axis resulting from a rate about another axis	deg/sec	0 + .99
8,9,22,23	Determines greatest allowable deviation from deadband center	deg	N: .1 +40 V: .01 +40
10,11,24,25	Determines greatest allowable rotation rate from deadband center	deg/sec	N: .2 +5 V: .01 +.5
12,13,26,27	1 = normal, 2 = nose only, 3 = tail only	none	0 + 3
14,28	0 = nominal vernier, 1 to 5 = vernier alternate	none	0 + 5
29,30,31	Principal axis inertias used only when CNTL ACCEL = 0)	$10^6$ slug • ft $^2$	IX: .75 + .9 IY,IZ: 6 +7

### 2.2.1.2 Orbital Maneuvering System (OMS) Thrust Vector Control (TVC)

- a. AUTO provides OMS engine gimbal steering during OMS burns with 100° RCS wraparound in pitch/yaw and 5° wraparound in roll. For a single-engine OMS burn, roll is controlled with RCS to a 5° deadband. See table 2-III.
- b. MAN provides RHC proportional rate command (for manual OMS gimbaling capability) from 0°/sec to 2°/sec in pitch/yaw until RHC soft stop is exceeded. When the RHC soft stop is exceeded, acceleration (ACCEL) command is invoked. RHC ROLL is commanded to 0.2°/sec when the RHC is out of detent but not past the soft stop. ACCEL is commanded when the RHC is past the soft stop in roll. (RCS jets in ACCEL mode complement the OMS gimbals.)

TABLE 2-III.- OMS TVC CONTROL

Mode	Engines on	RHC	Axes	Result
AUTO	2	Detent	All	Target commands (MNVR DISP)
	1	Detent	R. P,Y	RCS roll control if needed Target commands (MNVR DISP)
MAN	2	Within soft stop	Any	Proportional rate commands
		Beyond soft stop	Any	ACCEL: Gimbals at max rate, continuous RCS fire
	1	Within soft stop	R P,Y	RCS discrete rate Proportional rate commands
		Beyond soft stop	R P,Y	RCS ACCEL mode ACCEL: Gimbals at max rate, continuous RCS fire

### 2.2.1.3 Translation Hand Controller (THC)

The THC provides for continuous RCS thrusting (ACCEL) in each axis for which the THC is out of detent. There is one exception. When simultaneous X and Z translations are commanded through the THC, only the Z is executed because of propellant feed limitations. Only the THC at the commander's station is active in OPS 1 and 3.

### 2.2.1.4 Rotation Hand Controller (RHC)

The RHC provides for manual rotation maneuver control (forward RHC's only in OPS 1 and 3)

- a. DISC RATE of  $1.0^{\circ}/\text{sec}$  is commanded in the axis when DISC RATE is selected in on the DAP panel in any axis and the RHC is out of detent in that axis (but not past the soft stop). When the RHC is returned to detent in any axis in which DISC RATE is selected, the attitude is "snapshoted" and used as a phase plane center. The attitude is then held within a  $3.5^{\circ}$  deadband. If the RHC is deflected beyond the soft stop while in DISC RATE, jets are fired continuously, giving a constant angular acceleration (in the axis and sense of the RHC deflection). The jets will continue to fire until the RHC is backed out of the soft stop. With the RHC returned to detent, the attitude is snapshoted and jets are fired to stop the angular rates and initiate holding the snapshoted attitude. In effect, an ACCEL mode is provided if the RHC is deflected into the soft stop and a free mode is provided when returning the RHC from the soft stop while between the soft stop and detent. See figure 2.6.

RHC	DISCRETE	PULSE
DETENT	ATT HOLD NEW ATT HOLD	FREE DRIFT FREE DRIFT
DETENT TO SOFTSTOP	DISC RATE FREE DRIFT	PULSE FREE DRIFT
SOFTSTOP TO HARDSTOP	ACCEL ACCEL	ACCEL ACCEL

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Figure 2-6.- RHC downmoding.

- b. PULSE is a free mode. When PULSE is selected in an axis and the RHC is removed from detent (but not past the soft stop), a minimum impulse RCS jet firing is commanded in that axis.

When the RHC is deflected past the soft stop in any axis, acceleration is obtained in that axis until the RHC is allowed back out of soft stop. When this maneuver is completed, the mode becomes free.

- c. ACCEL can not be selected in any axis via the DAP pushbuttons in OPS 1 and 3. However, as described in the PULSE and DISCRETE RHC control (fig. 2-6), ACCEL is a resultant downmode of the RHC when in the soft stop to hard stop on the RHC. For DAP RCS translations, ACCEL is the only mode that is available.

#### 2.2.1.5 General Information - TRANS DAP

- a. Only primary RCS jets are available in OPS 1 and 3.
- b. Only guided (i.e., target must be input) OMS burns are available. TVC can be manual or auto. In manual, error signals are displayed to the crew on the ADI while the crew controls the thrust vector through the RHC.
- c. OMS engine start is not manual. Shutoff can be manual.
- d. The only guided RCS  $\Delta V$  burn that is available is  $+X$ ; the  $\Delta V$  burn is guided only in the sense that it can be targeted. Attitude and attitude errors are displayed. The  $+X$  jets, however, are commanded on and off manually through the THC.
- e. RCS translations can be done in any axis using the THC. Although RCS targeting must be input for  $+X$  it can be burned out in any attitude because the  $\Delta V$ -to-go components in the other axes are displayed for the current attitude.

<u>TRANS DAP type</u>	<u>Translation, no. of jets</u>
$+X$	4
$-X$	2
$\pm Y$	2
$+Z$	3
$-Z$	6

- f. The External Tank (ET) separation (SEP) maneuver is automatic and is the only automatic RCS translation in the TRANS DAP. The ET SEP maneuver is a 4-ft/sec-Z closed-loop translation following main engine cut-off (MECO).

g. Transition DAP deadbands

<u>Maneuver</u>	<u>Attitude, deg</u>	<u>Rate, deg/sec</u>
Mated coast	1	0.3
ET SEP	3	.5
Normal unmated coast	3.5	.33
OMS TVC wraparound	100 P,Y/5 R	1.25 P,Y .2 R
Guide +X	3	.33

h. The RHC provides "hot stick" downmoding from AUTO to MAN if the RHC is removed from detent.

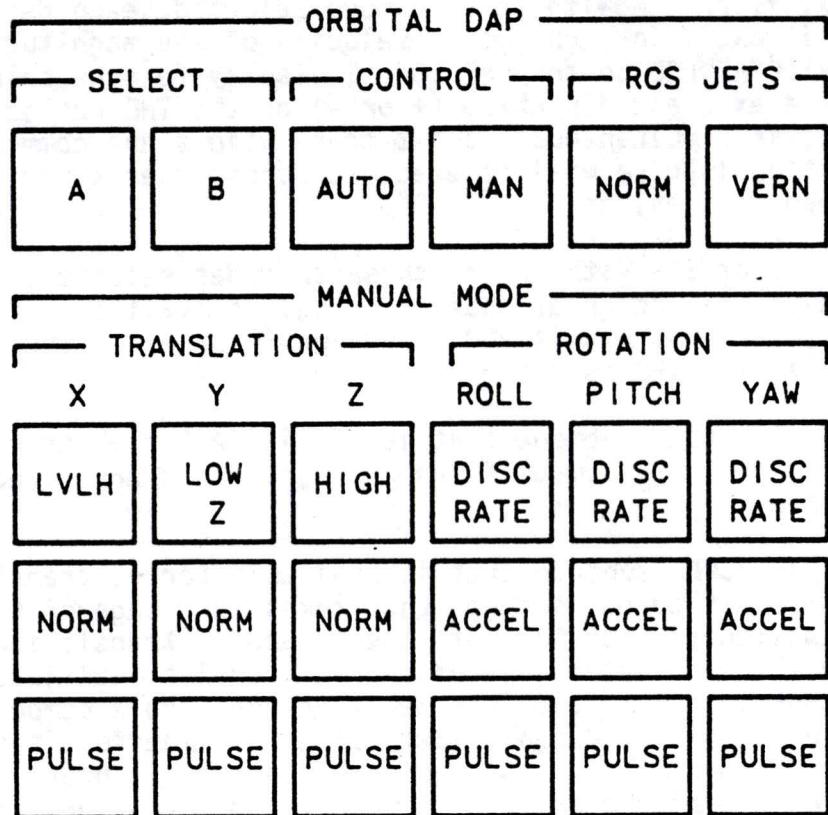
### 2.2.2 On-Orbit DAP (fig. 2-7)

The On-Orbit DAP functions are DAP A or B with AUTO, MAN, or LVLH rotation modes selected, and a choice of NORM or VERN jets. There is also a choice of DISC RATE, ACCEL, or PULSE manual (MAN) rotation submodes selectable by axis. With NORM jets selected, the following translational submodes are available: PULSE and NORM (ACCEL) in all axes; HIGH Z (high ACCEL) and LOW Z (low ACCEL) for +Z translations.

DAP's A and B each represent different sets of control parameters for the DAP. These parameters can be seen on the DAP CONFIG specialist function (SPEC 20). The parameters can also be changed through keyboard item entries on this display. These changes are invoked after the item execution if the parameter changed is applicable to the currently selected DAP (A or B and NORM or VERN). The following modes and submodes are available for DAP on-orbit operation.

#### 2.2.2.1 AUTO/MAN Selection

- a. AUTO enables execution by the DAP of auto maneuvers commanded by use of the universal pointing display.
- b. MAN enables execution of the selected rotation submodes commanded through the RHC.



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Figure 2-7.- DAP control panel - On-Orbit DAP.

#### 2.2.2.2 LVLH

With DISC RATE selected in all three axes and with the LVLH mode selected, the attitude that existed at the time of selection of LVLH will be held fixed within the LVLH frame until changed by use of the RHC. The RHC can be used with LVLH selected to change the LVLH attitude. When the RHC returns to detent in any axis, the LVLH attitude in that axis begins to be held fixed. One axis at a time can be put in the free mode with LVLH selected.

#### 2.2.2.3 NORM/VERN Jet Select

Primary RCS (PRCS or NORM) and vernier RCS (VRCS or VERN) jets can be used for attitude hold and maneuvers. NORM jets must be selected for translation maneuvers. These jets are bigger than the verniers (825-pound thrust versus 25-pound) and provide greater redundancy and authority. The vernier jets provide much better fuel efficiency and tighter attitude control. The verniers can tolerate a jet failure only if the failed jet is the left firing aft jet or the right firing aft jet. The primaries can tolerate a multiple failure in any axis. With primaries selected, there is a choice through the DAP CONFIG display (SPEC 20) via the JET OPT for tail jets only or nose jets only to be used for pitch/yaw control.

#### 2.2.2.4 Translation Submodes (NORM Jets Required)

- a. PULSE X, Y, or Z - With this submode selected, each deflection of the THC will result in a change in velocity of the magnitude specified for TRANSLATION PULSE on the DAP CONFIG display for the selected DAP (A or B) in the axis and direction (+ or -) of the THC deflection. In this submode, if simultaneous X and Z translations are commanded, the Z translational pulse will be executed first, then X because of propellant feed limitations.
- b. NORM X, Y, or Z - With one of these submodes selected, continuous acceleration will occur at whatever level is available with the commanded jets for the axis and direction (+ or -) of the THC deflection as long as the THC is deflected.
- c. HIGH Z - An ACCEL submode that is available for +Z translation only. Selection of this submode fires more jets than are fired for the NORM +Z command.
- d. LOW Z - An ACCEL submode that is available for +Z translation only. LOW Z was an "add-on" submode that takes advantage of some +Z thrust components that exist for both the +X and -X translational jets. To get the +Z translation, the +X and -X translational jets are fired simultaneously so that the jets nearly cancel the X components of each other and combine the small +Z components. The result is a small +Z velocity change. This mode was added because it provides translation away from a deployed payload without firing thrusters in the direction of the payload (plume impingement) as would the other +Z translational submodes.

#### 2.2.2.5 Manual Rotational Submodes

- a. DISC RATE - ROLL, PITCH, or YAW - When the DAP mode is manual, the submode is DISC RATE and the RHC is deflected out of the detent (but not past the soft stop) in an axis, jets are fired until an angular rate is achieved in that axis equal to DISC RATE specified in the DAP CONFIG display for the selected DAP (A or B) and selected jet option (NORM or VERN). When the rate is achieved, the jets are turned off until the RHC is returned to detent in that axis unless the jets are momentarily required to maintain attitude or rates within the dead-bands. When the RHC is returned to detent in an axis, the attitude in that axis is snapshotted and jets are fired to stop the rate in the axis and to begin holding the snapshotted attitude.

If the RHC is deflected beyond the soft stop while in DISC RATE, jets are fired continuously, giving a constant angular acceleration (in the axis and sense of the RHC deflection) until the RHC is backed out of the soft stop, at which time the jets are turned off. When the RHC is returned to detent, the attitude is snapshotted and jets are turned on to stop the angular rates and initiate holding the snapshotted attitude. In effect, this provides an ACCEL mode if the RHC is deflected into the soft stop and a free mode when returning the RHC from the soft stop while between the soft stop and detent.

- b. ACCEL - ROLL, PITCH or YAW - When the DAP mode is MAN/ACCEL and the RHC is deflected out of detent, a fixed number of jets are fired to provide constant angular acceleration as long as the RHC is out of detent in the axis and sense of the deflection. When the RHC is returned to detent, the jets are turned off but the angular rates continue. The result is a free mode since the attitude is uncontrolled when the RHC is in detent (free drift at the existing angular rates).
- c. PULSE - ROLL, PITCH or YAW - When the DAP mode is MAN/PULSE and the RHC is deflected out of detent; jets are fired just long enough to achieve the angular rate change specified on the DAP CONFIG display for rotation pulse for the axis and sense of the RHC deflection. PULSE is also a free mode.
- d. THC - From the descriptions, on-orbit THC is essentially the same as for the TRANS DAP (OPS 1 and 3) except for the following:
  - (1) The aft station THC is functional in OPS 2.
  - (2) The additional submodes are described previously for the ON-ORBIT DAP.
- e. RHC - The RHC function is the same as for the TRANS DAP RHC except for the following:
  - (1) The aft station RHC is functional in OPS 2 and has selectable -X and -Z sense.
  - (2) The additional submode is described for the ON-ORBIT DAP.

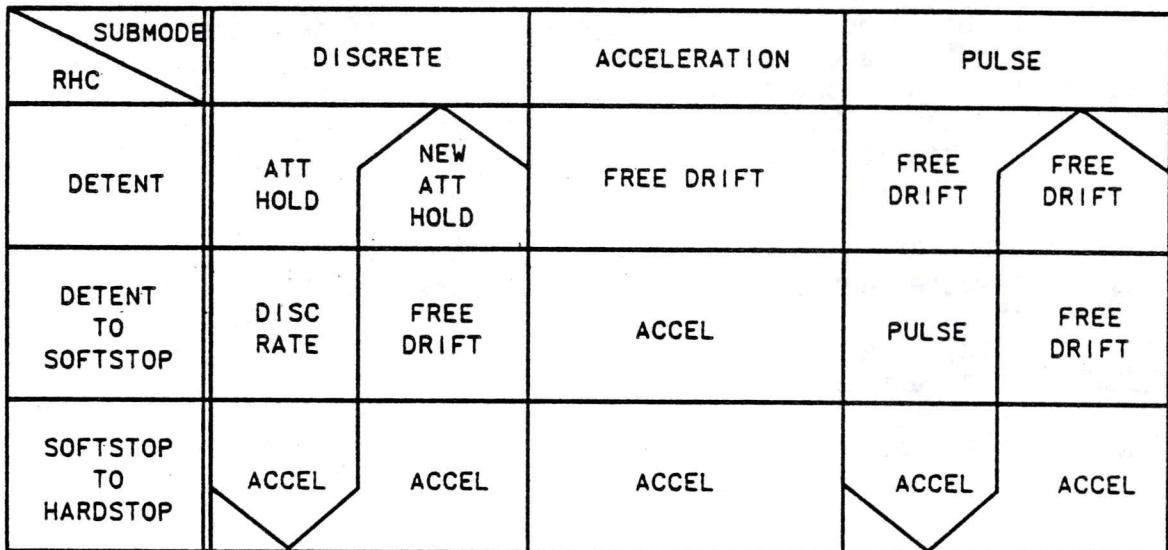
Figure 2-8 is a summary of RHC downmoding in OPS 2.

### 2.3 MNVR XXXXX DISPLAY

An auto maneuver to BURN ATT is available through the MNVR XXXXX display in major modes (MM's) 104, 105, 106, 202, 301, 302, and 303. In these major modes, the BURN ATT is computed and displayed upon execution of the target load (item 22). In major modes 301, 302, and 303, a BURN ATT can be entered through the keyboard (items 24, 25, and 26). (A BURN ATT can be entered at any attitude and need not be related to a burn.) With the DAP AUTO mode selected, the maneuver to BURN ATT will be executed upon execution of the MNVR (item 27).

In major mode 202, the BURN ATT can not be entered through a keyboard entry.

Item entries for the MNVR XXXXX display (fig. 2-9) are described in table 2-IV.



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Figure 2-8.- RHC downmoding in OPS 2.

XXXX/ /	XXXXX MNVR YYYYY	X X DDD/HH:MM:SS BFS DDD/HH:MM:SS
OMS BOTH 1X	BURN ATT	EXEC
L 2XS	24 R XXX	ΔVTOT XXX.X
R 3XS	25 P XXX	TGO XX:XX
RCS SEL 4X	26 Y XXX	
5 TV ROLL XXX	MNVR 27X	VGO X ±XXXX.XX
TRIM LOAD	REI XXXX	Y ±XXX.XX
6 P [±]XX.X	TXX XX:XX	Z ±XXX.XX
7 LY [±]XX.X	GMBL	HA HP
8 RY [±]XX.X	L R	TGT XXX ±XXX
9 WT XXXXXX	P ±X.XS ±X.XS	CUR XXX ±XXX
10 TIG	Y ±X.XS ±X.XS	
XXX/XX:XX:XX.X		
TGT PEG 4		
14 C1 XXXXX	PRI 28X 29X	35 ABORT TGT XX
15 C2 [±]XX.XXXX	SEC 30X 31X	FWD RCS
16 HT XXX.XXX	OFF 32X 33X	ARM 36X
17 eT XXX.XXX	GMBL CK 34X	DUMP 37X
18 PRLT [±]XXXXX	XXXXXXXX	OFF 38X
TGT PEG 7		SURF DRIVE
19 Δ VX [±]XXXX.X		ON 39X
20 Δ VY [±] XXX.X		OFF 40X
21 Δ VZ [±] XXX.X		(XX)
LOAD 22/TIMER 23		

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Figure 2-9.- MNVR XXXXX display. (See table 2-IV.)

TABLE 2-IV.- DESCRIPTION OF MNVR DISPLAY  
(See figure 2-9.)

