SHUTTLE ON-ORBIT RENDEZVOUS TARGETING: CIRCULAR ORBITS

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Aero-Astrodynamics Laboratory

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E.L. Bentley (Northrop Services, Inc., Huntsville, Ala.) May 1972 120 p CSCL 22A Unclas

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by
Earle L. Bentley

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NORTHROP SERVICES, INC.
HUNTSVILLE, ALABAMA
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ABSTRACT

This memorandum presents a description of the strategy and logic used in a space shuttle on-orbit rendezvous targeting program. The program generates ascent targeting conditions for boost to insertion into an intermediate parking orbit, and generates on-orbit targeting and timeline bases for each maneuver to effect rendezvous with a space station. Time of launch is determined so as to eliminate any plane change, and all work was performed for a near-circular space station orbit.
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KEY WORDS

Orbiter - chaser or pursuit vehicle

Space Station - any target vehicle, satellite

Shuttle Launch Vehicle - booster plus orbiter configuration

Intermediate Orbit - a phasing orbit for the orbiter on-orbit used to alleviate large phasing differences between vehicles. (= 100 n mi Parking orbit for this analysis)

Constant Delta Height (CDH) - a height differential existing between the orbiter and the space station (an orbit approximately 10 n mi below or above the space station). Same as coelliptic orbit.

Transfer Phase Initiation (TPI) - A point on the CDH orbit when gross rendezvous conditions have been met in order to make the final transfer to the rendezvous point.

On-Orbit - the pursuit vehicle after insertion and before rendezvous during all of its intermediate phasing orbits.
## SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta i$</td>
<td>Wedge angle between planes at TPI</td>
</tr>
<tr>
<td>$\Delta \phi$</td>
<td>Range angle difference at TPI after isolation</td>
</tr>
<tr>
<td>$\Delta \theta_N$</td>
<td>Nodal difference at TPI</td>
</tr>
<tr>
<td>$\Delta T_{LF}$</td>
<td>Lift-off time correction to compensate for nodal regression</td>
</tr>
<tr>
<td>$\Delta \phi_{TB}$</td>
<td>First pass Range angle difference using first guess two-body targeting</td>
</tr>
<tr>
<td>$X_S, Y_S, Z_S$</td>
<td>Space fixed launch coordinate system</td>
</tr>
<tr>
<td>$A_z$</td>
<td>Launch aximuth</td>
</tr>
<tr>
<td>$\phi_L$</td>
<td>Geodetic latitude of launch site (28.608°)</td>
</tr>
<tr>
<td>$\phi_{SV}$</td>
<td>Sun vector right ascension</td>
</tr>
<tr>
<td>$\alpha_{SV}$</td>
<td>Sun vector declination</td>
</tr>
<tr>
<td>U.T.</td>
<td>Universal Time measured from midnight Greenwich to launch meridian</td>
</tr>
<tr>
<td>$\lambda_L$</td>
<td>Longitude of launch site</td>
</tr>
<tr>
<td>$\Delta \phi$</td>
<td>Difference in range angles of orbiter and space station at time of orbiter insertion</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Insertion latitude, a function of inclination of the space station</td>
</tr>
<tr>
<td>$I_D$</td>
<td>Desired inclination for targeting purposes</td>
</tr>
<tr>
<td>$P_S$</td>
<td>Semi-latus rectum of CDH orbit</td>
</tr>
<tr>
<td>$e_S$</td>
<td>Eccentricity of CDH orbit</td>
</tr>
<tr>
<td>$\bar{\omega},</td>
<td>\omega</td>
</tr>
<tr>
<td>$P_P$</td>
<td>Semi-latus rectum of orbiter on-orbit during Hohmann transfer</td>
</tr>
<tr>
<td>$e_P$</td>
<td>Eccentricity of orbiter on-orbit during Hohmann transfer</td>
</tr>
<tr>
<td>TULO</td>
<td>Universal time of lift-off</td>
</tr>
<tr>
<td>$\phi_T$</td>
<td>Range angle</td>
</tr>
<tr>
<td>$\phi$</td>
<td>True anomaly</td>
</tr>
<tr>
<td>$\alpha_{PL}$</td>
<td>Argument of perigee</td>
</tr>
</tbody>
</table>
SYMBOLS (Continued)