Item	Description	Units	Limits
1,2, 3,4	Specifies L, R, both OMS or RCS (-X) for guidance computation (+ = pc out of limits).		<sup>a</sup> N/A
5	Defines roll angle at TIG (0 = heads up TVC). Can only be input by crew in MM 202. I-Loaded to 180 in TRANS DAP.	Deg	0 + 359
6,7,8	DAP computation of pitch, left yaw, and right yaw OMS gimbal trim angles.	Deg	-9.9 + 9.9
9	Mass - updatable by guidance, uplink or crew.	Lb	10 <sup>5</sup> + 999.999
10,11, 12,13	MET of ignition (-5 min < TIG-MET < 12 hours).	Deg, hr, min, sec	0 + 365,23,59
14-18	PEG 4 target info and prop usage (OPS 3 only).		
19,20, 21	PEG 7 target data in LVLH coordinates (OPS 1,2,3) PEG 4 and PEG 7 are mutually exclusive.	Ft/sec	X:-999.9 + 9999.9 Y,Z:-999.9 + 999.9
22	Must be executed after all new item entries.		N/A
23	Initiates cathode ray tube (CRT) time countdown to time of ignition (TIG).		N/A
24,25, 26	Specifies roll, pitch, and yaw of desired burn attitude in ADI inertial coordinates.	Deg	R,P:0 + 359 Y:0 + 90
27	Initiates auto preburn MNVR and drives needles.		N/A
28-33	Selects active gimbal drive system.		N/A

<sup>a</sup>Not applicable.

TABLE 2-IV.- Concluded

Item	Description	Units	Limits
34	Checks gimbals then resumes former position.		N/A
35	Selects AOA or ATO (MM104 or MM105 only).		1 + 12
36,37, 38	FWD RCS dump sequence (OPS 3 only).		N/A
39,40	Initiates motion of surfaces (OPS 3 only).		

## 2.4 UNIVERSAL POINTING DISPLAY

The Universal Pointing display provides the capability to input and execute the following maneuver options through keyboard inputs.

- a. MNVR - With this option, the crew can specify the attitude (R, P, Y) relative to an inertial reference for the DAP. The MNVR option can be used to maneuver the Orbiter to this position and to hold the attitude. The underlying sequence is P, Y, R. The inertial reference is the same as the INRTL position of the ADI reference switch.
- b. TRK - The track (TRK) option allows the crew to specify an Orbiter body vector to point at a ground or celestial target or another orbiting vehicle. The attitude can be unconstrained about the pointing vector (2 axes free) or constrained about the pointing vector by specifying a value for an omicron angle (sec. 1.9). If no value for omicron is specified, the DAP maneuvers through the shortest route from the starting attitude to move the pointing vector to the target. If a value for omicron is specified (including 0), then the DAP maneuvers to orient the body vector (pointing vector) to the target with the specified omicron. The DAP maneuvers to attitude at DISC rate plus track rate; track rate is 0 for a celestial target, orbit rate for tracking the center of the Earth (COE), and variable for ground targets. With the center of the earth as a target, this option is used to fly an auto LVLH attitude.
- c. ROT - The rotation option (ROT) allows the crew to initiate an Orbiter rotation about a specified body vector starting from the attitude that exists at the time of initiation of the rotation option.
- d. STOP/ATT HOLD - With this option, the attitude is frozen at the time of execution. If a manual maneuver away from this attitude is performed and TOTAL error is selected for display, the errors will be displayed relative to the initially frozen attitude.

Item entries for the universal pointing display (fig. 2-10) are described in table 2-V.

The capabilities and differences of the Universal Pointing display and the MNVR display in OPS 2 (on-orbit configuration) are summarized in table 2-IV.

2011/ /	UNIV PTG	XX X DDD/HH:MM:SS
	CUR MNVR COMPL	XXX:XX:XX DDD/HH:MM:SS
1	START TIME	XXX/XX:XX:XX CUR FUT
MNVR OPTION	START MNVR	18 X X
5 R XXX-XX	TRK	19 X X
6 P XXX-XX	ROT	20 X X
7 Y XXX-XX	STOP	21 X
TRK/ROT OPTIONS	ATT MON	
8 TGT ID XX	22 MON AXIS	X XX
9 RA XXX.XXX	ERR TOT	23X
10 DEC [±]XXX.XXX	ERR DAP	24X
11 LAT [±]XXX.XXX	ROLL	PITCH YAW
12 LON [±]XXX.XXX	CUR	XXX.XX XXX.XX XXX.XX
13 ALT [±]XXX.XX	REOD	XXX.XX XXX.XX XXX.XX
14 BODY VECT X	ERR	±XXX.XX ±XXX.XX ±XXX.XX
	RATE	±XXX.XX ±XXX.XX ±XXX.XX
15 P XXX-XX	LDG SITE UPDATE	
16 Y XXX.XX	25	PRI XX XXXXX
17 OM XXX.XX	26	SEC XX XXXXX
	27	ALT XX XXXXX
		( XX )

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Figure 2-10.- Universal Pointing display (UNIV PTG).  
(See table 2-V.)

TABLE 2-V.- DESCRIPTION OF UNIVERSAL POINTING DISPLAY  
(See figure 2-10.)

ITEM	DESCRIPTION	UNITS	LIMITS
1,2, 3,4	Specifies MET for start of selected control option. If time is in the past, option will be initiated immediately.	Day Hr Min Sec	0 + 365 0 + 28 0 + 59 0 + 59
5,6,7	Specifies inertial R, P, and Y of desired final attitude (initiated by item 18 EXEC).	Deg	RP:0 + 359.99 Y:0 + 90 or 270 + 359.99
8	Target options: 1 = orbiting vehicle 2 = center of Earth 3 = Earth surface target 4 = center of Sun 5 = celestial targets 11-60 = navigation stars		1 + 5, 11 + 50
9,10	Specifies right ascension and declination of celestial target to be tracked (target ID = 5 must be selected)	Deg	RA:0 + 359.99 DEC:-90 + 90
11,12, 13	Specifies latitude, longitude and altitude of an Earth surface target (target ID = 3 must be selected).	LAT:deg LON:deg ALT:n.mi	-90 + 90 -180 + 180 -99.99 + 99.99
14	1 = +X: 2 = -X: 3 = -Z: 4 = PTC: 5 = selectable		1 + 5 (See note.)
15,16, 17	Specifies pitch, yaw, and omicron of Orbiter body pointing vector (BODY VECT = 5 must be selected). OM remains blank for 2-axis hold and flashes for 3-axis hold.	Deg	P:0 + 359.99 Y:0 + 90 or 270 + 359.99 OM:0 + 359.99
18	Initiates maneuver to attitude specified by MNVR OPTION (items 5, 6, 7) at START TIME.		N/A
19	Points BODY VECT (ITEM 14) at TGT option selected (item 8) at designated START TIME.		N/A

TABLE 2-V.- Concluded

ITEM	DESCRIPTION	UNITS	LIMITS
20	Will rotate Orbiter about the BODY VECT (item 14) at DISC RATE (see SPEC 20).		N/A
21	Terminates maneuver and holds attitude.		N/A
22	Selects coordinate reference for display of attitude, errors and rates (1 = +X: 2 = -X)		1 + 2
23,24	Will display either total or DAP errors to ADI needles and ERR column on this display.		N/A

Note: Body vector 4 (PTC) does not provide rotation about the vehicle +X body axis. The actual axis of rotation is approximately  $2^{\circ}$  below the vehicle +X axis. This is due to the unequal distribution of vehicle mass about the X axis. Using body vector 4 (item 14) will result in a  $\theta \approx 92^{\circ}$ . If body vector 1 (+X axis) is selected, rotation will be about the +X body axis ( $\theta = 90^{\circ}$ ).

TABLE 2-VI.- COMPARISON OF UNIV PTG AND ORBIT MNVR IN OPS 2 (ON-ORBIT CONFIGURATION)

UNIV PTG (OPS 201)		ORBIT MNVR (OPS 202)
Uses	Any attitude maneuver.	Only for preburn maneuver.
R, P, Y entries	Enter items 5, 6, 7 in inertial coordinates or select a target option.	Burn attitude will appear when targeted data is LOADED.
Start time	No constraints on start time.	Time of ignition (TIG) time must be within 5 min in past or 12 hrs in future.
Initiate AUTO MNVR	Item 18 EXEC. * appears in CUR or FUT column	Item 27 EXEC. * appears when MNVR starts (MNVR starts immediately).
Error needles	Can select DAP or TOT. Error can also be read off display.	Total (TOT) errors only.
MAN Downmode during MNVR	Error needles continue to be driven. * remains in CUR column	Error needles zero. * goes away.
Stop MNVR in progress	MNVR STOP (Item 21) or RHC downmode to MAN.	RHC downmode to MAN.
Restart MNVR	Reselect AUTO (if MNVR was stopped due to RHC downmoding). Must also reselect MNVR if STOP option was used.	Reselect AUTO <u>and</u> initiate MNVR again.
At attitude	* remains in current column.	* goes away.

## SECTION 3 NAVIGATION STARS

### 3.1 NAVIGATION STAR DATA

This section considers the 50 navigation stars in special-purpose formats that are used by the pointers when developing vehicle attitude data. The stars are used currently for inertial measurement unit (IMU) alignment and crew optional alignment sight (COAS) calibration and verification purposes.

The 50 navigation stars are listed in table 3-I. The corresponding target identification (ID), right ascension (RA) and declinations (DEC), and magnitude are given.

### 3.2 STAR PAIR COMBINATIONS

The star pair combinations listed in table 3-II have separation angles of  $87.65^\circ \pm 5^\circ$ . These separation angles are the star tracker (ST) limits that allow each star to be within each star tracker's field of view. Table 3-II also includes the inertial attitudes (given a P, Y, R Orbiter maneuver sequence) that are based on the starball Relative Matrix (RELMAT).

Table 3-II(a) contains two sets of attitude data for each star pair; first, with the -Z star tracker boresight on star number 1, and second, with the -Z star tracker boresight on star number 2. This table is useful in determining star pair attitudes when -Z COAS activity uses the same star as will be used by the -Z star tracker.

In table 3-II(b), the two sets of inertial attitude data take into account the star pair separation angle and the star tracker separation angle. Basically, the attitudes shown have been determined by dividing the difference in the star tracker separation and star pair separation in roll. This table is commonly used for star pair attitudes for IMU alignments.

### 3.3 IMU ALIGNMENT ATTITUDES

The IMU alignment attitudes place a navigation star in each star tracker. The star pairs used are individually selected for each IMU alignment to maximize the availability of the stars for the time of the alignment period. Star selection is also based on the following:

- a. Sunlit Earth - Stars are selected that are greater than  $20^{\circ}$  above the Earth's horizon for the period of star tracker acquisition (bright object sensor (BOS) problem).
- b. Dark Earth - Stars are selected that are greater than  $3^{\circ}$  above the Earth's horizon for the period of star tracker acquisition (BOS problem).
- c. Moon - Stars are selected that are not within  $8^{\circ}$  of the Moon's horizon (BOS problem).
- d. Sun - Stars are selected that are not within  $25^{\circ}$  of the Sun's horizon (BOS problem).
- e. Planets - Stars are selected that are not within  $2^{\circ}$  of the planet's horizon.

During the star acquisition, the vehicle attitude deadband should not exceed  $3.5^{\circ}$  because of the real possibility of not being able to lock on the stars due to a combination of star pair separation and star tracker separation.

Stars selected for an alignment should have a separation angle within  $90^{\circ} \pm 30^{\circ}$ . With separation angles other than this, accuracy is degraded.

Note that, because of reflection problems on the star trackers due to very bright objects, the navigation star Sirius will not be used for star tracker alignments. This is star number 11.

TABLE 3-I.- NAVIGATION STARS

Celestial target ID	Name	Right ascension	Declination		Magnitude (S20)
			N/S	+/-	
11	SIRIUS	100.7316	16.6562 S	-16.6562	-1.50
12	CANOPUS	95.7107	52.6676 S	-52.6676	-0.80
13	RIGEL	78.0333	8.2581 S	-8.2581	0.30
14	VEGA	278.8134	38.7382 N	38.7382	0.10
15	HADAR	210.0684	60.1330 S	-60.1330	0.80
16	ACHERNAR	23.9647	57.4905 S	-57.4905	0.60
17	ACRUX	185.9523	62.8221 S	-62.8221	1.50
18	CAPELLA	78.2489	45.9459 N	45.9459	0.20
19	SPICA	200.6384	10.9014 S	-10.9014	1.20
20	ARCTURUS	213.3353	19.4253 N	19.4253	0.20
21	PROCYON	114.1654	5.3459 N	5.3459	0.50
22	ALTAIR	297.0903	8.7379 N	8.7379	0.80
23	BETELGUESE	88.1161	7.3995 N	7.3995	0.10
24	BELLATRIX	80.6121	6.3060 N	6.3060	1.70
25	REGULUS	151.4258	12.2122 N	12.2122	1.30
26	FOMALHAUT	343.7260	29.8891 S	-29.8891	1.20
27	DENEBO	309.9313	45.1008 N	45.1008	1.30
28	AL NA'IR	331.2740	47.2054 S	-47.2054	2.10
29	ALKAI	206.3914	49.5621 N	49.5621	1.90
30	ANTARES	246.5840	26.3230 S	-26.3230	1.20
31	CASTOR	112.8513	31.9985 N	31.9985	1.90
32	ALDEBARAN	68.2627	16.4087 N	16.4087	1.00
33	PEACOCK	305.4260	56.8980 S	-56.8980	2.10
34	MIAPLACIDUS	138.1618	69.5103 S	-69.5103	1.80
35	NUNKI	283.0414	26.3613 S	-26.3613	2.10
36	KAUS ASTRALIS	275.2130	34.4114 S	-34.4114	1.90
37	ALPHERATZ	1.4504	28.8131 N	28.8131	2.10
38	NAVI	13.4184	60.4464 N	60.4464	2.80
39	ALHENA	98.7062	16.4432 N	16.4432	1.90
40	MIRFAK	50.1854	49.6848 N	49.6848	1.90
41	DENEBOA	176.6233	14.8507 N	14.8507	2.20
42	ALPHECCA	233.1436	26.8808 N	26.8808	2.30
43	RASALHAGUE	263.1539	12.5931 N	12.5931	2.10
44	MERAK	164.7108	56.6511 N	56.6511	2.40
45	POLARIS	27.2247	89.0289 N	89.0289	2.10
46	ALCOR	177.8039	53.9728 N	53.9728	2.50
47	GIENAH	183.3065	17.2643 S	-17.2643	2.70
48	ZUBENESCHEMALI	228.5770	9.2000 S	-9.2000	2.70
49	KOCHAB	222.7061	74.3598 N	74.3598	2.20
50	AVIOR	125.3720	59.3480 S	-59.3480	1.70
51	ATRIA	250.8380	68.9392 S	-68.9392	1.80
52	HAMAL	31.0888	23.2257 N	23.2257	2.20
53	MENKENT	210.9275	36.1293 S	-36.1293	2.20
54	DIPHDA	10.2720	18.2605 S	-18.2605	2.20
55	ALPHARD	141.2824	8.4406 S	-8.4406	2.10
56	AL SUHAIL	136.5385	43.2299 S	-43.2299	2.20
57	ACAMAR	44.0906	40.5039 S	-40.5039	3.40
58	DENAB ALGEDI	326.0731	16.3577 S	-16.3579	2.90
59	SCHEAT	345.3384	27.8123 N	27.8123	2.60
60	ENIF	325.4323	9.6447 N	9.6447	2.50

TABLE 3-II.- STAR PAIRS FOR -Z ST/-Y ST

(a) Inertial attitude data with star 1 (2) boresight in -Z star tracker

Star pair	Star ID	SEP angle, deg (1)	Inertial attitudes, deg (P, Y, R, Euler sequence)					
			Maneuver sequence 1 (2)			Maneuver sequence 2 (3)		
			R	P	Y	R	P	Y
1	11	15	84.80	342.62	0.49	322.47	290.03	171.61
2	11	44	90.48	198.81	194.12	341.05	68.16	31.92
3	11	51	91.78	345.02	6.82	339.42	292.01	178.53
4	11	54	85.27	326.69	42.36	56.38	290.25	209.54
5	12	19	90.17	278.16	285.94	320.83	348.92	118.20
6	12	31	85.98	234.62	187.54	355.76	33.95	24.86
7	13	17	90.65	353.39	344.78	323.81	286.20	153.41
8	13	26	89.59	346.93	0.84	48.12	269.74	161.16
9	12	38	85.16	193.91	159.08	36.17	83.42	355.88
10	14	19	87.79	61.87	138.79	46.30	194.18	296.62
11	14	26	91.44	62.87	240.28	318.31	228.91	35.62
12	14	41	89.93	103.11	84.48	52.68	161.46	252.14
13	14	52	91.43	130.93	332.47	326.45	146.17	149.21
14	15	25	86.00	259.70	235.30	25.13	18.39	72.72
15	15	42	89.05	242.36	307.62	353.08	28.81	144.82
16	15	43	84.10	248.26	336.29	338.78	14.38	172.52
17	15	58	88.01	283.25	53.19	329.85	344.40	242.96
18	16	23	82.89	250.84	161.88	332.26	9.02	357.99
19	16	30	88.88	301.32	318.26	12.09	332.84	143.44
20	16	37	88.36	243.38	86.79	13.65	33.38	284.72
21	16	53	86.20	304.46	291.08	355.48	325.37	114.28
22	16	59	91.27	247.70	73.79	19.87	34.27	272.61
23	17	20	85.03	245.48	288.63	351.04	21.33	124.91
24	17	21	86.60	267.87	194.94	24.62	10.21	30.85
25	17	26	85.60	296.24	70.01	344.86	332.11	255.43
26	18	41	85.05	114.84	112.20	323.71	160.28	282.77
27	18	54	88.72	59.96	307.86	34.75	201.61	107.97
28	18	57	91.68	48.58	339.08	11.88	222.85	140.55
29	19	21	87.56	290.93	181.33	76.07	86.70	108.88
30	19	33	88.77	349.32	103.80	318.03	289.03	272.96
31	19	49	86.38	193.08	287.53	4.15	76.57	122.51
32	20	31	88.24	142.97	337.91	61.74	131.14	160.94
33	20	51	92.38	23.77	133.69	339.07	257.02	296.65
34	21	29	87.37	174.52	198.50	330.45	87.28	33.62
35	21	38	90.60	176.91	205.64	39.51	103.96	38.31
36	21	45	84.60	176.97	202.95	11.62	92.10	34.74
37	21	49	89.75	176.44	201.50	355.91	94.44	33.49
38	22	29	83.81	170.88	34.31	50.88	105.33	227.25
39	22	51	84.04	10.55	208.63	4.93	254.38	13.68
40	22	52	90.20	163.56	10.67	305.67	89.69	213.57
41	22	53	92.07	11.82	201.99	43.06	245.89	357.99
42	23	34	84.13	11.28	4.22	334.44	261.61	169.05
43	23	37	83.53	165.22	193.35	71.51	116.28	29.46
44	23	41	86.68	160.61	157.90	296.79	75.96	13.19
45	23	46	83.84	172.70	172.08	334.79	87.22	5.90
46	24	34	85.19	10.25	356.44	332.75	264.04	161.36
47	24	45	83.12	175.99	169.57	11.45	91.54	1.21
48	24	46	89.10	173.96	165.18	335.24	91.24	359.05
49	24	59	91.69	168.53	182.72	71.87	121.34	18.99
50	25	40	87.82	165.85	252.26	49.07	112.42	82.84
51	26	30	82.86	316.65	289.59	42.37	307.97	107.53
52	26	43	88.28	263.72	353.24	57.48	38.35	207.64
53	26	50	85.29	329.56	240.39	333.92	300.53	55.80
54	27	30	91.74	55.02	188.24	30.46	210.41	348.00

<sup>1</sup>SEP = 87.65° ± 5°.<sup>2</sup>R<sub>1</sub>, P<sub>1</sub>, Y<sub>1</sub> = star number 1 (-Z ST).<sup>3</sup>R<sub>2</sub>, P<sub>2</sub>, Y<sub>2</sub> = star number 2 (-Z ST).