a Semi-major axis
e eccentricity
\( \psi_{DS} \) desired insertion latitude for southerly launch
\( \psi_{DN} \) desired insertion latitude for northerly launch
\( \phi_{LS} \) Range angle at the desired latitude
\( \vec{X}_p, \vec{\dot{X}}_p \) State vector position and velocity of orbiter
\( \vec{X}_T, \vec{\dot{X}}_T \) State vector position and velocity of space station
\( T_1 \) Time of orbit insertion
\( \beta_{SVPT} \) instantaneous angle from the suns projection vector on orbital plane to the TPI point
\( \beta_{SVPD} \) same as above but is the desired input value
\( \hat{E}_{RA} \) Unit vector in the equatorial plane and through the launch longitude
\( \theta_{NT} \) descending node of space station referenced from space-fixed shuttle launch meridian in the equatorial plane
\( \theta_{NP} \) descending node of the orbiter referenced from space-fixed shuttle launch meridian in the equatorial plane
\( \Delta \phi_R \) desired range angle difference between vehicles at TPI
\( \Delta \phi_E \) difference between actual and desired range angle difference, this value to be driven < .05 in the isolation logic
\( \phi_T \) Range angle of space station measured from the descending node w.r.t. equatorial plane
\( \phi_P \) Range angle of orbiter measured from descending node w.r.t. equatorial plane
\( \phi_{NT} \) Range angle of the space station measured from the common (ascending) node of the space station and the orbiter planes
\( \phi_{NP} \) Range angle of the orbiter measured from the common (ascending) node of the space station and the orbiter planes
\( \Delta \phi \) difference in the range angles of the space station and the orbiter
**SYMBOLS (Concluded)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WATP</td>
<td>Wedge angle between the space station and the orbiters plane</td>
</tr>
<tr>
<td>WATOL</td>
<td>Tolerance to select which $\Delta \phi$ to use (for example, $\text{WATOL} &lt; .1 :: \Delta \phi = \phi_T - \phi_P$ or $\Delta \phi = \phi_{NT} - \phi_{NT}$)</td>
</tr>
<tr>
<td>TSTI</td>
<td>Time of Circularization</td>
</tr>
</tbody>
</table>
Section I
INTRODUCTION

This memorandum is primarily an equation defining document containing
the basic targeting equations in flowchart form to create targeting conditions
at lift-off for the shuttle launch vehicle. This also includes the method of
determining the on-orbit timeline of thrusting events* during orbital maneu-
vers and also determines the Universal Time of lift-off.

The basic mission profile considered for this targeting procedure includes
boost to insertion and three impulsive maneuvers, as listed below, to establish
a constant delta height position (Figure 1-1).

- Insertion (50 x 100 n mi)
- Circularization at apogee (100 n mi)
- Perigee impulse (≥ 100 x 265 n mi)
- Coelliptic impulse (≥ 260 n mi)

The launch azimuth (A₂), inclination (i) and node (θₜₙ) for the launch
phase are generated to achieve orbiter/satellite rendezvous. These are
generated in such a manner as to achieve orbiter/satellite rendezvous with
coplanar conditions near rendezvous and with the proper phase and coelliptic
height differential at TPI.

The given task assignment was to build a space shuttle on-orbit rendez-
vous targeting computer program that would depend only upon a target satellite
ephemeris and the initial in-plane orbital conditions of the space shuttle
(50 x 100 n mi). The computer program was to establish lift-off time for the
space shuttle so as to require no plane change in the ascent portion of flight,
or on-orbit portion of the rendezvous mission. The computer program estab-
lishes a timeline of the thrusting events and guidance targeting requirements.

*This targeting procedure is developed with impulsive maneuver simulations.
Using these targeting values on-orbit will result in ignition time deviations
for each maneuver. This could be alleviated by simulating finite burns with
the targeting deck itself.
Figure 1-1. COPLANAR PROFILE DEPICTING TIME BASES FOR NEAR-CIRCULAR RENDEZVOUS

1-2
Care was to be taken to minimize the number of instructions and storage requirements of the program so that it would be possible to have an on-board shuttle rendezvous capability. The Coordinators flowcharts were to be used, and deviations were to be made whenever necessary and storage instruction could be reduced.
Section II
DISCUSSION

The shuttle, being a performance critical vehicle, should be targeted to a zero plane change, on-time ascent to orbit (50 x 100 n mi) flight profile (as well as to basic satellite delivery missions). The shuttle should not be burdened with a requirement for a rendezvous launch window since this would degrade the payload delivery capability. The procedure presented here will allow launches to be achieved at each in-plane point. One in-plane point will occur for a northerly launch opportunity and the other for a southerly launch opportunity. These conditions occur twice per day, 365 days/year. These two launch opportunities that occur each day are only restricted if the launch site is too close to the in-plane point to allow pre-flight analysis to be performed before the launch. With more restrictive launch vehicles (short systems lifetimes), the correct in-phase and in-plane condition (rendezvous compatible) has to exist to achieve a rendezvous; but, this is not a requirement for the targeting technique presented in this memorandum. An intermediate near-circular phasing orbit at the apogee of the shuttle launch vehicle 50 x 100 n mi insertion orbit will eliminate the space station in-phase requirement at orbital insertion. (If the relative catch-up rate between the 100 n mi intermediate phasing orbit and the space station is not sufficient to null out phase differences, the use of an intermediate stay orbit at a higher altitude will be necessary.) An intermediate phasing orbit exists so that phase angle differences between the two vehicles can be eliminated by exploiting the difference in their respective orbital periods.

Other advantages of this targeting technique include:

- Launch vehicle performance variations will merely change the range correction of the terminal rendezvous maneuvers without causing unacceptable performance losses.

- Eliminates high closing rates of the orbiter w.r.t. the space station, which might be encountered when using direct rendezvous techniques and their resulting performance losses.
This technique allows launch opportunities to occur on a daily basis without degrading the payload delivery capabilities. This is important, for example, when considering the shuttle launch vehicle configuration which requires many launches each year for economical reasons.

If count-down is delayed the next opportunity can be utilized.

The targeting program generates complete targeting based upon space station ephemeris data. This is accomplished by assuming that the Manned Space Flight Tracking Network (MSFN) has made available the epoch (Universal) time when the launch site will be contained in the space station plane, based upon spherical trigonometry and also the ephemeris at this time. The orbital elements (node, inclination, eccentricity, etc.) describing the position of the space station at the in-plane time (U.T.) are presented in Section V.

The periodic perturbations of the space stations' inclination were determined and accounted for in the targeting procedure by using a rapid integration algorithm to advance the space station to the insertion latitude of the shuttle (at present a variable step size Runge Kutta numerical integration scheme is utilized).

The effects of orbital nodal regression are corrected by adjusting the shuttle launch vehicle lift-off time while maintaining the same ascent targeting parameters. The amount of nodal regression depends on the transfer orbits necessary to satisfy phasing requirements, navigation update requirements and lighting requirements.

The ascent trajectory was programmed as a functional representation of an ascent profile. This is presently a sixth order curve fit polynomial as shown in the flowchart on page D-6. Future work in this area includes curve fit techniques using exponential curves and other types of fits which will improve curve-fit accuracy and reduce ephemerical curve-fit coefficients.
Section III

RENDEZVOUS TARGETING TECHNIQUES

The procedures for effecting rendezvous includes integration of the space station to the insertion latitude (ψ) to determine the desired inclination (I_D) for the orbiter insertion. This causes the orbiter to have the same mean inclination as the space station at insertion. This procedure is necessary to account for periodic variations in the inclination of the space station orbit about the oblate earth. The variation of inclination versus time from insertion and time after circularization for both vehicles is presented in Figures 3-1 and 3-2. These figures depict variations with approximately the same mean inclination. Similar results, at a point on-orbit after the apsidal rotation maneuver where the orbiter is phasing 10 n mi below the space station, are presented in Figure 3-3. As can be observed at this point, the variations in inclinations are almost in-phase and thus nearly synchronized. This is desirable for rendezvous targeting to alleviate unnecessary plane change during coelliptic coast.

The desired inclination (I_D) for targeting purposes dictates the ascent targeting parameters for the shuttle booster/orbiter launch configuration. As shown on page D-6 of the flowchart the insertion conditions for the southerly and northerly launches are a function of the desired inclination. The launch azimuth, descending node, insertion time, and range angle are presently least square curve fit functions of the desired inclination (I_D).

A quick-look two-body analysis of the on-orbit phasing is executed after orbit insertion. Many of the two-body parameters (page D-8) are used for the initialization of the isolation technique for its "first guess".

The time bases for each on-orbit maneuver are given in Table 3-1. These time bases occur approximately 200 seconds prior to the actual maneuver. The actual times will be presented in Section IV. This timeline includes the insertion time, the time of circularization, time of perigee burn out of the
Figure 3-1. ORBITER AFTER INSERTION WITH APPROXIMATE SAME MEAN INCLINATION
Figure 3-2. ORBITER AFTER CIRCULARIZATION WITH APPROXIMATE SAME MEAN INCLINATION
Figure 3-3. SHUTTLE RENDEZVOUS INPLANE LAUNCH GEOMETRY
100 n mi intermediate orbit, time of coelliptic maneuver, and the time of Transfer Phase Initiation (TPI).

Table 3-1. TIME BASES FOR PREPARATION OF MANEUVERS

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$</td>
<td>Insertion time of orbiter</td>
<td>sec</td>
</tr>
<tr>
<td>TTEST 1</td>
<td>Preparation for the circularization maneuver begins at this time (approximately 200 seconds before apogee of initial insertion orbit of the orbiter)</td>
<td>sec</td>
</tr>
<tr>
<td>TTEST 2</td>
<td>Preparation for perigee maneuver out of the near-circular phasing orbit begins at this time</td>
<td>sec</td>
</tr>
<tr>
<td>TTEST 3</td>
<td>Preparation for the coelliptic maneuver begins at this time</td>
<td>sec</td>
</tr>
<tr>
<td>TSBST</td>
<td>Time for the transfer phase initiation (TPI)</td>
<td>sec</td>
</tr>
</tbody>
</table>

The mission time of insertion and time of circularization will not be changed during the isolation loop. This is a constraint which must be met to maintain the same ascent targeting parameters.