TABLE 3-II.- Continued

Star pair	Star ID		SEP angle, deg (1)	Inertial attitudes, deg (P,Y,R Euler sequence)						
	1	2		Maneuver sequence 1 (2)			Maneuver sequence 2 (3)			
				R	P	Y	R	P	Y	
55	27	36	85.51	48.08	208.85	13.98	216.73	10.92	347.77	
56	27	43	90.49	69.89	162.08	42.60	191.52	322.01	326.32	
57	27	54	83.70	71.06	279.59	321.73	210.48	77.86	44.38	
58	28	43	85.00	259.65	349.57	39.00	23.38	190.76	312.64	
59	28	48	91.72	293.46	298.67	35.52	349.98	130.53	308.39	
60	28	52	88.59	236.80	93.38	331.03	26.49	292.69	24.25	
61	28	56	88.63	313.17	226.95	344.09	318.77	47.82	358.06	
62	29	30	83.88	61.95	155.98	334.11	214.36	316.86	30.07	
63	29	39	88.48	103.55	8.38	41.33	162.49	177.87	334.26	
64	29	53	85.79	52.61	128.72	352.62	219.18	291.07	9.45	
65	30	56	85.42	330.41	174.79	27.95	294.39	348.08	315.36	
66	30	60	84.46	230.24	18.67	303.40	14.57	226.98	51.12	
67	31	37	90.90	127.48	249.66	52.18	144.34	66.03	325.74	
68	31	47	83.47	71.17	88.11	306.95	220.30	238.47	57.80	
69	31	50	91.94	35.56	33.91	347.02	243.21	195.91	8.59	
70	32	46	87.72	163.34	149.04	338.50	102.74	339.29	36.90	
71	32	49	87.78	165.68	157.16	4.29	104.98	346.14	11.09	
72	32	50	88.71	23.35	352.34	326.62	257.77	154.11	25.12	
73	32	56	86.26	30.52	2.06	310.85	255.99	158.72	42.21	
74	33	47	91.64	296.90	254.96	20.04	342.00	82.86	323.14	
75	33	59	91.17	240.92	54.77	345.18	29.82	252.65	9.92	
76	34	39	90.34	258.08	181.42	12.89	20.66	17.99	338.37	
77	34	41	88.58	253.35	252.45	348.87	16.74	88.28	2.60	
78	34	54	84.87	288.18	85.32	10.36	342.73	273.72	334.08	
79	35	47	90.74	315.53	232.82	49.12	319.72	54.07	292.80	
80	35	50	92.32	335.60	195.38	359.61	299.34	9.66	343.03	
81	36	50	82.96	327.38	189.61	2.40	298.14	5.19	340.89	
82	36	54	83.80	283.30	108.97	302.88	335.03	300.55	41.43	
83	36	57	91.53	318.20	156.22	321.45	316.89	335.98	20.39	
84	36	59	90.89	225.24	33.34	322.17	35.34	235.99	36.25	
85	37	39	88.26	131.06	47.43	311.28	143.76	223.76	66.46	
86	37	43	91.05	100.74	171.43	63.10	160.60	335.61	312.74	
87	38	42	86.85	114.05	143.83	22.63	154.64	317.52	353.98	
88	38	43	88.69	99.51	178.00	30.94	168.17	347.03	343.87	
89	38	58	85.66	66.64	253.50	18.30	198.20	56.95	348.96	
90	39	47	89.88	70.44	76.22	290.15	253.28	202.89	69.35	
91	40	57	90.35	51.88	326.12	357.94	222.79	128.11	3.50	
92	41	43	83.51	142.94	230.05	297.58	109.52	65.17	79.16	
93	41	50	84.95	16.69	85.47	13.18	246.80	248.92	339.36	
94	42	60	87.67	124.30	269.95	305.02	156.91	78.78	72.12	
95	43	44	84.07	166.82	1.94	42.96	106.87	192.57	332.15	
96	43	47	84.29	22.88	156.18	58.90	214.44	301.33	299.27	
97	44	48	83.95	81.63	145.68	330.41	195.76	308.02	39.12	
98	44	52	91.09	114.37	300.87	27.84	157.78	113.79	349.02	
99	48	49	83.64	191.84	314.34	11.54	76.96	149.04	357.84	
100	48	50	88.71	351.47	144.13	18.62	275.30	311.92	327.24	
101	48	55	86.01	329.71	169.71	68.37	256.16	305.30	276.42	
102	48	56	85.19	348.99	148.04	35.44	269.32	312.91	311.02	
103	49	60	84.10	98.73	248.58	348.14	172.35	57.60	25.83	
104	50	54	86.32	292.88	80.97	20.53	340.78	269.10	323.33	
105	51	54	82.84	280.67	95.97	338.45	343.28	284.92	6.78	
106	51	55	88.97	283.27	217.81	15.58	353.51	48.97	329.72	
107	55	57	89.93	349.52	60.74	37.53	272.68	225.03	308.24	
108	57	59	87.37	242.35	84.60	39.07	43.58	287.70	317.99	
109	57	60	87.79	267.29	50.25	47.06	23.39	254.78	303.34	

<sup>1</sup>SEP = 87.65° ± 50.<sup>2</sup>R1, P1, Y1 = star number 1 (-Z ST).<sup>3</sup>R2, P2, Y2 = star number 2 (-Z ST).

TABLE 3-II.- Continued

(b) Inertial attitude data with difference between star pair separation angle and star tracker separation angle split

Star pair	Star ID	SEP angle, deg (1)	Inertial attitudes, deg (P,Y,R Euler sequence)					
			Maneuver sequence 1 (2)			Maneuver sequence 2 (3)		
			R	P	Y	R	P	Y
1	11	15	84.80	344.04	0.49	322.47	291.45	171.61
2	11	44	90.48	197.39	194.12	341.05	66.74	31.92
3	11	51	91.78	342.96	6.82	339.42	289.95	178.53
4	11	54	85.27	327.88	42.36	56.38	291.44	209.54
5	12	19	90.17	276.90	285.94	320.83	347.66	118.20
6	12	31	85.98	235.46	187.54	355.76	34.79	24.86
7	13	17	90.65	351.89	344.78	323.81	284.70	153.41
8	13	26	89.59	345.96	0.84	48.12	268.77	161.16
9	13	38	85.16	195.15	159.03	36.17	84.66	355.88
10	14	19	87.79	61.80	138.79	46.30	194.11	296.62
11	14	26	91.44	60.98	240.28	318.31	227.02	35.62
12	14	41	89.93	101.97	84.48	52.68	160.32	252.14
13	14	52	91.43	129.04	332.47	326.45	144.28	149.21
14	15	25	86.00	260.53	235.30	25.13	19.22	72.72
15	15	42	89.05	241.66	307.62	353.08	28.11	144.82
16	15	43	84.10	250.04	336.29	338.78	16.16	172.52
17	15	58	88.01	283.07	53.19	329.85	344.22	242.96
18	16	23	82.89	253.22	161.88	332.26	11.40	357.99
19	16	30	88.88	300.70	318.26	12.09	332.22	143.44
20	16	37	88.36	243.02	86.79	13.65	33.02	284.72
21	16	53	86.20	305.19	291.08	355.48	326.10	114.28
22	16	59	91.27	245.89	73.79	19.87	32.46	272.61
23	17	20	85.03	246.79	288.63	351.04	22.64	124.91
24	17	21	86.60	268.39	194.94	24.62	10.73	30.85
25	17	26	85.60	297.27	70.01	344.86	333.14	255.43
26	18	41	85.05	116.14	112.20	323.71	161.58	282.77
27	18	54	88.72	59.43	307.86	34.75	201.08	107.97
28	18	57	91.68	46.57	339.08	11.88	220.84	140.55
29	19	21	87.56	290.97	181.33	76.07	86.74	108.88
30	19	33	88.77	348.76	103.80	318.03	288.47	272.96
31	19	49	86.38	193.72	287.53	4.15	77.21	122.51
32	20	31	88.24	142.67	337.91	61.74	130.84	160.94
33	20	51	92.38	21.41	133.69	339.07	254.66	296.65
34	21	29	87.37	174.66	198.50	330.45	87.42	33.62
35	21	38	90.60	175.43	205.64	39.51	102.48	38.31
36	21	45	84.60	178.49	202.95	11.62	93.62	34.74
37	21	49	89.75	175.39	201.50	355.91	93.39	33.49
38	22	29	83.81	172.80	34.31	50.88	107.25	227.25
39	22	51	84.04	12.36	208.63	4.93	256.19	13.68
40	22	52	90.20	162.29	10.67	305.67	88.42	213.57
41	22	53	92.07	9.61	201.99	43.06	243.68	357.99
42	23	34	84.13	13.04	4.22	334.44	263.37	169.05
43	23	37	83.53	167.28	193.35	71.51	118.34	29.46
44	23	41	86.68	161.10	157.90	296.79	76.45	13.19
45	23	46	83.84	174.61	172.08	334.79	89.13	5.90
46	24	34	85.19	11.48	356.44	332.75	265.27	161.36
47	24	45	83.12	178.26	169.57	11.45	93.81	1.21
48	24	46	89.10	173.23	165.18	335.24	90.51	359.05
49	24	59	91.69	166.51	182.72	71.87	119.32	18.99
50	25	40	87.82	165.76	252.26	49.07	112.33	82.84
51	26	30	82.86	319.05	289.59	42.37	310.37	107.53
52	26	43	88.28	263.40	353.24	57.48	38.03	207.64
53	26	50	85.29	330.74	240.39	333.92	301.71	55.80
54	27	30	91.74	52.98	188.24	30.46	208.37	348.00
55	27	36	85.51	49.15	208.85	13.98	217.80	10.92

<sup>1</sup>SEP = 87.650 ± 50.<sup>2</sup>R1, P1, Y1 = star number 1 (-Z ST).<sup>3</sup>R2, P2, Y2 = star number 2 (-Z ST).

TABLE 3-II.- Concluded

Star pair	Star ID	SEP angle, deg (1)	Inertial attitudes, deg (P,Y,R Euler sequence)						
			Maneuver sequence 1 (2)			Maneuver sequence 2 (3)			
			R	P	Y	R	P	Y	
56	27	48	90.49	68.47	162.08	42.60	190.10	322.01	326.32
57	27	54	83.70	73.04	279.59	321.73	212.46	77.88	44.38
58	28	43	85.00	260.97	349.57	39.00	24.70	190.76	312.64
59	28	48	91.72	291.42	298.67	35.52	347.94	130.53	308.39
60	28	52	88.59	236.33	93.38	331.03	26.02	292.69	24.25
61	28	56	88.63	312.68	226.95	344.09	318.28	47.82	358.06
62	29	30	83.88	63.83	155.98	334.11	216.24	316.86	30.07
63	29	39	88.48	103.13	8.38	41.33	162.07	177.87	334.26
64	29	53	85.79	53.54	128.72	352.62	220.11	291.07	9.45
65	30	56	85.42	331.53	174.79	27.95	295.51	348.08	315.36
66	30	60	84.46	231.84	18.67	303.40	16.17	226.98	51.12
67	31	37	90.90	125.85	249.66	52.18	142.71	66.03	325.74
68	31	47	83.47	73.26	88.11	306.95	222.39	238.47	57.80
69	31	50	91.94	33.42	33.91	347.02	241.07	195.91	8.59
70	32	46	87.72	163.30	149.04	338.50	102.70	339.29	36.90
71	32	49	87.78	165.61	157.16	4.29	104.91	346.14	11.09
72	32	50	88.71	22.82	352.34	326.62	257.24	154.11	25.12
73	32	56	86.26	31.21	2.06	310.85	256.68	158.72	42.12
74	33	47	91.64	294.90	254.96	20.04	340.00	82.86	323.14
75	33	59	91.17	239.16	54.77	345.18	28.06	252.65	9.92
76	34	39	90.34	256.73	181.42	12.89	19.31	17.99	338.37
77	34	41	88.58	252.89	252.45	348.87	16.28	88.28	2.60
78	34	54	84.87	289.57	85.32	10.36	344.12	273.72	334.08
79	35	47	90.74	313.99	232.82	49.12	318.18	54.07	292.80
80	35	50	92.32	333.26	195.38	359.61	297.00	9.66	343.03
81	36	50	82.96	329.72	189.61	2.40	300.48	5.19	340.89
82	36	54	83.80	285.22	108.97	302.88	336.95	300.55	41.43
83	36	57	91.53	316.26	156.22	321.45	314.95	335.98	20.39
84	36	59	90.89	223.62	33.34	322.17	33.72	235.99	36.25
85	37	39	88.26	130.75	47.43	311.28	143.45	223.76	66.46
86	37	43	91.05	99.04	171.43	63.10	158.90	335.61	312.74
87	38	42	86.85	114.45	143.83	22.63	155.04	317.52	353.98
88	38	43	88.69	98.99	178.00	30.94	167.65	347.03	343.87
89	38	58	85.66	67.64	253.50	18.30	199.20	56.95	348.96
90	39	47	89.88	69.33	76.22	290.15	252.17	202.89	69.35
91	40	57	90.35	50.53	326.12	357.94	321.44	128.11	3.50
92	41	43	83.51	145.01	230.05	297.58	111.59	65.17	79.16
93	41	50	84.95	18.04	85.47	13.18	248.15	248.92	339.36
94	42	60	87.67	124.29	269.95	305.02	156.90	78.78	72.12
95	43	44	84.07	168.61	1.94	42.96	108.66	192.57	332.15
96	43	47	84.29	24.56	156.18	58.90	216.12	301.33	299.27
97	44	48	83.95	83.48	145.68	330.41	197.61	308.02	39.12
98	44	52	91.09	112.65	300.87	27.84	156.06	113.79	349.02
99	48	49	83.64	193.84	314.34	11.54	78.96	149.04	357.84
100	48	50	88.71	350.94	144.13	18.62	274.77	311.92	327.24
101	48	55	86.01	330.53	169.71	68.37	256.98	305.30	276.42
102	48	56	85.19	350.22	148.04	35.44	270.55	312.91	311.02
103	49	60	84.10	100.50	248.58	348.14	174.12	57.60	25.83
104	50	54	86.32	293.54	80.97	20.53	341.44	269.10	323.33
105	51	54	82.84	282.08	95.97	338.45	345.69	284.92	6.78
106	51	55	88.97	282.61	217.81	15.58	352.85	48.97	329.72
107	55	57	89.93	348.38	60.74	37.53	271.54	225.03	308.24
108	57	59	87.37	242.49	84.60	39.07	43.72	287.70	317.99
109	57	60	87.79	267.22	50.25	47.06	23.32	254.78	303.34

<sup>1</sup>SEP = 87.65° ± 5°.<sup>2</sup>R1, P1, Y1 = star number 1 (-Z ST).<sup>3</sup>R2, P2, Y2 = star number 2 (-Z ST).

## SECTION 4 POINTING

This section will focus on some of the pointing computer programs that are used when developing vehicle attitude data for the CAP. These attitude data range from COAS/STAR TRACKER LOS information for specified targets to peculiar payload attitude requirements. The intent of the discussion is to provide the information necessary to understand what the programs do and what the inputs and the resultant outputs are.

These programs are available for use on an HP9825 desk top computer. In addition, some of the programs are duplicated for use on a real-time basis on the mission operations computer (MOC). These program duplications will be pointed out as appropriate in the discussion.

### 4.1 DESCRIPTION OF SUPERSIGHTER PROGRAM (HP9825)

#### 4.1.1 Purpose

The Supersighter Program will provide instrument pointing angles and the spacecraft attitude required to point at targets of interest. The Supersighter Program operates in seven different modes. An explanation of each mode and what is required to be input is discussed in section 4.1.4.

The Supersighter Program is for the HP9825 with floppy disk and thermal printer peripherals. The program is based on the Real-Time Computer Command (RTCC) Supersighter Program requirements.

#### 4.1.2 Display Description

The generic output format (fig. 4-1) for the Supersighter Program is output after each run. The display parameters and their descriptions are

Input Matrix - The source reference matrix for the input attitude.

Output Matrix - The desired reference matrix for the output A and B inertial attitudes.

ATT source - This will always be "MED" for this version of the program. It is hard coded to always appear on the format.

EPH - The ephemeris file being used for the Orbiter state vectors.

VID - The vector identification (ID) of the desired state vector to be used from the specified ephemeris file.

I/P LVLH Bias - The source bias matrix used with the source Relative Matrix (RELMAT) for local vertical local horizontal (LVLH) offset attitude reference. This matrix ID will

define whether the input LVLH attitude is offset and either a P, Y, R or Y, P, R Euler angle sequence.

**O/P LVLH Bias** - The desired bias matrix used with the desired reference matrix for LVLH offset attitude reference. This matrix ID will define whether the output A & B LVLH attitudes are either a P, Y, R or Y, P, R Euler angle sequence.

**Mode** - The desired supersighter mode.

**Eigen vector** - The eigen axis is defined by a pitch and yaw (P, Y) to bring the Orbiter +X axis along the single axis of rotation. The eigen angle (eigen ang) is the rotation about that axis.

**ELV** - Elevation angle for ground targets is the angle between the target local horizontal and the line-of-sight (LOS) from the Orbiter to the target. For celestial targets, the elevation angle is the angle between the line-of-sight from the Orbiter to the Earth horizon and the line-of-sight from the Orbiter to the target.

**Input ATT sense** - The sense direction for input attitude direction indicator (ADI) or LVLH attitudes. For inertial measurement unit (IMU) input attitudes, the input matrix defines which IMU is to be used.

**VEH range** - The slant range to target 1 when target 1 is another vehicle.

**Mode 2 Lat&Lon** - In mode 2, the latitude and longitude is output if the instrument LOS intersects the Earth.

**R, P, Y** - The input desired attitude angles roll (R), pitch (P), and yaw (Y) WRT the input matrix reference frame.

**MGA** - The input middle gimbal angle (second angle of attitude Euler sequence).

**Target 1** - The target 1 identification.

**Target 2** - The target 2 identification.

**Target 1&2 RA, DEC** - The right ascension (RA) and declination (DEC) of target 1 or 2.

**Target 1 Lat, Lon, Alt** - When a ground site ID is input, the latitude, longitude, and altitude of the ground site.

**Target 1 RNG** - The slant range to target 1 when target 1 is a ground target.

**Output A attitude** - The computed angles via modes 3, 4, 5, 6, and 7 or the attitude which is input by modes 1, 2 (input via attitude source). The computed angles are for acquisition of signal (AOS) time. LVLH A attitudes

are also computed at AOS time. For ADI and LVLH attitudes, the +X, -X, and -Z sense attitudes are output. For IMU attitudes, only the +X sense inertial and LVLH attitudes are output.

**Output B attitude** - The second solution for mode 5 at AOS time (same attitude sense and start time definition as solution A). LVLH B attitudes are also computed at AOS time.