The time of perigee burn out of the 100 n mi intermediate orbit is a variable and depends on the desired value of the phase angle difference ($\Delta \phi_D$) at TPI. It also depends on the oblate earth effects on the "first guess" two-body timing.

The effects of orbital nodal regression are corrected by adjusting the shuttle lift-off time. Once the desired phase angle ($\Delta \phi_D$) at TPI is isolated, then the existing nodal error is mapped into a Universal Time correction at lift-off. This is demonstrated on page D-18 of the flowchart.
The manner in which the sun's declination and right ascension are evaluated is illustrated in Figure 3-4, and the sun's position in the launch coordinate system is depicted in Figure 3-5. Knowledge of the sun's position is necessary in the targeting procedures when proper lighting is considered.

A general flowchart of the rendezvous targeting technique is presented in Figure 3-6. Detailed flow of this targeting procedure is included on pages D-2 through D-20.

A typical mission profile is illustrated in Figure 1-1. The orbiter is inserted into a 50 x 100 n mi orbit. A coast to apogee occurs where an apogee burn is made to circularize into the 100 n mi circular orbit (TEST1). After circularization a coast of at least a half-orbit is necessary (and is handled by the scale factor input SFNO1). A value of SFNO1=0.5 insures at least a half-orbit before the perigee burn onto a Hohmann transfer at time TTEST2. This scale factor can be initialized to any desired value. More stay time would be desired if phasing or lighting constraint is to be satisfied. The purpose of extra stay time would be to insure time needed for real time preparations. The scale factor for the Hohmann phasing (SFNO2) and the coelliptic phasing, 10 n mi below or above target, (SFNO3) will insure extra stay time in all phasing orbits until rendezvous is accomplished. This extra stay time will enforce adequate time for crew and orbiter check-out, orbit evaluation and system checkout, propulsion checkout, tracking acquisition, and navigation up-date. Any realistic targeting technique has to provide this extra controlled stay time for real time targeting.

After the perigee maneuver at time base TTEST2, a coast of approximately a half an orbit brings the vehicle to an intersection with the coelliptic orbit. The derivation of the equations for determining the intersection of the near-Hohmann transfer with the Constant Delta Height (CDH) orbit at time base TTEST3 is presented in Appendix A. The equations necessary for determining the desired values for the differential height are included in Appendix 3-6.
\[ \phi_{SV} = \pi + \lambda_L - U.T. |\bar{\omega}| \]
\[ \alpha_{SV} = a \cos(b + c \cdot T_Y) \]

Figure 3-4. RIGHT ASCENTION AND DECLINATION OF SUN WITH RESPECT TO LAUNCH MERIDIAN
Figure 3-5. ROTATIONS FROM LAUNCH COORDINATE SYSTEM TO SUN VECTOR

\[
x_N = \begin{bmatrix} \phi_L \\ \alpha_S \\ \pi/2 \end{bmatrix} \begin{bmatrix} A_z \\ \varphi \end{bmatrix} \chi_S
\]

\[
\chi_{SV} = \begin{bmatrix} -\alpha_{SV} \\ -\phi_{SV} \end{bmatrix} \begin{bmatrix} \chi_N \\ \chi_S \end{bmatrix}
\]
Figure 3-6. GENERAL FLOWCHART TO CORRECT LIFT-OFF TIME FOR NO PLANE CHANGE ON-TIME SHUTTLE ASCENT TARGETING
Figure 3-6. GENERAL FLOWCHART TO CORRECT LIFT-OFF TIME FOR NO PLANE CHANGE ON-TIME SHUTTLE ASCENT TARGETING (Concluded)
B. These equations have been presented in a earlier publication (ref. 1), but in a different manner.

A pictorial illustration of the position of the orbiter and space station at insertion (T_N + T_1) and at lift-off (T_N) for the tracking network is given in Figure 3-7. The Δφ angle represents the range angle difference between the space station and the orbiter at insertion time T_1. It is reasoned that the tracking network will supply the ephemeris of the target when it is in-plane at U.T. of T_N or T_S, and not the ephemeris that the target vehicle has at any acquisition time T. The ephemeris will be used to determine the time deviation (ΔT_{Lo}) for lift-off from this in-plane time (T_N) which will result in coplanar on-orbit phasing near the rendezvous point. It is not a necessary criterion, as stated earlier, that this be a rendezvous compatible orbit, so any Δφ relation may exist at lift-off/insertion and rendezvous can be accomplished through proper on-orbit phasing.

Figure 3-7. SPACE STATION AT ACQUISITION TIME \((T_N)\) AND AT INSERTION \((T_N + T_1)\)
Section IV
RESULTS AND CONCLUSIONS

The rendezvous targeting program was developed to generate targeting conditions for the shuttle launch vehicle at launch. The desired inclination ($I_D$) and launch azimuth ($A_Z$) at lift-off can be determined to achieve rendezvous with near-circular target satellites at various inclinations and various altitudes. Also, the time of launch (Universal Time, U.T.) and the timeline bases from lift-off have been determined for the orbital maneuver to accomplish rendezvous.

Verification of the targeting scheme included a total of 30 cases being run with varying phase relationships of the space station ($0 < \Delta \phi < 2\pi$) at the time of orbiter insertion (Figure 4-1). Included were cases with lighting constraints, northerly and southerly launch opportunities, and different phase relationships at transfer phase initiation.

Several cases were run for a northerly launch, without a lighting constraint. The phase relation of the orbiter at TPI is below and behind the space station by a 10 n mi height differential (the orbiter lags the space station by a desired $\Delta \phi = -0.29$ degree). Isolated phase angles at TPI of 0.29, 0.32, 0.28, and 0.24 degree were obtained (as shown in Table 4-1), which are all within the desired tolerance of 0.05 degree. Also, the inplane conditions at TPI are within acceptable limits as can be observed from the values of $A_i$ and $A_{\phi N}$. These inplane conditions could be improved, if desired, by decreasing the tolerance (of 0.02 degree) on pages D-18 through D-20 of the flowchart. Also, the timeline for the on-orbit maneuvers is listed in Table 4-1 for different range angles of the space station at the time of orbiter insertion (255, 345, 75, and 165 degrees). The adjustment required in the lift-off time is listed as $\Delta T_{LO}$, with the negative values representing launch before the spherical in-plane point.

Similar results for a southerly launch with a lighting constraint are presented in Table 4-2. The desired sun angle input was 110.0 degrees.
\[ \Delta \phi = \phi_T - \phi_p \]

3.3° < \( \Delta \phi < 4.8° \)

Figure 4-1. INCLINATION SYNCHRONIZATION DURING ELLIPTIC COAST-ON-ORBIT DECK-
Table 4-1. LIFT-OFF TIME CORRECTION FOR NEAR-CIRCULAR TARGET ORBITS
FOR NORTHERLY LAUNCH WITH NO LIGHTING CONSTRAINT

<table>
<thead>
<tr>
<th>TRUE ANOMALY</th>
<th>ABOVE AND AHEAD</th>
<th>RANGE ANGLE</th>
<th>255°</th>
<th>345°</th>
<th>75°</th>
<th>165°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insertion</strong></td>
<td></td>
<td></td>
<td>0 hr. 6 m. 11 s.</td>
<td>0 hr. 6 m. 11 s.</td>
<td>0 hr. 6 m. 11 s.</td>
<td>0 hr. 6 m. 11 s.</td>
</tr>
<tr>
<td><strong>Circularization</strong></td>
<td></td>
<td></td>
<td>0 hr. 48 m. 27 s.</td>
<td>0 hr. 48 m. 27 s.</td>
<td>0 hr. 48 m. 27 s.</td>
<td>0 hr. 48 m. 27 s.</td>
</tr>
<tr>
<td><strong>Perigee</strong></td>
<td></td>
<td></td>
<td>1 hr. 26 m. 7 s.</td>
<td>7 hr. 14 m. 41 s.</td>
<td>12 hr. 23 m. 5 s.</td>
<td>18 hr. 36 m. 11 s.</td>
</tr>
<tr>
<td><strong>Constant Delta Height</strong></td>
<td></td>
<td></td>
<td>2 hr. 14 m. 33 s.</td>
<td>8 hr. 4 m. 42 s.</td>
<td>13 hr. 13 m. 17 s.</td>
<td>19 hrs. 27 m. 3 s.</td>
</tr>
<tr>
<td><strong>Transfer Phase Initiation</strong></td>
<td></td>
<td></td>
<td>5 hr. 48 m. 19 s.</td>
<td>11 hr. 10 m. 59 s.</td>
<td>16 hr. 37 m. 46 s.</td>
<td>21 hr. 58 m. 17 s.</td>
</tr>
<tr>
<td>Sun Angle (deg)</td>
<td></td>
<td></td>
<td>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
</tr>
<tr>
<td>Δi (deg)</td>
<td></td>
<td></td>
<td>5.3 x 10^{-4}</td>
<td>1.1 x 10^{-2}</td>
<td>6.9 x 10^{-4}</td>
<td>4.4 x 10^{-4}</td>
</tr>
<tr>
<td>Δψ (deg)</td>
<td></td>
<td></td>
<td>0.29</td>
<td>0.32</td>
<td>0.28</td>
<td>0.24</td>
</tr>
<tr>
<td>ΔθN (deg)</td>
<td></td>
<td></td>
<td>-4.0 x 10^{-4}</td>
<td>-1.3 x 10^{-2}</td>
<td>-2.8 x 10^{-4}</td>
<td>4.6 x 10^{-4}</td>
</tr>
<tr>
<td>ΔTLO (sec)</td>
<td></td>
<td></td>
<td>-284.7</td>
<td>-226.4</td>
<td>-199.06</td>
<td>-143.6</td>
</tr>
<tr>
<td>ΔΦTB (deg)</td>
<td></td>
<td></td>
<td>-0.81</td>
<td>-2.21</td>
<td>-4.43</td>
<td>5.94</td>
</tr>
<tr>
<td>SFN03 (unitless)</td>
<td></td>
<td></td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Table 4-2. LIFT-OFF TIME CORRECTION FOR NEAR-CIRCULAR TARGET ORBITS FOR SOUTHERLY LAUNCH WITH LIGHTING CONSTRAINT