**IA1, IA2, IB1, IB2** - Supersighter temporary instrument ID. The instrument ID indicators signify

I = Instrument  
A = Solution computed for this instrument when vehicle assumes output A attitudes.  
B = Solution computed for this instrument when vehicle assumes output B attitudes.  
1 = Solution computed for this instrument corresponding to position of target 1 (for A or B).  
2 = Solution computed for this instrument corresponding to position of target 2 (for A or B).

For each instrument, the occultation of the target by the Earth, Moon, Sun, and Earth airglow (400,000 feet) will be tested for all modes, and an E, M, S, A symbol will be output to the right of the instrument ID if occultation occurs.

**A1 & A2** - Instrument pointing angles A1 and A2 corresponding to a given instrument (IA1, IA2, IB1, IB2) and its associated attitudes (A or B) and target ID (1 or 2) such that the target is seen at the instrument angles through the instrument at the given attitudes at AOS. An \* will be output to the right of the instrument angle if the angle is outside the instruments minimum or maximum angle limits.

**A3** - Omicron, the angle between the plane formed by the target vector and the negative orbital angular momentum vector and the plane formed by the target vector and the body -Y axis when the pointing vector is aligned with the target vector.

**ST** - The mission elapsed time (MET) or Greenwich mean time (GMT) input for start time. If the input MET or GMT is during a viewing period or mode 2 is selected, then the input start time will be used for solutions. Otherwise, the next AOS time will be used for the solutions.

**AOS** - The MET and GMT of acquisition of target.

**TCA** - The MET and GMT of time of closest approach to the target by the Orbiter.

LOS - The MET and GMT of loss of target.

+X, -Z RA/DEC - The right ascension and declination of the +X and -Z axes of the Orbiter for output A attitude at AOS.

P, Y and T, P - The look angles in a pitch, yaw sequence (P, Y) and phi, theta sequence (T, P) that would place the vehicle body X axis along the LOS to the Earth, Moon and Sun. The angles are computed for all modes at AOS for the output A attitude.

SUPERSIGHTER

INPUT MATRIX	SSSSSS	ATT SOURCE	SSSS	I/P	LVLH	BIAS	SSSSSS
OUTPUT MATRIX	SSSSSS	EPH S	VID SSS	O/P	LVLH	BIAS	SSSSSS

MODE SSSSS

EIGEN VECTOR

P XXX.XX  
Y XXX.XX  
EIGEN ANG XXX.XX

ELV +XXX.XX  
VEH

INPUT ATT SENSE SSSSS

R XXX.XX MGA XXX.XX  
P XXX.XX  
Y XXX.XX

RANGE XXXXX.X  
MODE 2  
LAT XXX.XXS  
LON XX.XXS

IA1 SSS SSSSS

! A1 +XXX.XX S

TARGET 1 SSSSS

OUTPUT A

! A2 +XXX.XX S

RA XXX.XX

R XXX.XX R XXX.XX R XXX.XX

! A3 +XXX.XX S

DEC XX.XXS

P XXX.XX P XXX.XX P XXX.XX

!IA2 SSS SSSSS

LAT XX.XXS

Y XXX.XX Y XXX.XX Y XXX.XX

! A1 +XXX.XX S

LON XXX.XXS

R XXX.XX R XXX.XX R XXX.XX

! A2 +XXX.XX S

ALT XXXXXX

P XXX.XX P XXX.XX P XXX.XX

LVLH!

RNG XXXXX.X

Y XXX.XX Y XXX.XX Y XXX.XX

(SSS)!

!IB1 SSS SSSSS

OUTPUT B

! A1 +XXX.XX S

+X -X -Z

! A2 +XXX.XX S

TARGET 2 SSSSS

R XXX.XX R XXX.XX R XXX.XX

!IB2 SSS SSSSS

RA XXX.XX

P XXX.XX P XXX.XX P XXX.XX

! A1 +XXX.XX S

DEC XX.XXS

Y XXX.XX Y XXX.XX Y XXX.XX

! A2 +XXX.XX S

R XXX.XX R XXX.XX R XXX.XX

LVLH!

P XXX.XX P XXX.XX P XXX.XX

(SSS)!

!IB1 SSS SSSSS

MET

GMT

ST XXX:XX:XX:XX

XXX:XX:XX:XX

+X RA XXX.XX

E M S

P XXX XXX XXX

AOS XXX:XX:XX:XX

XXX:XX:XX:XX

DEC XX.XXS

Y XXX XXX XXX

TCA XXX:XX:XX:XX

XXX:XX:XX:XX

-Z RA XXX.XX

T XXX XXX XXX

LOS XXX:XX:XX:XX

XXX:XX:XX:XX

DEC XX.XXS

P XXX XXX XXX

Note: For modes 1, 4, 5, 6, and 7 if the target is not AOS at input time, the ST will be automatically changed to target AOS time. As a result, the LVLH attitude will be referenced to that target AOS time, not the input time.

#### 4.1.3 Med Inputs

On the HP9825, special function keys are used by the Supersighter Program for input of the required data for each mode. Figure 4-2 shows what the special function key overlay looks like. The upper label for each key is obtained by keying "shift" then the desired function key. The following is a list of key inputs and, where required, what the valid inputs are.

Mode - The desired Supersighter mode. Valid modes are 1 thru 7.

INMAT - The input matrix ID. Valid inputs are

RLMTxx = ADI reference matrix (RELMAT)  
RFMTxx = IMU reference matrix (REFSMMAT)  
LPYR = Input ATT is LVLH with a P, Y, R Euler sequence.  
LYPR = Input ATT is LVLH with a Y, P, R Euler sequence.

OUTMAT - The output matrix ID. Valid inputs are

RLMTxx = ADI reference matrix (RELMAT)  
RFMTxx = IMU reference matrix (REFSMMAT)

EPHxxx - Ephemeris ID. Valid inputs are 1 to end-of-file.

VID - Vector ID. Valid inputs are 1 to end-of-file.

ELV - Elevation angle

TGT1 - Target 1 ID. Valid inputs are

Cxxx = Celestial targets 001-400 (star tracker stars  
are 11 to 60)  
Gxxx = Ground targets 001-100  
Ex = Orbital target ephemeris (EPHxxx) (A target ephemeris  
cannot be the same as the Orbiter ephemeris.)

ΔCOE = Center of Earth

ΔCOM = Center of Moon

ΔSUN = Center of Sun

TDRE = TDRS east

TDRW = TDRS west

TDRS = TDRS spare

Note: Δ means space or blank.

TGT2 - Target 2 ID. Valid inputs are the same as those valid for target 1 with the one exception of ground targets. Ground targets cannot be input as a target 2 ID.

IA1 - Instrument ID for output A attitude and target 1. Valid inputs are S01 thru S25. The instruments currently defined are listed in table 1-1.

IA2 - Instrument ID for output A attitude and target 2. Valid inputs same as for IA1.

IB1 - Instrument ID for output B attitude and target 1. Valid inputs same as for IA1.

IB2 - Instrument ID for output B attitude and target 2. Valid inputs same as for IA1.

ATT Sense - The sense direction of the input ADI or LVLH attitudes. For IMU input attitudes, the input matrix defines which IMU is to be used. Valid inputs are +X, -X, and -Z.

Input/Angle - The input angles can be for input attitude (ATT); instrument angles A1, A2 (IA1, IA2, IB1, IB2); middle gimbal angle for mode 5 (MGA); Omicron angle for mode 7 (OMI); Eigen axis and eigen angle (EIG). Valid inputs are ATT, IA1, IA2, IB1, IB2, MGA, OMI and EIG. The necessary input parameters are indicated by prompts prior to their input.

Start Time - The start time for the computations. Valid inputs are 0 = MET and 1 = GMT. For either MET or GMT, days, hours, minutes, and seconds are input.

I/P LVLH Bias - The input LVLH bias matrix ID. Valid inputs are

LPYRxx = Matrix 01-05 (P, Y, R Euler sequence)

LYPRxx = Matrix 01-05 (Y, P, R Euler sequence)

O/P LVLH Bias - The output LVLH bias matrix ID. Valid inputs are the same as I/P LVLH Bias inputs.

EXEC - Executes the program when required input data has all been loaded.

ΔCOE, ΔCOM, ΔSUN, TDRE, TDRW, TDRS - Special target ID's that are provided as typing aids. These special function keys will place the indicated characters in the display when keyed in after keying TGT1 or TGT2.

Note: Δ means space or blank.

SPECIAL KEY FUNCTIONS							SUPERSIGHTER	KEYING SHIFT
FUNCTION	! MODE	! INMAT	! OUTMAT	! EPH	! VID	! ELV	!UPPER CASE	
KEY	!f0!	!f1!	!f2!	!f3!	!f4!	!f5!		
FUNCTION	TGT1	TGT2	IA1	IA2	IB1	IB2	!LOWER CASE	
	ATT	INPUT	START	I/P LV	O/P LV			
	SENSE	ANG	TIME	BIAS	BIAS	EXEC	!UPPER CASE	
KEY	!f6!	!f7!	!f8!	!f9!	!f10!	!f11!		
FUNCTION	ΔCOE	ΔCOM	ΔSUN	TDRE	TDRW	TDRS	!LOWER CASE	

Figure 4-2.- Supersighter special key functions.

#### 4.1.4 Modes of Operation

##### 4.1.4.1 Mode 1 - Moveable Line-of-Sight Mode

Mode 1 computes the instrument pointing angles to a target for a given attitude and instrument ID for AOS of target 1.

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT ID  
OUTMAT ID  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
ELV  
INPUT ATT SENSE  
INPUT ATT (R, P, Y)  
TGT 1 ID  
IA1 ID  
TGT 2 ID (optional)  
IA2 ID (optional)

Outputs for this mode are

AOS/TCA/LOS for TGT 1 for the input ELV angle  
OUTPUT A ATTITUDES (input for this mode)  
IA1 - A1, A2 instrument pointing angles  
A3 - Omicron  
IA2 - A1, A2 instrument pointing angles (if this option is  
exercised)  
TGT 1 LAT, LON & ALT (if ground target input)  
RA/DEC - of TGT 1 and TGT 2 (if this option is exercised)  
RNG or VEH RANGE - if appropriate per definition of times  
PHI, THETA & PITCH, YAW - to the Earth, Moon, and Sun  
RA/DEC - of the body axes (+X, -Z)

##### 4.1.4.2 Mode 2 - Fixed Attitude/Fixed Line-of-Sight Mode

Mode 2 computes the RA/DEC of a given instrument LOS and Orbiter attitude for input start time (ST).

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT ID  
OUTMAT ID  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
ELV

INPUT ATT SENSE  
INPUT ATT (R, P, Y)  
IA1 ID  
IA1 instrument pointing angles A1, A2

Outputs for this mode are

OUTPUT A ATTITUDE (input for this mode)  
 $\phi$ ,  $\theta$  & PITCH, YAW - for the Earth, Moon, and Sun  
RA/DEC - of the body axes (+X, -Z)  
RA/DEC - of instrument LOS  
MODE 2 LAT, LON - output if instrument LOS intercepts the Earth's surface

#### 4.1.4.3 Mode 3 - Fixed Line-of-Sight Rotation Mode

Mode 3 - Computes a new Orbiter attitude given a source Orbiter attitude, rotation vector (eigen axis), and rotation angle (eigen angle) for input start time (ST). This mode will also compute instrument pointing angles if target and instrument ID's are input.

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT ID  
OUTMAT ID  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
INPUT ATT SENSE  
INPUT ATT (R, P, Y)  
EIGEN AXIS (P, Y) and EIGEN ANGLE  
TGT 1 ID (optional)  
IA1 ID (optional)  
TGT2 ID (optional)  
IA2 (ID optional)

Outputs for this mode are

OUTPUT A ATTITUDE  
IA1 - instrument pointing angles A1, A2 (optional)  
A3 - Omicron  
IA2 - instrument pointing angles A1, A2 (optional)  
PHI, THETA & PITCH, YAW - to the Earth, Moon, and Sun  
RA/DEC - of the body axes (+X, -Z)  
RA/DEC - of TGT 1 and TGT 2 (if this option exercised)  
TGT 1 LAT, LON & ALT (if ground target input)  
RNG or VEH RANGE - if appropriate per definition of terms

#### 4.1.4.4 Mode 4 - Minimum Maneuver Mode

Mode 4 computes a new Orbiter attitude which is a minimum maneuver (least amount of rotation) from a given initial attitude to a final attitude that points an instrument (IA1) specified LOS at target 1 for AOS of target 1. This mode will optionally compute instrument IA2 pointing angles to a second input target.

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT  
OUTMAT  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
INPUT ATT SENSE  
INPUT ATT (R, P, Y)  
ELV  
TGT 1 ID  
IA1 ID  
IA1 - A1, A2 instrument pointing angles  
TGT 2 ID (optional)  
IA2 ID (optional)

Outputs for this mode are

AOS/TCA/LOS for TGT 1 for the input ELV angle  
OUTPUT A ATTITUDES (computed final attitudes)  
EIGEN AXIS  
EIGEN ANGLE  
IA1 - A1, A2 instrument pointing angles (optional)  
A3 - Omicron  
TGT 1 LAT, LON, ALT (if ground target input)  
RA/DEC - of TGT 1 ANG TGT 2 (optional)  
RNG or VEH RANGE - if appropriate per definition of terms  
PHI, THETA & PITCH, YAW - to the Earth, Moon and Sun  
RA/DEC - of the body axis (+X, -Z)

#### 4.1.4.5 Mode 5 - Fixed Line-of-Sight/MGA Mode

Mode 5 computes two sets of Orbiter attitudes (A and B solutions) given a specific middle gimbal angle (MGA) and instrument IA1 ID and instrument angles to point at target 1 for AOS of target 1. Optionally, instrument pointing angles may be requested for up to three other instrument indicators (IA2, IB1, IB2). A target 2 will also be input corresponding to IA2 and IB2.

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT

OUTMAT  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
ELV  
MGA

INPUT ATT SENSE

TGT 1 ID - corresponding to instrument IA1 and, optionally,  
IB1 indicators

IA1 ID

IA1 - A1, A2 instrument pointing angles

IB1 ID (optional)

TGT 2 ID - corresponding to instrument IA2 and IB2 (optional)

IA2 ID (optional)

IB2 ID (optional)

Outputs for this mode are

AOS/TCA/LOS for TGT 1 for the Input ELV Angle

OUTPUT A ATTITUDES

OUTPUT B ATTITUDES

IA2 - A1, A2 instrument pointing angles (optional)

IB1 - A1, A2 instrument pointing angles (optional)

IB2 - A1, A2 instrument pointing angles (optional)

TGT 1 LAT, LON, ALT (if ground target input)

RA/DEC - of TGT 1 and TGT 2 (optional)

RNG or VEH RANGE - if appropriate per definition of terms

PHI, THETA & PITCH, YAW - to the Earth, Moon, and Sun

RA/DEC - of the body axis (+X, -Z)

#### 4.1.4.6 Mode 6 - Optimum Second Line-of-Sight Mode

Mode 6 computes an Orbiter attitude that points a given LOS at target 1 and also minimizes the angle between a second LOS for target 2, for AOS of target 1.

The inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT  
OUTMAT  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
ELV

TGT 1 ID corresponding to instrument IA1

IA1 ID

IA1 - A1, A2 instrument pointing angles

TGT 2 ID corresponding to instrument IA2

IA2 ID

IA2 desired instrument pointing angles

The outputs are

AOS/TCA/LOS - for TGT 1 for the input ELV angle  
OUTPUT A ATTITUDES  
IA2 - A1, A2 actual instrument pointing angles  
OMICRON  
TGT 1 LAT, LON, ALT (if ground target input)  
RA/DEC - of TGT 1 and TGT 2  
RNG or VEH RANGE - if appropriate per definition of terms  
PHI, THETA & PITCH, YAW - to the Earth, Moon, and Sun  
RA/DEC - of the body axis (+X, -Z)

#### 4.1.4.7 Mode 7 - Fixed Line-of-Sight Omicron Mode

Mode 7 computes an Orbiter attitude (output A) given a specific Omicron angle and instrument IA1 ID and instrument angles to point at target 1 for AOS of target 1. Optionally, instrument pointing angles may be requested for the IA2 instrument ID. A target 2 will also be input corresponding to IA2.

Inputs for this mode are

MODE ID  
EPH ID & VID #  
INMAT  
OUTMAT  
I/P LVLH BIAS ID  
O/P LVLH BIAS ID  
ST  
ELV  
OMICRON  
TGT 1 ID - corresponding to instrument IA1  
IA1 - instrument ID  
IA1 - A1, A2 instrument pointing angles  
TGT 2 ID - corresponding to instrument IA2 (optional)  
IA2 - instrument ID (optional)

Outputs for this mode are

AOS/TGA/LOS for TGT 1 for the input ELV angle  
OUTPUT A ATTITUDES  
IA2 - A1, A2 instrument pointing angles (optional)  
TGT 1 LAT, LON, ALT (if ground target input)  
RA/DEC - of TGT 1 and TGT 2 (optional)  
RNG or VEH RANGE - if appropriate per definition of terms  
PHI, THETA & PITCH, YAW - to the Earth, Moon, and Sun  
RA/DEC - of the body axis (+X, -Z)

## 4.2 SUPERSIGHTER PROGRAM ACTIVITIES

### 4.2.1 Systems Preparation

- o Turn on HP 9825 calculator, the disk drive unit, and the thermal printer.
- o Insert disk into drive unit and close door.

The system is now operational and the required Program can be obtained from the disk and stored in the calculator for use as required.

### 4.2.2 Supersighter Activation

The Supersighter Program can be activated in two ways.

- a. Fresh initialization of the program
- b. Retrieval of a saved memory from a previous run

#### 4.2.2.1 Fresh Initialization

- o Type in get "SS" and key EXECUTE. This will retrieve the Supersighter Initialization Program from the disk and store it in the calculator memory.
- o Key RUN to start the initialization program. A prompt will appear, requesting an input of the date. This should be input as MM/DD/YY and is used only for record keeping. If no date is desired, key SPACE. After entering the desired data, key CONTINUE to complete the program initialization.

When the program is finished, the statement "SUPERSIGHTER INITIALIZED" appears in the display. At this point, the display format, the Special Function Key Programs, and the Supersighter Executive Programs have been loaded into the calculator memory. The Supersighter Program is now ready for use.

The first time the program is used after initialization, all the required inputs for a desired mode must be input.

#### 4.2.2.2 Memory Retrieval

If a previous Supersighter load was saved, the load can be retrieved and operations picked up exactly where they were left off when the memory was saved.

- o Type in getm "your identification label" and key EXECUTE.
- o The program is now ready for use where it was left when the calculator memory was saved.

NOTE: If the calculator memory was saved while in the middle of the program, a key RESET will be required before a new parameter can be input. If the program is desired to be resumed from the point at which it was saved, a key CONTINUE is required to start the program again. (Program had to be stopped before it could be saved.)

#### 4.2.3 Supersighter Operation

After all the required inputs have been made, the program is initiated by keying the special function key EXEC. When the program has been completed, a prompt will appear in the display, requesting the current time be input (for record keeping only). After entering the time "HHMM" or "SPACE" (if no time desired), key CONTINUE. The results are then output on the thermal printer.

For additional calculations, only those inputs that are to be changed or that have never been loaded must be loaded. There are two exceptions to this because of an oversight when this version of the program was built.

- a. Omicron (IA1:A3)
- b. EIGEN AXIS (P, Y, and ANG)

These have a common storage location for both the input and output parameters and thus will change from what had been loaded at an earlier time to whatever was last output. The message is, for these two sets of parameters, if the values output on the last mode that outputs them is not what you want, reload them.