<table>
<thead>
<tr>
<th>TRUE ANOMALY</th>
<th>45°</th>
<th>135°</th>
<th>225°</th>
<th>315°</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABOve AND AHEAD</td>
<td>RANGE ANGLE</td>
<td>255°</td>
<td>345°</td>
<td>75°</td>
</tr>
<tr>
<td>Insertion</td>
<td>0 hr. 6 m.</td>
<td>0 hr. 6 m.</td>
<td>0 hr. 6 m.</td>
<td>0 hr. 6 m.</td>
</tr>
<tr>
<td></td>
<td>11 s.</td>
<td>1111 s.</td>
<td>11 s.</td>
<td>11 s.</td>
</tr>
<tr>
<td>Circularization</td>
<td>0 hr. 50 m.</td>
<td>0 hr. 60 m.</td>
<td>0 hr. 50 m.</td>
<td>0 hr. 50 m.</td>
</tr>
<tr>
<td></td>
<td>48 s.</td>
<td>4 48 s.</td>
<td>48 s.</td>
<td>48 s.</td>
</tr>
<tr>
<td>Perigee</td>
<td>18 hr. 27 m.</td>
<td>2 hr. 39 m.</td>
<td>7 hr. 51 m.</td>
<td>13 hr. 30 m.</td>
</tr>
<tr>
<td></td>
<td>36 s.</td>
<td>29 s.</td>
<td>52 s.</td>
<td>17 s.</td>
</tr>
<tr>
<td>Constant Delta Height</td>
<td>19 hr. 16 m.</td>
<td>3 hr. 30 m.</td>
<td>8 hr. 42 m.</td>
<td>14 hr. 19 m.</td>
</tr>
<tr>
<td></td>
<td>59 s.</td>
<td>3 s.</td>
<td>23 s.</td>
<td>59 s.</td>
</tr>
<tr>
<td>Transfer Phase Initiation</td>
<td>26 hr. 22 m.</td>
<td>8 hr. 37 m.</td>
<td>14 hr. 33 m.</td>
<td>18 hr. 50 m.</td>
</tr>
<tr>
<td></td>
<td>50 s.</td>
<td>27 s.</td>
<td>22 s.</td>
<td>34 s.</td>
</tr>
<tr>
<td>Sun Angle (deg)</td>
<td>109.91</td>
<td>109.88</td>
<td>109.92</td>
<td>109.84</td>
</tr>
<tr>
<td>Δi (deg)</td>
<td>8.17 x 10^-4</td>
<td>2.8 x 10^-3</td>
<td>7.9 x 10^-3</td>
<td>1.27 x 10^-3</td>
</tr>
<tr>
<td>Δφ (deg)</td>
<td>-.332</td>
<td>-.256</td>
<td>-.317</td>
<td>-.278</td>
</tr>
<tr>
<td>ΔθN (deg)</td>
<td>-1.87 x 10^-4</td>
<td>-2.53 x 10^-3</td>
<td>-9.3 x 10^-3</td>
<td>5.2 x 10^-4</td>
</tr>
<tr>
<td>ΔTLO (sec)</td>
<td>319.65</td>
<td>190.1</td>
<td>235.9</td>
<td>275.42</td>
</tr>
<tr>
<td>ΔΦTB (deg)</td>
<td>35.5</td>
<td>13.36</td>
<td>22.7</td>
<td>16.11</td>
</tr>
<tr>
<td>SFN03 (unitless)</td>
<td>4.0</td>
<td>3.0</td>
<td>3.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
The results presented in Tables 4-1 and 4-2 are for effecting rendezvous with the baseline target in a 270 n mi orbit with an approximate 55 degree inclination. Rendezvous targeting was accomplished in all cases considered, with a time constraint of approximately 24 hours to the TPI point.

It should be noted that rendezvous with satellites at altitudes other than 270 will result in violation of a 24 hour time constraint, but targeting is still possible. This violation will most likely happen when the target satellite has a lower altitude and thus additional phasing in the 100 n mi phasing orbit will be required to alleviate large phase differences which may exist.

The executed listing presented as an example in Appendix C gives the eccentricity vector $\vec{e}$, angular momentum ($\vec{h}$) and delta velocity required ($\Delta V_R$) at each maneuver time to effect each burn. These on-orbit targeting conditions at each maneuver time can be used as inputs for any guidance package to simulate that particular orbital maneuver.

Results to date show that the present rendezvous targeting deck will establish lift-off time and on-orbit targeting parameters to effect gross rendezvous at TPI.
Section V
PROGRAM INPUTS AND OUTPUTS

5.1 INPUT

The rendezvous targeting deck was programmed in Fortran IV language for use on the CDC-3200 computer. Inputs to the program are described in the following text, and are listed in Table 5-1.

Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL: SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISURF</td>
<td>ISURF</td>
<td>=1, Boost cut-off surface =0, Steady state trajectory comp. (see page D-6 of flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>ILIG</td>
<td>ILIG</td>
<td>=1, Lighting constraint considered =0, No lighting considered (see page D-10 of flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>A_0^A_6</td>
<td>A(7)</td>
<td>Polynomial coefficients as a function of inclination to determine latitude of insertion for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>B_0^B_6</td>
<td>B(7)</td>
<td>(Same as above for southerly launch).</td>
<td>Deg</td>
</tr>
<tr>
<td>C_0^C_6</td>
<td>C(7)</td>
<td>Polynomial coefficients as a function of inclination to determine azimuth of insertion for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>D_0^D_6</td>
<td>D(7)</td>
<td>(Same as above for northerly node).</td>
<td>Deg</td>
</tr>
<tr>
<td>E_0^E_6</td>
<td>E(7)</td>
<td>(Same as above for northerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>F_0^F_6</td>
<td>F(7)</td>
<td>Polynomial coefficients as a function of inclination to determine azimuth of insertion for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>G_0^G_6</td>
<td>G(7)</td>
<td>(Same as above for southerly node)</td>
<td>Deg</td>
</tr>
<tr>
<td>H_0^H_6</td>
<td>H(7)</td>
<td>(Same as above for southerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>Q_0^Q_6</td>
<td>Q(7)</td>
<td>Range angle of insertion (northerly).</td>
<td>Deg</td>
</tr>
<tr>
<td>S_0^S_6</td>
<td>S(7)</td>
<td>Range angle of insertion (southerly).</td>
<td>Deg</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>The universal time ephemeris data received from tracking station.</td>
<td>Sec</td>
</tr>
</tbody>
</table>
Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS (Continued)

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;sub&gt;N&lt;/sub&gt;</td>
<td>TN</td>
<td>The universal time of the in-plane opportunity for northerly launch.</td>
<td>Sec</td>
</tr>
<tr>
<td>T&lt;sub&gt;S&lt;/sub&gt;</td>
<td>TS</td>
<td>The universal time of the in-plane opportunity for southerly launch.</td>
<td>Sec</td>
</tr>
<tr>
<td>TTOL</td>
<td>TTOL</td>
<td>Maximum time necessary to perform pre-flight analysis using this targeting deck.</td>
<td>Sec</td>
</tr>
<tr>
<td>HAP</td>
<td>HAP</td>
<td>Altitude of apogee of orbiter insertion ellipse</td>
<td>N MI</td>
</tr>
<tr>
<td>H&lt;sub&gt;PER&lt;/sub&gt;</td>
<td>HPER</td>
<td>Altitude of perigee of orbiter insertion.</td>
<td>N MI</td>
</tr>
<tr>
<td>A&lt;sub&gt;N&lt;/sub&gt;</td>
<td>AN</td>
<td>Semi-major axis of space station received from tracking network for northerly opportunity (T&lt;sub&gt;N&lt;/sub&gt;).</td>
<td>M</td>
</tr>
<tr>
<td>e&lt;sub&gt;N&lt;/sub&gt;</td>
<td>EN</td>
<td>Eccentricity of space station received from tracking network for northerly opportunity (T&lt;sub&gt;N&lt;/sub&gt;).</td>
<td>Unitless</td>
</tr>
<tr>
<td>i&lt;sub&gt;N&lt;/sub&gt;</td>
<td>X&lt;sub&gt;ENCN&lt;/sub&gt;</td>
<td>Inclination of space station received from tracking network for northerly opportunity (T&lt;sub&gt;N&lt;/sub&gt;).</td>
<td>Deg</td>
</tr>
<tr>
<td>θ&lt;sub&gt;NN&lt;/sub&gt;</td>
<td>TNNN</td>
<td>Descending node for northerly launch (TN).</td>
<td>Deg</td>
</tr>
<tr>
<td>α&lt;sub&gt;PLN&lt;/sub&gt;</td>
<td>ALFAN</td>
<td>Argument of perigee for northerly launch (measured from descending node opposite direction of flight).</td>
<td>Deg</td>
</tr>
<tr>
<td>φ&lt;sub&gt;N&lt;/sub&gt;</td>
<td>PNIN</td>
<td>True anomaly of space station for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>A&lt;sub&gt;S&lt;/sub&gt;</td>
<td>AS</td>
<td>Semi-major axis for southerly launch.</td>
<td>M</td>
</tr>
<tr>
<td>e&lt;sub&gt;S&lt;/sub&gt;</td>
<td>ES</td>
<td>Eccentricity for southerly launch</td>
<td>Unitless</td>
</tr>
<tr>
<td>i&lt;sub&gt;S&lt;/sub&gt;</td>
<td>X&lt;sub&gt;ENCNS&lt;/sub&gt;</td>
<td>Inclination for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>θ&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>THNS</td>
<td>Node for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>α&lt;sub&gt;PLS&lt;/sub&gt;</td>
<td>ALFAS</td>
<td>Argument of perigee for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>φ&lt;sub&gt;S&lt;/sub&gt;</td>
<td>PHIS</td>
<td>True anomaly for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>φ&lt;sub&gt;L&lt;/sub&gt;</td>
<td>PHI</td>
<td>Geodetic latitude of launch site measured from equatorial plane.</td>
<td>Deg</td>
</tr>
</tbody>
</table>
Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEVOUS (Concluded)