#### 4.2.4 Supersighter Deactivation

The Supersighter Program can be deactivated in either of the following ways.

- a. If there is no desire to save what is in the calculator, stop the program (if still processing) by keying STOP and remove disk; then turn off systems.
- b. If the program is still processing and it is desired to complete the calculations at a later time or it is desired to save the current input data after completing calculations, the calculator memory can be saved. If the calculator memory is saved, when it is reloaded, the program can be reinitiated at the point it was stopped and stored. The calculator memory is saved by typing savem "identification label" in display and keying EXECUTE. This will save all program code and variables stored in the calculator memory.

If an error code is displayed when the memory save is executed, indicating the label has already been used, the contents of the disk can be checked by typing cat 6 and keying EXECUTE to list the contents of the disk. The HP book for the floppy disk explains what information is presented when the disk catalog is listed.

NOTE: A memory save label can only be used once. If the same label is desired to be used again, the old memory save must be deleted from the disk. This is done by typing kill "identification label" and keying EXECUTE. Care must be taken to ensure that the label is the correct one. The kill command will purge whatever is typed in as the label; there is no recovery if a mistake is made.

#### 4.2.5 Data Files Required

The Supersighter Program uses several data files during the execution of any of the modes.

<u>Label</u>	<u>File</u>
EPHxxx	Ephemeris containing the general ephemeris data at the reference epoch and the state vectors
REL	RELMAT
REF	REFSMMAT
BIAS	LVLH Bias Matrix (LPRY or LYPR, 01-05)
C	Celestial Target (C001-400)
G	Ground Targets (G001-100)
INST	Instrument Definition (S01-25)

#### 4.2.6 MOC Usage

All the Supersighter Program modes are available through MED inputs to the MOC. However, some of the mode numbers are different. Table 4-I indicates the MOC MED input requirement by mode and the HP9825 equivalent mode. Reference the CCS Trajectory Users Guide for further information on the MOC inputs/outputs for the Supersighter Programs.

### 4.3 SUPERSIGHTER SUPPORT PROGRAMS

The data files used by the Supersighter Program are maintained or generated by the following programs.

TABLE 4-I.- MOC SS MODE

Parameter	Mode								
	1	2	3	4	5A	5B	6	TM1	TM2
G31 Ephemeris ID	X	X	X	X	X	X	X	X	X
Source matrix	X	X	X	X	X	X	X	X	X
Source bias matrix	X	X	X	X	X	X	X	X	X
Desired matrix	X	X	X	X	X	X	X	X	X
Desired bias matrix	X	X	X	X	X	X	X	X	X
Attitude source	X	X	X	X	X	X	X	TLM	TLM
Start time	X	X	X	X	X	X	X		
Elevation angle	X	X	X	X	X	X	X	X	X
G32 Eigen axis pitch				X					
Eigen axis yaw				X					
Eigen angle				X					
G33 Target ID	X			X	X	X	X	X	X
Instrument indicator	X	X		X	X	X	X	X	X
Instrument ID	X	X		X	X	X	X	X	X
Angle no. 1	X	X		X	X	X	X	X	X
Angle no. 2			X		X	X	X		
Omicron					X				
Middle gimbal angle (MGA)					X				
G51 Attitude user	S	S	S	S	S	S	S	S	S
Source reference	X	X	X	X	X	X	X	X	X
Roll	X	X	X	X					
Pitch	X	X	X	X					
Yaw	X	X	X	X					
Desired reference	X	X	X	X	X	X	X	X	X
G30 SS mode	1	2	3	4	5A	5B	6	TM1	TM2
<u>MOC mode</u>	<u>HP/MOC comparison</u>					<u>HP equivalent mode</u>			
1	Moveable line-of-sight mode					1			
2	Fixed attitude/fixed line-of-sight mode					2			
3	Fixed line-of-sight rotation mode					3			
4	Minimum maneuver mode					4			
5A	Fixed line-of-sight/MGA input					5			
5B	Fixed line-of-sight/omicron input					7			
6	Dual line-of-sight mode					6			

<u>Label</u>	<u>Program</u>
VCEP	Vector Conversion Ephemeris
RLFILE	RELMAT Matrix File Maintenance
RFFILE	REFSMMAT Matrix File Maintenance
BFILE	LVLH BIAS Matrix File Maintenance
CFILE	Celestial Targets File Maintenance
GFILE	Ground Targets File Maintenance
IFILE	Instrument Definition File Maintenance

#### 4.3.1 Vector Conversion Ephemeris Program (VCEP) (HP9825)

##### 4.3.1.1 Purpose

This program generates the reference epoch data for the Sun and Moon and the RNP Matrix for rotating from the Mean of 1950 (M50) reference frame to the Earth-True-of-Date reference frame. The epoch is at a GMT of 00:00:00.0 on the specified day of the year (normally, launch day). The program then converts the input orbital parameters, which are used to define a state vector (S.V.) for the Orbiter, into an invariant set of orbital parameters. The invariant elements of the orbit can be propagated to other points in time with a high degree of accuracy. The program generated data can be stored under any three-character ephemeris file name on a floppy disk for use by other programs.

##### 4.3.1.2 System Preparation

The HP 9825 calculator disk drive and thermal printer must be turned on. Then the VCEP program is retrieved from the disk by keying get "VCEP".

##### 4.3.1.3 Program Operation

The program is initiated by keying RUN. The program will display the prompt in the display indicating what input data is required. The first input tells the program if only state vectors are going to be converted using the reference ephemeris data previously generated and stored in an Ephemeris File.

Loading S.V. Only (NO = 0, Yes = 1)

Enter either "0" or "1" and key CONTINUE.

For the purpose of discussing the operation of the program, "0" will be assumed to have been input. This will cause the program to generate the ephemeris data before S.V. inputs for conversion into invariant elements can be made. If only S.V. conversions need to be made, see paragraph.

#### 4.3.1.4 Ephemeris Generation

For generation of the epoch ephemeris data, the following prompts will appear, requesting the required data inputs.

o Epoch Ephemeris

EPH # (X X X) - Ephemeris File # in which the data is to be stored. The file # can be a 1 to 3 character ID.

Comment (32 char) - Provision for a title of up to 32 characters that will be output on the printout only.

LOAD GMT Date of L/O - A momentary prompt displayed to alert the user that the next set of prompts define the date of liftoff. The next three prompts are the GMT CALENDAR YEAR, MONTH, and DAY. This defines the date as 00:00:00 GMT of that day.

LOAD GMT of L/O - A momentary prompt displayed to alert the user that the next set of prompts define the GMT time of day of liftoff. The three prompts are the GMT hr, min, and sec from midnight.

The program then generates the following ephemeris data for the epoch time and prints them out (see fig. 4-3). The parameters are

GHA - Greenwich hour angle at the reference epoch time in degrees East of the Prime Meridian

We - Earth's rotation rate in radians per second

M50 to EFEPOCH(RNP2) Matrix - A 3 by 3 matrix defining the angular difference between the M50 and Earth Fixed Epoch reference system.

o Sun Ephemeris

G - Mean longitude of perigee

E - Mean obliquity of the ecliptic

e - Eccentricity

g - Mean anomaly

RA<sub>Sun</sub> - Right ascension of Sun

DEC<sub>Sun</sub> - Declination of Sun

o Lunar Ephemeris

D = Half argument of the "variation"

Mean Long = The mean longitude of the Moon

I = Argument of the principal elliptic term

Omega = Longitude of the mean ascending node of the lunar orbit on the ecliptic

EPS = Mean obliquity of the ecliptic

I' = Argument of the "annual equation"

EPH 1 STS-1 September 15, 1979 Cycle 2

Base Reference Time (Midnight prior to Launch)  
Year 1979 Month 9 Day 15 JD 2444131.5

GMT of EPOCH 22291200.00000 Secs

GMTLO 12 Hours 0 Min 0.0 Sec  
GMTLO 43200.00000 Secs

GHA 353.3620 We 7.29211579822E-05

M50 to EFEPOCH(RNP2)

9.92506333E-01	-1.22159778E-01	-2.85794073E-03
1.22159414E-01	9.92510446E-01	-3.02369375E-04
2.87347340E-03	-4.90208518E-05	9.99995870E-01

SUN Ephemeris

G 282.59134945100 E 23.43965743050 e 0.01671764514 g 250.77831140000

X -0.9892044 Y 0.1344493 Z 0.0582919  
RAsun 172.2600 DECsun 3.3418

LUNAR Ephemeris

D 281.7380000000	MEAN LONG 297.4913240000	1 117.6448540000
Omega 157.6164620000	EPS 23.4396574305	1' 250.7784188000

X -0.2016170 Y 0.9265285 Z 0.3176405  
RAmoon 102.2765 DECmoon 18.5203

Figure 4-3 - Typical ephemeris data printout.

RAmoon = Right ascension of Moon

DECmoon = Declination of Moon

The program then displays the prompt

0 = STORE DATA ON DISK, 1 = NO

and if it is desired to save the data for later use, input "0" and key CONTINUE. The data must be saved if S.V. conversions are to be made using this reference data.

The next prompt asks if a file needs to be opened (NO = 0, # of records if yes).

#### 4.3.1.5 State Vector Conversion

The state vector conversion part of the program is reached either following ephemeris generation or by having entered "1" when questioned "Loading S.V. Only." The first group of prompts associated with the State Vector Conversion Program identifies in which data file the parameters are stored, gives a comment, and shows the time of the state vector. These prompts

EPH# (X X X) for SV STORE - Ephemeris file # (X X X) in which S.V. data is to be stored on the disk.

VID#(1-xx) for S.V. (1-xx) - Vector ID # in (1-xx) in which S.V. data is to be stored on the disk.

Comment (32 char) - 32 characters available for identification of vector.

SV MET (Days) - The MET time for when the state vector inputs are valid  
Hr  
Min

The program then asks which input option is to be used by displaying the prompt "SV INPUT (0 = M50 SV, 1 = OTHER OPT's)." The five options available and the input parameters/prompts for each option are shown in table 4-II.

TABLE 4-II.-- INPUT PARAMETERS/PROMPTS

<u>Option</u>	<u>Symbol</u>	<u>Description</u>	<u>Unit</u>
0	X	M50 components of vehicle position	Ft
	Y		
	Z		
	XD	M50 components of vehicle velocity	Ft/sec
	YD		
	ZD		
1	X	Earth-center true of date components of vehicle position	FT
	Y		
	Z		
	XD	Earth-center true of date components of vehicle velocity	Ft/sec
	YD		
	ZD		

TABLE 4-II.- Concluded

Option	Symbol	Description	Unit
2	A	Semimajor axis	Ft
	E	Eccentricity	-
	I	Inclination	Deg
	G	Argument of perigee	Deg
	H	Longitude of ascending node (Earth long)	Deg
	L	Mean anomaly	Deg
3	RAD	Radius of the orbit	Ft
	VEL	Vehicle total velocity	Ft/sec
	GAM	Flight path angle	Deg
	LAT	Latitude	Deg
	LON	Longitude	Deg
	INC	Inclination	Deg
	A/D	Ascending/descending flag	-
4	HA	Apogee altitude	N. mi.
	HP	Perigee altitude	N. mi.
	TA	True anomaly	Deg
	LAT	Latitude	Deg
	LON	Longitude	Deg
	INC	Inclination	Deg
	A/D	Ascending/descending flag	-

The output is a printout of all the parameters used for the different input options and the invariant elements (fig. 4-4). The invariant elements are

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>
AK	Semimajor axis	Ft
EK	Eccentricity	-
IK	Inclination	Deg
GK	Argument of perigee	Deg
HK	Ascending node longitude	Deg
MK	Mean anomaly	Deg
ETA	Mean motion	Deg/sec
GDOT	Rate of change of argument of perigee	Deg/sec
HDOT	Rate of change of ascending node	Deg/sec

After the printout of the data is complete, the user is asked if the vector is to be stored on the disk. The displayed prompt is "0 = STORE DATA ON DISK, 1 = NO." If the data are to be saved for later use, input "0" and key CONTINUE.

The program next asks if more vectors are to be loaded by displaying the prompt "PRESS CONT TO LOAD MORE SV." If no additional vectors are to be

input, the program can be terminated or erased at this time. If additional vectors are desired to be added at a later date to the same ephemeris file for the same epoch time, they can be added by keying "1" when asked at the start of the program "Loading S.V. Only (NO = 0, YES = 1)." This procedure will bypass the ephemeris data inputs for the epoch time and go directly to the vector input portion of the program.

INPUT - M50 S.V.

EPH = 1 VID = 1

Nominal MECO

SV MET	0 Days	0 Hours	8 Mins 42.40 Sec
SV GMT	258 Days	12 Hours	8 Mins 42.40 Sec

GMT S.V 22334922.40 Sec

M50 S.V.

ETD S. V.

Opt 4 Param

X	-5177028.5	X	6462147.2	HA	79.4217434971	A	21216817.1504
Y	16713775.0	Y	-16271885.9	HP	16.3945228000	e	9.02493219931E-03
Z	12129377.0	Z	12113631.5	TA	113.0193716500	G	-51.84601540700
XD	-21031.47300	XD	20070.60361	LAT	34.6788643785	H	237.55596569000
YD	-12206.69900	YD	13765.09363	LON	-68.3402051100	L	112.06502533800
ZD	8219.27920	ZD	8159.41026	INC	40.5005245240	GAM	4.77590371584E-01
R	21290225.11	V	25668.71457	A/D	1	RD	213.9597204560

INVARIANT ELEMENTS

AK	2121098.2	EK	9.30932905882E-03	IK	40.4899730
GK	-53.0021623	HK	237.5286913	MK	113.2171251
ETA	6.95611313E-02	GDOT	1.03806139E-04	HDOT	-8.35873427E-05

Figure 4-4.- Typical State Vector Conversion printout.

Notes on VCEP:

- a. Files can be opened to any record length.
- b. Program will purge the VID records of an old file when a new base ephemeris is created with the same file name.
- c. When creating VID's for circular orbits using option 4, do not use a true anomaly (TA) of 0 because the use of a TA of 0 causes singularity problems.

#### 4.3.1.6 Vector Conversion and Ephemeris Program - Variant I (VCEP1) (HP9825)

The purpose of the VCEP1 is to create a new base ephemeris file for a different liftoff time and date, using an existing source file, and to recopy the VID records to the destination file with adjustments for the new launch time. The program thus permits the operator to rapidly convert the ephemeris for an actual or contingency launch time without having to manually enter each of the Earth relative vectors. With up to 20 VID files to be carried over, the program permits a considerable time saving and less chance of error when only a simple change in launch time is involved in updating an ephemeris file. The program has no provision for manual entry or update of individual VID files, as this capability is supported by the original VCEP. If the destination file has not been opened, the program permits an opportunity to open it with any number of records. The program, however, transfers only 20 VID records; if a larger number is required, the "for" statement in line 103 should be temporarily changed to agree with the actual number of VID records (total records -1) in the source file. If the destination file contains fewer VID records than the source file, the program displays a warning "Dest. file insuff. for VID" to indicate that not all the VID files were transferred. In cases when the source file is inactive (contains only an EOF), an EOF is written to the destination file to prevent the possibility of spurious data remaining there from earlier use. This purge feature is intact even when line 103 is changed to agree with a file size larger than 20 VID records.

The creation of the base ephemeris file is unchanged from VCEP, and none of this coding was altered. The VCEP feature to create the VID invariant element matrix from state vector inputs has been replaced by coding to transfer each nine-element invariant matrix and the comment to the destination file without change but to adjust the GMT time for seconds since beginning of year until state vector time.

$$\text{GMT SV} = \text{GMT Epoch } \Delta + \text{GMT L/O} + \text{MET SV}$$

The nine invariant elements are Earth relative and require no modification for a change in liftoff time. The definition of invariant element  $H_k$  in VCEP differs from its MPAD counterpart in that VCEP defines  $H_k$  at the state vector time, and the MPAD version computes  $H_k$  with respect to midnight before the day of launch. The MPAD  $H_k$  is therefore not Earth relative and would require adjustment by  $WE \cdot SV$  GMT where  $WE$  is the Greenwich Hour Angle rate. Programs using each version, of course, account for this difference.

To access the program, key get "VCEP1" and depress the RUN key. The first prompt asks what is the source ephemeris file ID. The next prompt asks what is the new file name or destination ephemeris ID. Two options are available: (a) create a new ephemeris file or (b) overwrite the source file with the new ephemeris.

The next prompt asks for a comment statement to identify the file. If no comment statement is desired, continue the program. The following prompts after the comment statement asks the operator to load.

- a. GMT date of L/O: Year
- b. Month
- c. Day
- d. GMT of L/O: Hours, minutes, seconds

The program then generates the ephemeris data for the epoch time and prints these out. (The printout is the same as generated by VCEP.)

Then, the program will ask if it is OK to store (0 = Yes, 1 = No). The next prompt will ask if you need to open a file (No = 0, # records (VID's) if yes). If overwriting a previous record, key 0. If this is a new file, enter the number of VID's stored in the source ephemeris.

#### 4.3.2 Relmat Matrix File Maintenance Program (RLFILE) (HP9825)

##### 4.3.2.1 Purpose

This program is used to maintain the RELMAT File. It provides the capability to LOAD IN or READ OUT data in the RELMAT File. The file is stored on the disk as file "REL." This file can contain 25 RELMATS, each consisting of a 3 by 3 matrix defining the rotation angles from the Mean-of-1950 coordinate system to the ADI coordinate system.

##### 4.3.2.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the RLFILE program is retrieved from the disk by keying get "RLFILE."

##### 4.3.2.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD" requests the user to define the desired mode by entering either "0" or "1" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program mode has been initiated, the program will remain in that mode until the program is terminated and reinitialized.

###### o READ mode

The first prompt to appear in the READ mode is "RLMT01-25" requesting the input of the desired RELMAT ID whose data is to be read out. The legal input that can be entered is RLMTxx (where xx = 01 to 25). After entering the desired RELMAT's ID and keying CONTINUE, the requested RELMAT data will be printed out. The printout will consist of the RELMAT ID, Comment, and a 3 by 3 matrix (see fig. 4-5). After the data is printed out, the program will redisplay the prompt "RLMT01-25" requesting the next RELMAT ID to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

## o LOAD mode

The first prompt to appear in the LOAD mode is "RLMT01-25" requesting the input of the desired RELMAT ID for the RELMAT to be loaded. The legal input that can be entered is RLMTxx (where xx = 01 to 25). After entering the desired RELMAT ID to be used for the RELMAT and keying CONTINUE, the prompt "COMMENT (30 char)" will appear. This prompt is requesting an input of up to 30 characters for use as a title or comment for the RELMAT. If no title is desired, enter a SPACE. After the desired comment has been entered, key CONTINUE to get the next prompt. The program will then display the prompts "M50 to ADI Rx<sub>x</sub>," "Rx<sub>y</sub>," "Rx<sub>z</sub>," "Ry<sub>x</sub>," ..., "Rz<sub>z</sub>" requesting the input of the elements of the RELMAT matrix. After the Rz<sub>z</sub> element has been input, the input data will be stored on the disk and printed out (fig. 4-5). After the data is printed out, the program will redisplay the prompt "RLMT01-25" requesting the next RELMAT ID data is to be loaded for. This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

RELMAT ID RLMT10

IDENTITY MATRIX

M50 to ADI MATRIX

Xx	1.00000000	Xy	0.00000000	Xz	0.00000000
Yx	0.00000000	Yy	1.00000000	Yz	0.00000000
Zx	0.00000000	Zy	0.00000000	Zz	1.00000000

Figure 4-5.- Typical RELMAT printout.

### 4.3.3 REFSMMAT Matrix File Maintenance Program (RFFILE) (HP9825)

#### 4.3.3.1 Purpose

This program is used to maintain the REFSMMAT File. It provides the capability to LOAD IN or READ OUT data in the REFSMMAT File. The file is stored on the disk as file "REF". This file can contain 12 REFSMMATS, each consisting of a 3 by 3 matrix defining the rotation angles from the Mean-OF-1950 coordinate system to an IMU's coordinate system. In addition, a 3 by 3 matrix defining the rotation angles from the IMU cluster to Shuttle body coordinate system is stored with each REFSMMAT. This matrix nominally is the NAV Base to Body Matrix, but if misalignment errors must be accounted for, this matrix would be modified by the misalignment matrix prior to loading and the resultant matrix used for the misaligned IMU.

#### 4.3.3.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the RFFILE program is retrieved from disk by keying get "RFFILE".

#### 4.3.3.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD" requests the user to define the desired mode by entering either "0" or "1" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program mode has been initiated, the program will remain in that mode until the program is terminated and reinitialized.

##### o READ mode

The first prompt to appear in the READ mode is "RFMT01-12" requesting the input of the desired REFSMMAT ID whose data is to be read out. The legal input that can be entered is RFMTxx (where xx = 01 to 12). After entering the desired REFSMMAT ID and keying CONTINUE, the requested REFSMMAT data will be printed out. The printout will consist of the REFSMMAT ID, Comment, and a 3 by 3 matrix for M50 to IMU Matrix and Cluster to Body Matrix (see fig. 4-6). After the data is printed out, the program will redisplay the prompt "RFMT01-12" requesting the next REFSMMAT ID to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

##### o LOAD mode

The first prompt to appear in the LOAD mode is "RFMT01-12" requesting the input of the desired REFSMMAT ID for the REFSMMAT to be loaded. The legal input that can be entered is RFMTxx (where xx = 01 to 12). After entering the desired REFSMMAT ID to be used for the REFSMMAT and keying CONTINUE, the prompt "COMMENT (30 char)" will appear. This prompt is requesting an input of up to 30 characters for use as a title or comment for the REFSMMAT. If no title is desired, enter a SPACE. After the desired comment has been entered, key CONTINUE to get the next prompt. The program will then display the prompts "M50 to IMU Rxx," "Rxy," "Rxz," "Ryx," ..., "Rzz" requesting the input of the elements of the REFSMMAT matrix. After the Rzz element has been input, the prompts for "CLUSTER to BODY Cxx," "Cxy," ..., "Czz" are displayed, requesting the input of the elements of the Cluster to Body matrix. After the Czz element has been input, the input data will be stored on the disk and printed out (see fig. 4-6). After the data is printed out, the program will redisplay the prompt "RFMT01-12" requesting the next REFSMMAT ID that data is to be loaded for. This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

REFSMMAT ID RFMT06

IDENTITY MATRIX

M50 to ADI MATRIX

Xx	1.00000000	Xy	0.00000000	Xz	0.00000000
Yx	0.00000000	Yy	1.00000000	Yz	0.00000000
Zx	0.00000000	Zy	0.00000000	Zz	1.00000000

CLUSTER to BODY MATRIX

Xx	1.00000000	Xy	0.00000000	Xz	0.00000000
Yx	0.00000000	Yy	1.00000000	Yz	0.00000000
Zx	0.00000000	Zy	0.00000000	Zz	1.00000000

Figure 4-6.- Typical REFSMMAT printout.

#### 4.3.4 LVLH BIAS Matrix File Maintenance Program (BFILE) (HP9825)

##### 4.3.4.1 Purpose

This program is used to maintain the LVLH BIAS File. The program provides the capability to LOAD IN or READ OUT data in the BIAS File. The file is stored on the disk as file "BIAS." This file can contain 5 BIAS Matrices, each consisting of a 3 by 3 matrix defining the rotation angles from the instantaneous LVLH coordinate system to the biased LVLH coordinate system.

##### 4.3.4.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the BFILE program is retrieved from the disk by keying get "BFILE."

##### 4.3.4.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD" requests the user to define the desired mode by entering either "0" or "1" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program mode has been initiated, the program will remain in that mode until the program is terminated and reinitialized.

###### o READ mode

The first prompt to appear in the READ mode is "LVLH BIAS MAT (LPYR or LYPR,01-05)" requesting the input of the desired LVLH BIAS MAT ID whose data is to be read out. The legal input that can be entered is LPYRxx or LYPRxx (where xx = 01 to 05). After entering the desired LVLH BIAS MAT ID and keying CONTINUE, the requested LVLH BIAS MAT data will be printed out. The printout will consist of the LVLH BIAS MAT ID, Comment, and a 3 by 3 matrix (see fig. 4-7). After the data is printed out, the program will redisplay the prompt "LVLH BIAS MAT (LPYR or LYPR, 01-05)" requesting the next LVLH BIAS MAT to be read out. This

cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

o LOAD mode

The first prompt to appear in the LOAD mode is "LVLH BIAS MAT (LPYR or LYPR, 01-05)" requesting the input of the desired LVLH BIAS MAT ID for the LVLH BIAS MAT to be loaded. The legal input that can be entered is LPYRxx or LYPRxx (where xx = 01-05). After entering the desired LVLH BIAS MAT ID to be used for the LVLH BIAS MAT and keying CONTINUE, the prompt "COMMENT (30 char)" will appear. This prompt is requesting an input of up to 30 characters for use as a title or comment for the LVLH BIAS MAT. If no title is desired, enter a SPACE. After the desired comment has been entered, key CONTINUE to get the next prompt. The program will then display the prompts "BIAS MAT Rxx," "Rxy," "Rxz," "Ryx," ..., "Rzz" requesting the input of the elements of the LVLH BIAS matrix. After the Rzz element has been input, the input data will be stored on the disk and printed out (see fig. 4-7). After the data is printed out, the program will redisplay the prompt "LVLH BIAS MAT (LPYR or LYPR, 01-05)" requesting the next LVLH BIAS MAT ID that data is to be loaded for. This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

LVLH BIAS MAT ID LPYR05

IDENTITY MATRIX

BIAS MATRIX

Xx	1.00000000	Xy	0.00000000	Xz	0.00000000
Yx	0.00000000	Yy	1.00000000	Yz	0.00000000
Zx	0.00000000	Zy	0.00000000	Zz	1.00000000

Figure 4-7.- Typical LVLH BIAS Matrix printout.

#### 4.3.5 Celestial Target File Maintenance Program (CFILE) (HP9825)

##### 4.3.5.1 Purpose

This program is used to maintain the Celestial Target File. It provides the capability to LOAD IN, READ OUT, or MODIFY data in the Celestial Target File. The file is stored on the disk as the file "C." This file can contain 400 star or celestial targets, which consist of right ascension and declination in the Mean of 1950 coordinate system, its visible magnitude, and name.

##### 4.3.5.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the CFILE program is retrieved from the disk by keying get "CFILE".

#### 4.3.5.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD, 2 = MOD" requests the user to define the desired mode by entering either "0," "1," or "2" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program mode has been initiated, the program will remain in that mode until the program is terminated or reinitialized.

##### o READ mode

The first prompt to appear in the READ mode is "FIRST STAR # (1-400)" requesting the input of the first celestial target (1 to 400) that are to be read out. After entering the first target number and keying CONTINUE, the prompt "FINAL STAR # (1-400)" will appear, requesting the last target (1 to 400) whose data are to be read out. When the final target number has been entered and CONTINUE keyed, the prompt "RA/DEC OUTPUT (DECIMAL = 0, HMS/DMS = 1)" will appear, requesting that the user indicate whether the data is to be printed out as decimal degrees or as hours, minutes, seconds (RA) and degrees, arc minutes, arc seconds (declination). After entering the desired output format and keying CONTINUE, the stored data for each target ID between the two input numbers, including the input numbers, will be retrieved from the disk and printed out. The printout will consist of the celestial target ID #, name, position, and magnitude (fig. 4-8). After the final target data has been printed out, the program will redisplay the prompt "FIRST STAR # (1-400)" requesting the first target ID of the next set of targets to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

##### o LOAD mode

The first prompt to appear in the LOAD mode is "RA/DEC INPUT (Decimal = 0, HMS/DMS = 1)" requesting designation of whether the target position is to be input and output as decimal degrees or as hours, minutes, seconds (right ascension) and degrees, arc-minutes, and arc-seconds (declination). After designating the desired form by entering "0" or "1" and keying CONTINUE, the program will display the appropriate prompts to input the required data as follows.

<u>Prompt</u>	<u>Decimal input</u>
STAR # (1-400)	Star or celestial target identification number
NAME (15 char)	Target name or identifier (up to 15 char)
RA (deg)	Right ascension of the target in degrees
DEC (deg, +=North)	Declination of the target in degrees
MAG	Visual brightness of target

### HMS/DMS input

STAR # (1-400)	Star or celestial target identification number
NAME (15 char)	Target name or identifier (up to 15 char)
RA (hr)	Right ascension of target (hours)
RA (min)	Right ascension of target (min)
RA (sec)	Right ascension of target (sec)
DEC (+/-deg)	Declination of target, + for North (degrees)
DEC (+/-min)	Declination of target, + for North (arc-min)
DEC (+/-deg)	Declination of target, + for North (arc-sec)
MAG	Visual brightness of target

After the MAG has been entered and CONTINUE keyed, the input data is stored on the disk and printed out (see fig. 4-8). After the data is printed out, the program will redisplay the prompt "RA/DEC INPUT (Decimal = 0, HMS/DMS = 1)" for the next target to be loaded. This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

#### o Modification mode

The first prompt to appear in the MOD mode is "STAR # (1-400)." Enter the STAR number that is to be modified. The next prompt will momentarily appear. This prompt will indicate that the operator can either change the star name or continue. Then, the prompt "Name (15 char)" and the star name presently loaded will appear. After continuing, the operator will see prompts with the respective current data. These prompts are RA, DEC, MAG. The operator can change or continue past the inputs. If a continue is chosen with no change, the previously loaded information will not change. Continuing after MAG, a printout will show the final load for the star. The last prompt will ask the operator to continue to load the file. The following is a summary of the MOD data inputs. See figure 4-8 for output.

<u>Prompt</u>	<u>Decimal input</u>
New Name (15 char)	New target name or identifier (up to 15 characters)
New ID # (1-400)	New star or celestial target identification number
New RA (deg)	New right ascension of the target (deg)
New DEC (deg+=North)	New declination of the target (deg)
New MAG	New visual brightness for the target

This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

### DECIMAL FORM

CELESTIAL TARGET ID	NAME	RIGHT ASCENSION	(N/S)	DECLINATION (+/-)	MAG
C011	SIRIUS	100.7325	16.6542 S	-16.6542	-1.50
C012	CANOPUS	95.7107	52.6675 S	-52.6675	-0.80

Figure 4-8.- Typical celestial target printout.

#### 4.3.5.4 MOC Usage

There is a similar program available through MED inputs to the MOC. See the CCS Trajectory Users Guide for more information.

#### 4.3.6 Ground Target File Maintenance Program (GFILE) (HP9825)

##### 4.3.6.1 Purpose

This program is used to maintain the Ground Target File. It provides the capability to READ OUT or LOAD IN data in the Ground Target File. The file is stored on the disk file "G." This file can contain 50 ground targets, which consist of longitude, latitude, altitude above Fisher ellipsoid, and name.

##### 4.3.6.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the GFILE program is retrieved from the disk by keying get "GFILE".

##### 4.3.6.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD" requests the user to define the desired mode by entering either "0" or "1" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program mode has been initiated, the program will remain in that mode until the program is terminated or reinitialized.

###### o READ mode

The first prompt to appear in the READ mode is "FIRST GRD TGT # (1-40)" requesting the input of the first target (1 to 50) that is to be read out. After entering the first target number and keying CONTINUE, the prompt "FINAL GRD TGT # (1-50)" will appear, requesting the last target (1 to 50) whose data is to be read out. When the final target number has been entered and CONTINUE keyed, the prompt "LAT/LON Form (DECIMAL = 0, DMS = 1)" will appear, requesting that the user indicate whether the data are to be printed out as decimal degrees or as degrees, arc-minutes, arc-seconds. After entering the desired output format and keying CONTINUE, the stored data for each target ID between

the two input numbers, including the input numbers, will be retrieved from the disk and printed out (fig. 4-9). The printout will consist of the ground target ID #, name, and position altitude. After the final target data have been printed out, the program will redisplay the prompt "FIRST GRD TGT # (1-50)" requesting the first target ID of the next set of targets to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

o LOAD mode

The first prompt to appear in the LOAD mode is "LAT/LON Form (Decimal = 0, DMS = 1)" requesting designation of whether the target position is to be input and output as decimal degrees or as degrees, arc-minutes, and arc-seconds. After designating the desired position data form by entering "0" or "1" and keying CONTINUE, the program will display the appropriate prompts to input the required data as follows.

<u>Prompt</u>	<u>Decimal input</u>
GRD TGT # (1-50)	Ground target identification number
NAME (20 char)	Target name or identifier (up to 20 char)
LON (deg,+=East)	Longitude of the target in degrees
DEC (deg,+=North)	Latitude of the target in degrees
ALT (ft)	Altitude of target above the Fisher Ellipsoid
	<u>DMS input</u>
GRD TGT # (1-50)	Ground target identification number
NAME (20 char)	Target name or identifier (up to 20 char)
LON (deg,+=East)	Longitude of target + for East (deg)
LON (min,+=East)	Longitude of target + for East (arc-mins)
LON (sec,+=East)	Longitude of target + for East (arc-secs)
LAT (+/-deg)	Latitude of target, + for North (deg)
LAT (+/-min)	Latitude of target, + for North (arc-mins)
LAT (+/-sec)	Latitude of target, + for North (arc-secs)
ALT (ft)	Altitude of target above the Fisher Ellipsoid (ft)

After the ALT has been entered and CONTINUE keyed, the input data is stored on the disk and printed out (fig. 4-9). After the data is printed out, the program will redisplay the prompt "LAT/LON Form (Decimal = 0, DMS = 1)" for the next target to be loaded. This cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

### DECIMAL FORM

GROUND TARGET ID	NAME	LONGITUDE	LATITUDE	ALTITUDE
G011	YELLOW RIVER VALLEY	100.7325	16.6542 S -16.6542	-1.50
G012	CAPE GOOD BYE	95.7107	52.6675 S -52.6675	-0.80

### DMS FORM

GROUND TARGET ID	NAME	LONGITUDE	LATITUDE	ALTITUDE
G011	YELLOW RIVER VALLEY	6:42:55.6	16:39:22.4 S -16:39:22.4	-1.50
G012	CAPE GOOD BYE	6:22:50.6	52:40:03.4 S -52:40:03.4	-0.80

Figure 4-9.- Typical ground target printout.

#### 4.3.6.4 MOC Usage

There is a simliar program available through MED inputs to the MOC. See the CCS Trajectory Users Guide for more information.

#### 4.3.7 Instrument Definition File Maintenance Program (IFILE) (HP9825)

##### 4.3.7.1 Purpose

This program is used to maintain the Instrument Definition File. It provides the capability to LOAD IN or READ OUT data in the file. The file is stored on the disk as file "INST." This file can contain 25 instrument definitions, which consist of the instrument ID, name, instrument type, mount ID, Euler angles ( $\phi$  1,  $\theta$ ,  $\phi$  2), MAX and MIN angle limits for instrument angle 1 and 2, reticle ID, and a 3 by 3 mount matrix.

##### 4.3.7.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the IFILE program is retrieved from the disk by keying get "IFILE".

##### 4.3.7.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "0 = READ, 1 = LOAD" requests the user to define the desired mode by entering either "0" or "1" and keying CONTINUE. The program will then display the appropriate prompts for the selected mode. Once the program

mode has been initiated, the program will remain in that mode until the program is terminated or reinitialized.

o READ mode

The first prompt to appear in the READ mode is "INST ID (S01-25)" requesting the input of the desired Instrument ID whose data is to be read out. The legal input that can be entered is Sxx (where xx = 01 to 25). After entering the desired instrument ID and keying CONTINUE, the requested data will be printed out. The printout will consist of instrument ID, comment, instrument type, mount ID, Euler angles, MAX and MIN angle limits for instrument angle 1 and 2, reticle ID, and a 3 by 3 mount matrix (fig. 4-10). After the data is printed out, the program will redisplay the prompt "INST ID (S01-25)" requesting the next instrument ID to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

o LOAD mode

The first prompt to appear in the LOAD mode is "INSTR ID (S01-25)" requesting the input of the desired ID for the instrument definition to be loaded. The legal inputs that can be entered are Sxx (where xx = 01 to 25). After entering the ID and keying CONTINUE, the prompt "COMMENT (20 char)" will appear. This prompt is requesting an input of up to 20 characters for use as a title or identifier for the instrument definition. If no comment is desired, enter a SPACE. After the desired comment has been entered and CONTINUE keyed, the following instrument definition prompts will appear.

INSTR TYPE - A three-digit number ABC that defines the rotation sequence of the instrument and the null axis of the instrument.

A - axis for 1st rotation,

B - axis for 2nd rotation

C - null axis of the instrument

The number code for each axis is

1 = +X axis

2 = +Y axis

3 = +Z axis

4 = -X axis

5 = -Y axis

6 = -Z axis

MT ID - No longer used because mount matrix is now included as part of instrument definition data. Can put any number you like in it.

Phi 1 - Euler angle of rotation about X mount axis to the X', Y', Z' coordinate system.

Theta - Euler angle of rotation about Y' axis to the X", Y", Z" coordinate system.

Phi 2 - Euler angle of rotation about X" axis to the instrument coordinate system.

A1 MIN - The minimum angle limit for the first instrument rotation angle.

A1 MAX - The maximum angle limit for the first instrument rotation angle.

A2 MIN - The minimum angle limit for the second instrument rotation angle.

A2 MAX - The maximum angle limit for the second instrument rotation angle.

RET ID - Identifies whether a special reticle is to be used or not. 0 = NO Reticle, 1 = Reticle (Hor, Vert).

**Note:** See Rev 1, OFT MCC Level B/C definition and Formulation for Instrument Definition Table, JSC-11537, for details on what each parameter does and how it is used.

After the RET ID prompt request has been entered, the program will display the prompts "MT M11," "M12," "M13," "M21," ..., "M33" requesting the input elements of the mount matrix. The mount matrix is the rotation matrix from the Orbiter body coordinate system to the instrument mount coordinate system. After the M33 element has been input, the input data will be stored on the disk and printed out (fig. 4-10). After the data are printed out, the program will redisplay the prompt "INSTR ID (S01-25)" requesting the next instrument ID for which data are to be loaded. The cycle will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

INSID S03 Yaw, Pitch wrt BDY

TYPE 213 MT ID 1 Phi 1 90.000 Theta 90.000 Phi 2 0.000  
A1MIN 0.000 A1MAX 360.000 A2MIN -90.000 A2MAX 90.000 RET ID 0

## **MOUNT MATRIX**

```

M11  1.000000    M12  0.000000    M13  0.000000
M21  0.000000    M22  1.000000    M23  0.000000
M31  0.000000    M32  0.000000    M33  1.000000

```

Figure 4-10.- Typical instrument definition table printout.

#### 4.3.7.4 MOC Usage

There is a similar capability available by MED inputs to the MOC. See the CCS Trajectory Users Guide for required inputs.

## 4.4 STATE VECTOR FILE READ PROGRAM (RSV) (HP9825)

### 4.4.1 Purpose

This program is used to verify the contents of the ephemeris files by providing a means of retrieving the information stored in the files and printing it out.

### 4.4.2 System Preparation

The HP 9825 calculator, disk drive, and thermal printer must be turned on. Then the program is retrieved from the disk by keying get "RSV".

### 4.4.3 Program Operation

The program is initiated by keying RUN. The program will display prompts in the display indicating what input data is required. The first prompt "EPH # (X X X)" requests the user to enter the desired ephemeris file to be read out. After entering the ephemeris # (X X X) and keying CONTINUE the program will display the prompt "EPHEM & SV, Yes = 0, No = 1 (SV Only)" requesting the entry of "0" or "1" for the desired data to be read. If "0" was input, the program will read and print out the general ephemeris data (fig. 4-11) before displaying the prompt "VID # (1-20)" requesting input of which vector ID is desired to be read out. If "1" was input when "Ephem & SV, Yes = 0, No = 1 (SV Only)" was displayed, the program will skip the retrieval and printout of the general ephemeris data and go directly to the prompt "VID # (1-20)." After entering the vector ID # desired to be read out and keying CONTINUE, the data are retrieved from the file and printed out (fig. 4-12). After the VID data are printed out, the program will redisplay the prompt "VID # (1-20)" requesting the next vector ID to be read out. This will continue until the program is terminated (by keying STOP or RESET) and reinitialized or erased.

EPH 1

GMT of EPOCH 22291200.00000 sec

GMTLO from GMT of EPOCH 43200.00000 sec

GHA 353.3620 We 7.292.11579822E-05

M50 to EFEPOCH (RNP2)

9.92506333E-01	-1.22159778E-01	-2.85794073E-03
1.22159414E-01	9.92510446E-01	-3.02369375E-04
2.87347340E-03	-4.90208518E-05	9.99995870E-01

Sun Ephemeris

G 282.5913494945100 E 23.43965743050 e 0.01671764514 g 250.77831140000

Lunar Ephemeris

D 281.73800000000 Mean Long 297.4913240000 1 117.64485400000  
Omega 157.6164620000 EPS 23.4396574305 1' 250.7784188000

Figure 4-11.- Typical general ephemeris data printout.

EPH = 1 VID = 1

Nominal MECO

GMT SV 22334922.40 secs

#### INVARIANT ELEMENTS

AK 21212098.2	EK 9.30932905882E-03	IK 40.4899730
GK -53.0021623	HK 237.5286913	MK 113.2171251
ETA 6.95611313E-02	GDOT 1.03806139E-04	HDOT -8.35873427E-05

Figure 4-12.- Typical vector invariant element printout.

## 4.5 GEM PROGRAM (GEM) (HP9825)

### 4.5.1 Purpose

HP9825 calculator program GEM lists star pair combinations that meet separation, horizon, and Sun/Moon proximity constraints for a specified time period and orbit. From the 50 navigation stars, potential pair candidates meet the following separation constraints.

-Z star tracker/-Y star tracker IMU alignment  $87.650 \pm 5^{\circ}$   
-Z COAS/-Y star tracker calibration/alignment  $90.0 \pm 4^{\circ}$

To be considered visible, the stars must be above the Earth horizon.

Day	200
Night	30

#### 4.5.2 Program Operation

In GEM, day/night determination is done by the program for three times: start, midpoint, and end of the specified time period. Star visibility is sorted for each of these times. The midpoint check was incorporated in the event that the time period specified is so long (over 40 minutes) that stars on the wrong side of the Earth would meet start and end times visibility tests. To incorporate AOS LOS determination, per se, into GEM would be difficult, but this capability is available in SEARCH (to a limited extent) or FP or its variant FP1. The stars should also be sufficiently separated from the Sun and the Moon in accordance with

<u>Instrument</u>	<u>Sun</u>	<u>Moon</u>
Star tracker COAS	30° Night only	8° 20°

The program excludes stars that fail the 30° and 8° separation constraints but prints out a warning when the separation of the Moon from a COAS star is less than 20°. The program does not check for day/night conditions for COAS stars except insofar as horizon constraints are concerned. The separations are calculated for the center of the time period, so for very marginal cases, technical violations of the separation constraints can possibly occur for a portion of the time period. Since the Sun "moves" about 1° per day and the Moon about 0.5° per hour, these violations would not be large.

Bright planets (Jupiter, Saturn, Mars, Venus) in close proximity to target stars should be avoided. When the candidate stars are close to the ecliptic, the program prints out a warning of possible planetary interference. The pointer should ascertain the possibility of interference by referring to the celestial object plot prepared from planet ephemeris tables, as GEM has no facility for planet location determination.

Three modes of operation are available for selection.

- Z star tracker boresight/-Y star tracker closest
- Z star tracker/-Y star tracker split difference
- Z COAS boresight/-Y star tracker closest

Generally, the operator will be concerned with the first two: -Z/-Y star trackers with either -Z star tracker boresighted or the separation difference approximately evenly split between the two targets. The pairs table contains attitudes (for lookup by GEM) that boresight the -Z star tracker (or the COAS) on each target star. Therefore, for each pair, two attitudes exist: one for boresight -Z on each star. For adjustment of these attitudes for split-difference, roll is adjusted by half the difference between the star separation and the star tracker separation, 87.65°. This adjustment is accomplished in line 115. The adjustment is only an approximation, but is adequate because the star tracker lines of sight form a plane near the Y -Z plane, and roll is the last rotation in the PYR Euler sequence. Therefore, no cross coupling occurs in pitch or yaw for only a roll change.

Since two possible orientations exist for each star pair (-Z boresighted on one star or the other), there is a dilemma as to which to select. This dilemma is resolved by determinations of the eigen axis maneuvers from starting and ending attitudes specified by the user. The total rotation for the star pair attitude that is the lesser of the two is selected for printout along with the eigen rotations for each maneuver. The user can make a judgment in comparing several pair candidates by taking total rotation into consideration. When specifying start or end attitudes, the user may specify either LVLH or inertial (starball), whichever is known or more convenient. For LVLH attitudes, the program asks for MET to calculate inertial attitude for the internal eigen axis rotation calculations. The input attitudes are listed in the output together with LVLH or INRTL identifiers as a further operator aid. The program makes no internal practical distinction between "from" and "to" attitudes. If the attitude resulting in a minimum maneuver with respect to a single attitude is sought, the program can be "fooled" by entering in the same attitude (and time, if LVLH) for both from and to entries.

## 4.6 MANEUVER PROGRAM (M) (HP9825)

### 4.6.1 Purpose

The calculator program MANEUVER enables the operator to determine the maneuver time, eigen angle, and eigen axis of rotation for a maneuver from ATTITUDE 1 to ATTITUDE 2. This program uses either INRTL, LVLH, or REF input attitudes. However, the input attitudes (both attitude 1 and 2) must be of the same reference frame.

### 4.6.2 Program Operation

The program is accessed by typing in get "M" and executing. After depressing run, the first prompt will ask for the "MNVR Rate (deg/sec)." The operator can input the rate, if known, or continue because the output will automatically give maneuver times for 0.2, 0.5, and 1.0 deg/sec maneuvers.

The next prompt asks the operator to specify the Euler sequence; whether a pitch, yaw, roll (continue) or a yaw, pitch, roll (2). The Euler sequence for the Shuttle is pitch, yaw, roll.

The next prompt asks the operator to specify the type of output desired. A "continue" will give the operator a short printout (fig. 4-13(a)), "2" will give the operator a long printout (fig. 4-13(b)). The prompts that follow ask for the inputs for attitude 1 and attitude 2.

### 4.6.3 MOC Program

A similar program (Attitude Maneuver Predictor) is available through MED input to the MOC. Reference the CCS Trajectory Users Guide for required inputs. Note that the MOC maneuver processor uses only inertial inputs.

PITCH, YAW, ROLL SEQUENCE:  
 ROLL 1 = 180.00 ROLL 2 = 0.00 EIGENVECTOR DATA: ANGLE = 120.00  
 PITCH 1 = 0.00 PITCH 2 = 90.00 PITCH = -45.00 PHI = 135.00  
 YAW 1 = 0.00 YAW 2 = 270.00 YAW = 35.26 THETA = 54.74  
 MANEUVER RATE (deg/sec) = 0.20 0.50 1.00  
 MANEUVER TIME (min) = 10.00 4.00 2.00

(a) Short printout.

PITCH, YAW, ROLL SEQUENCE:  
 ROLL 1 = 180.00 ROLL 2 = 0.00 EIGENVECTOR DATA: ANGLE = 120.00  
 PITCH 1 = 0.00 PITCH 2 = 90.00 PITCH = -45.00 PHI = 135.00  
 YAW 1 = 0.00 YAW 2 = 270.00 YAW = 35.26 THETA = 54.74  
 MANEUVER RATE (deg/sec) = 0.20 0.50 1.00  
 MANEUVER TIME (min) = 10.00 4.00 2.00  
 EIGENVEC. X COMP. = 0.57735027  
 EIGENVEC. Y COMP. = 0.57735027  
 EIGENVEC. Z COMP. = 0.57735027  
 QUAT. SCALAR = 0.50000000  
 QUAT. VEC. X COMP. = -0.43301270  
 QUAT. VEC. Y COMP. = -0.43301270  
 QUAT. VEC. Z COMP. = -0.43301270  
 ROLL ANG (1+2) = 180.00  
 PITCH ANG (1+2) = 180.00  
 YAW ANG (1+2) = 90.00  
 TRANSFORM MAT. FROM M50 TO 1ST ATTITUDE:  
 1.00000000 0.00000000 0.00000000  
 0.00000000 -1.00000000 0.00000000  
 0.00000000 0.00000000 -1.00000000  
 TRANSFORM MAT. FROM M50 TO 2ND ATTITUDE:  
 0.00000000 -1.00000000 0.00000000  
 0.00000000 0.00000000 -1.00000000  
 1.00000000 0.00000000 0.00000000  
 TRANSFORM MAT. FROM 1ST ATTITUDE TO 2ND ATTITUDE:  
 0.00000000 1.00000000 0.00000000  
 0.00000000 0.00000000 1.00000000  
 1.00000000 0.00000000 0.00000000

(b) Long printout.

Figure 4-13.- Typical printout of maneuver data.

## 4.7 IMU GIMBAL FLIP AVOIDANCE (LOCK) (HP9825)

### 4.7.1 Purpose

The IMU Gimbal Flip Avoidance Program is designed to identify IMU alignment attitude, i.e., REFSMMAT combinations that might be susceptible to gimbal flip. The programs output is intended to aid time-line development by avoiding problem stair pair attitude or, if no other star pair is available, to advise that a particular IMU be taken off-line to avoid a gimbal flip condition.

The program examines each of the star pairs used for IMU alignments (both attitudes), in the OPS 2 and OPS 3 modes, for each of the specified REFSMMAT's. The middle gimbal angle, (MGA), pitch, is compared with 270° and 90°. The program then flags the attitude as -Lock-(LK) if the MGA is within 0.6° and -marginal-(MG) if it is within 5° of the 270° or 90° singularities.

### 4.7.2 Program Operation

Before accessing the Gimbal LOCK Program, the operator should update the REFSMMAT file using RFFILE. After the REFSMMAT file is updated, type get "LOCK", execute, and then run. The first prompts will ask for the first REFSMMAT and last REFSMMAT number to be used in checking IMU gimbal resolver angles. If you are checking only one REFSMMAT, input the same REFSMMAT for the last as you did for the first. The next program prompt will ask the operator if he wishes to input a comment to appear on the output. If no comment is desired, continue the program. The next prompt will ask the operator to select if bad attitudes only or if all star pair attitudes (good and bad) are to be printed. After continuing the program, the processing will begin. The program takes about 20 minutes to run and can easily be rerun when the REFSMMAT file is updated.

Figure 4-14 is a sample output. The stair pair attitudes are referenced to the "starball" RELMAT. The MGA column indicates the susceptibility of the star pair.

REFSMMAT REFERENCE			RFMT#	DESCRIPTION						
	1			ASCENT	IMU	1	r5			
	2			ASCENT	IMU	2	r5			
	3			ASCENT	IMU	3	r5			
	4			ENTRY	IMU	1	r6			
	5			ENTRY	IMU	2	r6			
	6			ENTRY	IMU	1	r2			
	7			ENTRY	IMU	3	r2			

IMU MGA LOCK TABLES										PAGE 1
PAIR	NAMES	OPS	ADI	ATT	(strbl)	RFMT	IMU	RES.	ANG	
-Z -Y	-Z	-Y	R	P	Y	#	R	P	Y	MGA
52 14	HAMAL	VEGA 2	146.2	149.2	51.6	6	155.6	274.6	285.5MG	
52 14	HAMAL	VEGA 3	144.3	149.2	51.6	6	157.7	274.4	281.5MG	
52 14	HAMAL	VEGA 2	146.2	149.2	51.6	7	154.7	274.6	286.4MG	
52 14	HAMAL	VEGA 3	144.3	149.2	51.6	7	156.9	274.5	282.3MG	

Figure 4-14.- Typical printout of IMU Gimbal Flight Avoidance Program.

#### 4.8 ASPECT (ASPECT) (HP9825)

##### 4.8.1 Purpose

The calculator program Aspect enables the pointer to rapidly develop attitude time-line products after an attitude outline is known (CAP's attitude outline). The inputs to Aspect consist of either INRTL or LVLH Euler sequences, the MET and the ephemeris file containing the desired state vectors. Outputs include the three ADI attitudes (LVLH, REF, INRTL); the Earth, Sun body vector (P, Y and  $\theta$ ,  $\phi$ ); and the amount of eigen axis rotation from the previous input. This last output can be used to plan minimum maneuvers.

The program is intended as an alternative to other utility programs, such as Supersighter and M.

##### 4.8.2 Program Operation

To access the program, type in get "ASPECT", execute, and depress run. The first prompts will ask for the ephemeris name and state vector ID. The next prompt will ask for a reference RELMAT. Prior to running this program, the RELMAT of interest here must have been loaded in the RELMAT files. This RELMAT should be the reference or REF RELMAT.

The next prompt will ask for the event's time in MET days, hours, minutes, and seconds. The prompt that follows gives the operator a chance to label the event for record keeping. The next prompt will ask if the input attitude is LVLH (0) or INRTL (1). After selection, the operator can input the attitude. Following this last input is a repeat of the prompts for time, comment, and attitude for a total 25 events.

The operator can defeat the additional entries by input of zero in the time prompts. This action may be necessary due to a state vector change.

Figure 4-15 is a sample output.

EPH 2	VID 2	RLMT 1
MET	EVENT	ATTITUDE (PYR EULER SEQ)
D/HH:MM:SS		ROLL PITCH YAW
0/02:00:00		-ZLV YPOP INRTL 342.45 35.70 325.64 EARTH 90 0 90 0
		REF 342.45 35.70 325.64 EIG ANGLE 55.5
		LVLH 180.00 0.00 0.00 SUN 176 -53 127 273

Figure 4-15.- Typical printout of Aspect Program.

#### 4.9 FLIGHT PLAN (FP) (HP9825)

##### 4.9.1 Purpose

The calculator program, Flight Plan, has nine modes of operation which provide the capability to ascertain: Sun and Moon rise and set time, STDN and TDRS AOS/LOS, celestial and ground target AOS/LOS, orbit ascending node, groundtrack, and deorbit opportunities. All these programs are used for flight planning purposes.

##### 4.9.2 Program Operation

The program is accessed by typing get "FP", executing, and depressing run. The first prompt asks for the reference ephemeris file (EPH#). The next prompt asks the operator to select the program option number.

<u>Option</u>	<u>Program</u>
1	Day/night
2	Moon rise/Moon set
3	STDN
4	TDRS
5	CTGT (celestial target)
6	GTGT (ground target)
7	Ascending node
8	GTRK (groundtrack)
9	DORBITGT (deorbit target)

#### 4.9.3 Option 1 - Day/Night

The following is a list of the inputs for option 1.

<u>Program Prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
ELV ANG	Elevation angle (deg)
VID# (1-20)	State vector ID from reference ephemeris
START TIME	MET
STOP TIME	MET

Option 1 output printout includes the above input parameters and the following generated data.

<u>Generated parameters</u>	<u>Generated data</u>
SR	Sun rise
TR	Terminator rise (Earth)
NOON	
TS	Terminator set (Earth)
SS	Sun set
Beta	Beta angle

Figure 4-16 is a sample output for option 1.

OPT 1=DAY/NIGHT,2=MS/MR,3=STDN,4=TDRS,5=CTGT,6=GTGT,7=A/N,8=GTRK,9=DORBTGT

OPTION 1

EPH 2 VID 2 ELANG 0.0  
START MET 0/01:00:00.0 STOP MET 1/01:00:00.0

SR	TR	NOON	TS	SS	Beta
0/01:08:06	0/01:14:26	0/01:36:42	0/01:58:57	0/02:05:16	-53.3
0/02:37:08	0/02:43:30	0/03:05:46	0/03:28:01	0/03:34:22	-53.4
0/04:06:11	0/04:12:34	0/04:34:50	0/04:57:05	0/05:03:28	-53.6
0/05:35:14	0/05:41:38	0/06:03:54	0/06:26:09	0/06:32:33	-53.7
0/07:04:17	0/07:10:42	0/07:32:58	0/07:55:14	0/08:01:39	-53.9
0/08:33:19	0/08:39:46	0/09:02:02	0/09:24:18	0/09:30:45	-54.0
0/10:02:22	0/10:08:51	0/10:31:07	0/10:53:22	0/10:59:51	-54.2
0/11:31:25	0/11:37:55	0/12:00:11	0/12:22:27	0/12:28:56	-54.3
0/13:00:29	0/13:06:60	0/13:29:16	0/13:51:31	0/13:58:02	-54.4
0/14:29:32	0/14:36:04	0/14:58:20	0/15:20:36	0/15:27:08	-54.6
0/15:58:35	0/16:05:09	0/16:27:25	0/16:49:41	0/16:56:14	-54.7
0/17:27:38	0/17:34:14	0/17:56:30	0/18:18:45	0/18:25:20	-54.8
0/18:56:42	0/19:03:18	0/19:25:35	0/19:47:50	0/19:54:26	-54.9
0/20:25:46	0/20:32:23	0/20:54:39	0/21:16:55	0/21:23:32	-55.0
0/21:54:49	0/22:01:28	0/22:23:44	0/22:45:60	0/22:52:38	-55.2
0/23:23:53	0/23:30:33	0/23:52:49	1/00:15:05	1/00:21:44	-55.3
1/00:52:57	1/00:59:38	1/01:00:00	1/01:00:00	1/01:00:00	-55.4

Figure 4-16.- Typical printout of Flight Plan option 1 - day/night.

#### 4.9.4 Option 2 - Moon Set and Moon Rise (MS/MR)

The following is a list of the inputs for option 2.

<u>Program prompt</u>	<u>Input</u>
STORE DATA	Yes = continue / No = 1
ELV ANG	Elevation angle
VID # (1-20)	State vector ID from reference ephemeris file
START TIME	MET
STOP TIME	MET

Option 2 printout (fig. 4-17) includes the input parameters and generated outputs.

OPT 1=DAY/NIGHT, 2=MS/MR, 3=STDN, 4=TDRS, 5=CTGT, 6=GTGT, 7=A/N, 8=GTRK, 9=DORBTGT

OPTION 2

EPH 2 VID 2 ELANG 0.0  
START MET 0/01:00:00.0 STOP MET 1/01:00:00.0

MOON	AOS(MET)	TCA(MET)	LOS(MET)	DLT
	0/01:00:00	0/01:00:00	0/01:25:17	0:25:17
	0/01:57:45	0/02:26:16	0/02:54:47	0:57:02
	0/03:27:08	0/03:55:42	0/04:24:17	0:57:09
	0/04:56:32	0/05:25:09	0/05:53:47	0:57:15
	0/06:25:57	0/06:54:37	0/07:23:17	0:57:20
	0/07:55:22	0/08:24:05	0/08:52:47	0:57:25
	0/09:24:49	0/09:53:33	0/10:22:17	0:57:29
	0/10:54:16	0/11:23:01	0/11:51:47	0:57:31
	0/12:23:43	0/12:52:30	0/13:21:17	0:57:33
	0/13:53:11	0/14:21:59	0/14:50:46	0:57:35
	0/15:22:40	0/15:51:27	0/16:20:15	0:57:35
	0/16:52:09	0/17:20:56	0/17:49:43	0:57:34
	0/18:21:39	0/18:50:25	0/19:19:11	0:57:32
	0/19:51:08	0/20:19:53	0/20:48:38	0:57:30
	0/21:20:38	0/21:49:21	0/22:18:04	0:57:26
	0/22:50:08	0/23:18:49	0/23:47:30	0:57:22
	1/00:19:38	1/00:48:17	1/01:00:00	0:40:22

Figure 4-17.- Typical printout of Flight Plan option 2 - MS/MR.

#### 4.9.5 Option 3 - STDN

The Station Tracking and Data Network site (STDN) option provides AOS/LOS for the input time span for the following sites: BDA, GDS, HAW, IOS, MIL, ORR, QUI, AGO, ACN, GWM, MAD.

Or the operator can input the STDN site of interest for a given time span.

The inputs for this option are

<u>Program prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
STANDARD SITES	0 = yes/1 = no

If "0" is input (fig 4-18)

<u>Input parameters</u>	<u>Input</u>
ELV ANG	Elevation angle
VID # (1-20)	State vector ID
START TIME	MET
STOP TIME	MET

If "1" is input

<u>Input parameters</u>	<u>Input</u>
No. sites (1-25)	Enter no. sites desired
Site ID (3 char)	i.e. EDW
ELV ANG	Elevation angle
VID # (1-20)	State vector ID
START TIME	MET
STOP TIME	MET

The output includes

<u>Site</u>	<u>Name</u>
AOS	Acquisition of site
TCA	Closest approach
LOS	Loss of site
DLT	Time in daylight
MAXEL	Site elevation
SLRNG	Slant range
S-ANG	Sun angle

OPT 1=DAY/NIGHT,2=MS/MR,3=STDN,4=TDRS,5=CTGT,6=GTGT,7=A/N,8=GTRK,9=DORBTGT

OPTION 3

EPH	2	VID	2	ELANG	0.0	START MET	0/01:00:00.0	STOP MET	0/03:00:00.0			
SITE		AOS(MET)		TCA(MET)		LOS(MET)		DLT		MAXEL	SLRNG	S-ANG
BDA		0/01:38:52		0/01:42:35		0/01:46:18		07:27		17.2	370.6	38.6
GDS		0/01:29:43		0/01:32:15		0/01:34:47		05:05		4.0	729.9	23.2
HAW		0/02:53:06		0/02:55:20		0/02:57:34		04:27		2.9	764.7	15.1
IOS		0/02:12:55		0/02:13:10		0/02:13:26		00:30		0.0	949.0	-44.3

Figure 4-18.- Typical printout of Flight Plan option 3 - STDN.

#### 4.9.6 Option 4 - TDRS

When the Tracking and Data Relay Satellites (TDRS's) are placed in orbit, this program will give the approximate AOS/LOS for the eastern and western (plus one spare TDRS) satellites.

The following is a list of program inputs.

<u>Program prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
No. TDR's (1-3)	Satellites of interest
TDRS ID	TDRE (eastern), TDRW (western), TDRS (spare)
ELEV ANG	Elevation angle
VID ID (1-20)	State vector from reference ephemeris
START TIME	MET
STOP TIME	MET

Figure 4-19 is an example output.

OPT 1=DAY/NIGHT, 2=MS/MR, 3=STDN, 4=TDRS, 5=CTGT, 6=GTGT, 7=A/N, 8=GTRK, 9=DORBTGT

OPTION 4

EPH 2 VID 2 ELANG 0.0  
START MET 0/01:00:00.0 STOP MET 0/02:30:00.0

TDRS	AOS(MET)	TCA(MET)	LOS(MET)	DLT
TDRE	0/01:23:47	0/01:49:52	0/02:15:52	0:52:06
TDRW	0/01:00:00	0/01:15:46	0/01:40:58	0:40:58
TDRW	0/02:24:26	0/02:30:00	0/02:30:00	0:05:34
TDRS	0/01:35:32	0/02:00:43	0/02:25:52	0:50:21

Figure 4-19.- Typical printout of Flight Plan option 4 - TDRS.

#### 4.9.7 Option 5 - Celestial Target (CTGT)

The celestial target option provides AOS/LOS times for an input star and input elevation angle. The option of FP is useful in determining AOS/LOS times for stare in daylight (20° Earth elevation input) and darkness (3° Earth elevation input) and in determining star AOS/LOS at Earth horizon (0° elevation).

The program inputs are

<u>Program prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
Are Tgts Seq.	0 = yes/1 = no

This prompt allows the operator the choice of running all the stars (sequential) or running only the stars of interest.

For sequential star AOS/LOS

<u>Program prompt</u>	<u>Input</u>
First tgt #	First star number
Last tgt #	Last star number

For star of interest

<u>Program prompt</u>	<u>Input</u>
No. cel tgts	Number of stars to be examined
Cel tgt (1-400)	Star ID number

The following inputs are the same for both of the modes.

<u>Program prompt</u>	<u>Input</u>
ELV ANG	Elevation angle
VID # (1-20)	State vector from reference ephemeris
START TIME	MET
STOP TIME	MET

Figure 4-20 is an example printout.

OPT 1=DAY/NIGHT,2=MS/MR,3=STDN,4=TDRS,5=CTGT,6=GTGT,7=A/N,8=GTRK,9=DORBTGT

OPTION 5

EPH	2	VID	2	ELANG	20.0	START	MET	0/01:00:00.0	STOP	MET	0/03:00:00.0	CTGT	AOS(MET)	TCA(MET)	LOS(MET)	DLT	
C	21		0/01:00:00			0/01:13:43			0/01:34:34		0:34:34	C	21	0/02:21:50	0/02:42:42	0/03:00:00	0:38:10

Figure 4-20.- Typical printout of Flight Plan option 5 - CTGT.

NOTE: The celestial target must be input in CFILE before the operator can access the AOS/LOS using this program.

MOC Program - Celestial Target is a MOC program similar to option 5 that is accessed through MED inputs. See the CCS Trajectory Users Guide for inputs and program requirements.

#### 4.9.8 Option 6 - Ground Target (GTGT)

This option provides the user with AOS/LOS data ground targets of interest. The output includes the time of closest approach, maximum elevation angle of the site, slant range, and Sun angle.

The inputs must be loaded in GFILE before they can be used as inputs to this program.

The inputs for this option are

<u>Program prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
Are tgt seq	0 = yes/1 = no

If the ground targets are sequential, the following inputs are required.

<u>Program prompt</u>	<u>Input</u>
First tgt #	Ground tgt number from GFILE
Last tgt #	Ground tgt number from GFILE

If the user is interested in a particular ground target, the following inputs are required.

<u>Program prompt</u>	<u>Input</u>
No. grd tgts	Number of tgts of interest
Grd tgt # (1-100)	Ground tgt number from GFILE

The following inputs are required for both modes.

<u>Program prompt</u>	<u>Input</u>
ELV ANG	Elevation angle
VID # (1-20)	State vector from reference ephemeris
START TIME	MET
STOP TIME	MET

Figure 4-21 is an example output.

OPT 1=DAY/NIGHT, 2=MS/MR, 3=STDN, 4=TDRS, 5=CTGT, 6=GTGT, 7=A/N, 8=GTRK, 9=DORBTGT

OPTION 6

EPH	2	VID	1	ELANG	0.0	START MET	0/01:00:00.0	STOP MET	0/02:00:00.0	GTGT	AOS(MET)	TCA(MET)	LOS(MET)	DLT	MAXEL	SLRNG	S-ANG
*	2.										0/01:38:57	0/01:42:31	0/01:46:06	07:09	13.0	445.3	39.9

\* This is the target number assigned to the ground target in GFILE.

Figure 4-21.- Typical printout of Flight Plan option 6 - GTGT.

MOC Program - Ground Target is a MOC program similar to option 6 that is accessed through MED inputs. See the CCS Trajectory Users Guide for inputs and program requirements.

#### 4.9.9 Option 7 - Ascending Node (A/N)

This option provides the user with the ascending node time, longitude, and RA beginning with an initially input orbit and time span.

The following represent the required inputs for option 7.

<u>Program Prompt</u>	<u>Input</u>
STORE DATA	0 = yes/1 = no
INITIAL ORBIT	Orbit number
VID # (1-20)	State vector from reference ephemeris
START TIME	MET
STOP TIME	MET

Figure 4-22 is an example output for this option.

OPT 1=DAY/NIGHT, 2=MS/MR, 3=STDN, 4=TDRS, 5=CTGT, 6=GTGT, 7=A/N, 8=GTRK, 9=DORBTGT

**OPTION 7**

EPH 2 VID 2 Init Orb 2  
START MET 0/01:00:00.0 STOP MET 0/03:00:00.0

**ORB**

2	0/01:21:30.6	-143.7514	121.6908	155.4350
3	0/02:50:23.7	-166.5434	121.7014	154.9250

Figure 4-22.- Typical printout of Flight Plan option 7 - A/N.

#### 4.9.10 Option 8 - Groundtrack (GTRK)

This option provides the user with the latitude, longitude, altitude, RA, and DEC (LOS from the center of the Earth through the ground point to the celestial sphere) of ground track given time interval and steps and the initial orbit.

The following is a list of the required inputs for this mode.

<u>Program prompt</u>	<u>Input</u>
Step interval (min)	Time increments
Init Orb #	Orbit number
VID # (1-20)	State vector from reference ephemeris
START TIME	MET
STOP TIME	MET

Figure 4-23 is an example output.

OPT 1=DAY/NIGHT,2=MS/MR,3=STDN,4=TDRS,5=CTGT,6=GTGT,7=A/N,8=GTRK,9=DORBTGT

OPTION 8

	EPH 2	VID 2	Step Interval	30.0000 Mins	Init Orb	1	
	START MET	0/01:00:00.0	STOP MET	0/03:00:00.0			
MET	ORB	LATC	LON	ALTC	LATD	RA	DEC
0/01:00:00.0	1	-37.9550	135.3632	122.3403	-38.1417	69.2861	-38.0156
0/01:30:00.0	1	20.3529	-117.6687	121.1344	20.4786	183.6510	20.5279
0/02:00:00.0	1	14.5392	6.9557	120.8014	14.6330	315.8224	14.4122
0/02:30:00.0	1	-37.6377	118.0680	122.3534	-37.8240	74.5548	-37.6830
0/03:00:00.0	1	22.7526	-136.5485	121.0732	22.8901	187.3381	22.9264

Figure 4-23.- Typical printout of Flight Plan option 8 - GTRK.

MOC Program - Ground Track is a similar program available in the MOC that is accessed through MED inputs. See the CCS Trajectory Users Guide for more information.

#### 4.9.11 Option 9 - Deorbit Target (DORBTGT)

This option provides the user with deorbit opportunities.

The following is a list of required inputs.

<u>Program prompt</u>	<u>Input</u>
Cross range limit	Nautical miles
Initial orbit	Orbit number
TIGDT (min)	Time to deorbit burn in landing minus time
EI DT (min)	Time to entry interface in landing minus time
LG DT (min)	Landing time
Day of site SR/SS	Calendar of landing
Landing site	Landing site name (3 char)
VID # (1-20)	State vector from reference ephemeris

Figure 4-24 is an example output.

OPT 1=DAY/NIGHT, 2=MS/MR, 3=STDN, 4=TDRS, 5=CTGT, 6=GTGT, 7=A/N, 8=GTRK, 9=DORBTGT

OPTION 9

EPH 2 VID 2 CROS RNG LIMIT 600 TIG Dt -50.00 EI Dt -35.00 LDG Dt 0.00  
START MET 0/02:00:00.0 STOP MET 0/12:00:00.0

EDW SR -1/23:14:48 EDW NOON 0/04:27:20 EDW SS 0/09:39:52  
EDW SR 0/23:14:56 EDW NOON 1/04:27:28 EDW SS 1/09:40:01

SITE EDW

ORB	DEORB	TIG	EI	LNDG	CROS	RNG	dT	wrt	SR/SS	Sun Az	Sun EI
2	0/02:15:12		0/02:30:12	0/03:05:12	165.9	R	3:50:24		156.3	33.8	
3	0/03:48:45		0/04:03:45	0/04:38:45	-145.2	S	5:01:07		183.4	37.2	
4	0/05:22:29		0/05:37:29	0/06:12:29	-165.5	S	3:27:23		209.7	31.6	
5	0/06:56:04		0/07:11:04	0/07:46:04	108.6	S	1:53:48		230.2	19.2	

Figure 4-24.- Typical printout of Flight Plan option 9 - DORBTGT.

#### 4.9.12 Flight Plan - Variant 1 (FP1) (HP9825)

This program is designed as a flight planning tool for determining celestial target AOS/LOS times with respect to Sun and Earth star tracker limits. The program automatically gives the user an AOS/LOS for the targets using the daylight/darkness Earth horizon constraints. This program is a variant of FP option 5.

The following is a list of required inputs.

<u>Program prompt</u>	<u>Input</u>
STORE DATA	0 = yes/continue = no
EPH #	Ephemeris file number
VID # (1-20)	State vector ID number
Time base	Continue = MET 0 = TIG minus
START TIME	either MET or TIG minus
STOP TIME	
Are tgts seq.	0 = yes/continue = no

If the targets are sequential, the following is the required inputs.

First tgt #                    Target number as input to  
Last tgt #                    CFILE

If the targets are not sequential, the operator must input

## Program prompt

## Input

Cel tgt # (1-400); 0 = EXIT      Celestial target number from CFILe

This prompt will repeat after each target input. The user can exit this loop by keying "0" and continue. The program will then process the inputs.

Figure 4-25 is an example output.

EPH 2: L/0 = 316/15:09:59.78 GMT VID 2: 0/02:00:00.00 MET

START 0/02:00 STOP 0/04:00 Time ref: MET

	AOS	(e1)	LOS	(e1)	TCA	DLT
C 12	0/02:07:27	( 3)	0/02:53:47	(20)	0/02:32:49	0:46:20
	0/03:36:23	( 3)	0/04:00:00	( )	0/04:01:46	0:23:37
C 13	0/02:06:08	( 3)	0/02:52:40	(20)	0/02:31:48	0:46:32
	0/03:35:08	( 3)	0/04:00:00	( )	0/04:00:48	0:24:52
C 14	0/02:00:00	( )	0/02:15:14	( 3)	0/01:50:02	0:15:14
	0/02:58:01	(20)	0/03:44:12	( 3)	0/03:19:00	0:46:10

Figure 4-25.- Typical printout for FP1.

APPENDIX A  
ABBREVIATIONS AND ACRONYMS

ADI	Attitude Director Indicator
ATT	Attitude
CAP	Crew Activity Plan
COAS	Crewman Optical Alignment Sight
CONFIG	Configuration
CRT	Cathode Ray Tube
DAP	Digital Auto Pilot
DEC	Declination
DISC	Discrete
ERR	Error
EXEC	Execute
FCS	Flight Control System
FDF	Flight Data File
FOV	Field of Vision
FTO	Flight Test Objectives
GNC	Guidance, Navigation and Control
GPC	General Purpose Computer
ID	Identification
IMU	Inertial Measurement Unit
INRTL	Inertial
Lat	Latitude
Lon	Longitude
LOS	Line-of-Sight
LVLH	Local Vertical Local Horizontal (Orbital rate)
MCC	Mission Control Center

MED                    Medium  
MET                    Mission Elapsed Time  
MM                    Major Mode  
MNVR                  Maneuver  
MPAD                  Mission Planning and Analysis Division  
NORM                  Normal Jets  
OFT                   Orbital/Orbiter Flight Test  
OMS                   Orbiter Maneuvering System  
OPS                   Operational Sequence  
ORB                   Orbiter/Orbit  
PBI                   Push Button Indicator  
PFRX                  Preflight RELMAT (X = 1,2,3...9 or A,B,C...Z)  
PLBD                  Payload Bay Door  
PTC                   Passive Thermal Control  
RA                    Right Ascension  
RCS                   Reaction Control System  
REF                   Reference  
RELMAT                Relative Matrix  
RHC                   Rotational Hand Controller  
RMS                   Remote Manipulator System  
ROT                   Rotation  
SPEC                  Specialist Function  
THC                   Translational Hand Controller  
VERN                  Vernier Jets

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K. Russell  
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CF6/D. Whittle

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CG/J. W. Bilodeau  
C. B. Shelley  
D. K. Warren  
J. F. Schuessler (MDTSCO)  
W. H. Todd (Rockwell) (10)  
CG3/K. Flanagan (50)  
J. Wegener  
J. B. Cotter  
R. D. Dell'Osso  
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E. L. Pavelka  
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J. H. Greene (4)  
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P. E. Collector  
CH4/T. A. Guillory  
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R. D. Snyder  
M. S. Rowles  
C. B. Lau  
D. K. Mosel  
R. H. Nute  
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E. B. Pippert  
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L. W. Dunn  
D. L. Freeman  
W. R. Holmberg  
W. F. Huning  
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W. Molnar  
EC/H. L. Stutesman  
EC2/E. Nitsch  
J. Jaax  
EC3/D. F. Hughes  
ED8/H. A. Kuehnel  
EE4/J. H. Johnson  
J. Fowler (2)  
EF/P. M. Kurten  
EF2/W. W. Killingsworth (3)  
EH13/R. E. Lewis  
T. P. Lins  
C. R. Price  
EH2/D. A. Dyer  
P. C. Kramer  
EH6/J. A. Vernon  
S. Bachman  
EP/H. J. Brasseaux  
EP2/C. R. Gibson

EP4/R. Taeuber  
EP5/W. A. Chambers  
EW/W. W. Petynia  
EX/J. E. DeFife  
EX3/L. O. Hayman  
E. I. Abadie (6)  
FE2/C. C. Olasky  
FE3/K. I. Mansfield (3)  
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