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_L$</td>
<td>XLAMAL</td>
<td>Longitude of launch site measured negative west of prime meridian.</td>
<td>Deg</td>
</tr>
<tr>
<td>$\beta_{SVD}$</td>
<td>BSVD</td>
<td>Desired sun angle, measured from sun projection on space-station plane in direction of flight to TPI.</td>
<td>Deg</td>
</tr>
<tr>
<td>$a, b, c$</td>
<td>A1, B1, C1</td>
<td>Coefficients for calculation of the declination angle of the sun W.R.T. in the equatorial plane. (see page D-10 of the flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>$e_{TOL}$</td>
<td>TOLE</td>
<td>When the space station gets within this tolerance, a simplified logic for the space station in a circular orbit will be inacted (eccentricity tolerance).</td>
<td>Unitless</td>
</tr>
<tr>
<td>$T_Y$</td>
<td>TY</td>
<td>Number of days past January 1 of launch year.</td>
<td>Days</td>
</tr>
<tr>
<td>$\Delta H_D$</td>
<td>DLHD</td>
<td>The desired differential height for the orbiter: &gt; 0 :: CHD below target; &lt;0 :: CDH above target.</td>
<td>N MI</td>
</tr>
<tr>
<td>$\Delta H_B$</td>
<td>DLHB</td>
<td>A bias used to insure that the transfer orbit will intersect the C.D.H. orbit.</td>
<td>N MI</td>
</tr>
<tr>
<td>SFN01</td>
<td>SFN01</td>
<td>Scale factor for the initial orbiter insertion orbit. (Generally = .5)</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFN02</td>
<td>SFN02</td>
<td>Transfer orbit scale factor for intermediate phasing orbit (SFN02 = .5 for second orbital intersection).</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFN03</td>
<td>SFN03</td>
<td>Scale factor for phasing time in the coelliptic C.D.H orbit (normally = 1.5).</td>
<td>Unitless</td>
</tr>
<tr>
<td>SLM</td>
<td>SLM</td>
<td>Slope of the $\Delta q = f(\Delta H)$ curve assumed to be linear.</td>
<td>Unitless</td>
</tr>
</tbody>
</table>

The first input card contains two fixed point options with a 2I2 format. Presently the first option ISURF is flagged as 1. This designates that a sixth order polynomial curve fit will be utilized for describing the Shuttles insertion surface (Figure 3-3). A future mode may be programmed to execute
a steady state trajectory. When this mode is developed the user would read
ISURF=0. The second option ILIG is for the lighting constraint. If ILIG=1,
lighting is considered and future inputs will include $\beta_{SVD}$, $a$, $b$, $c$, $T_Y$ as
described in the input nomenclature.

The format for the remaining inputs is 6E13.8. $A_0$ through $S_6$ contain
the coefficients for the curve fit surface of the orbiters cut-off. These
are contained on the next 20 cards.

Input on card 22 are the universal times from the tracking station,
along with the radius of apoee and perigee of the orbiter insertion orbit.
Card 23 provides input for the ephemeris for the space station at the time
(U.T.) the launch site is in-plane with the space station for a northerly
launch opportunity. Similar values for the southerly launch opportunity are
input on card 24. The latitude of the launch site $\phi_L$, longitude $\lambda_L$, desired
sun angle $\beta_{SVD}$, and coefficients for calculation of the sun's declination
$A_l$, $B_l$, $C_l$ are input on card 25. Cards 26 and 27 will be changed by the user
as different mission profiles are desired. These cards contain the desired
differential height ($\Delta H$) for the final phasing orbit (coelliptic) before TPI.
The desired phase angle ($\Delta \phi$) at TPI is determined as a function of $\Delta H$ and is
presently read in as a linear function with a slope SLM.

Three flags are input which represent whole or fractional stay time
periods in each of the orbiters phasing orbits. SFN01 and SFN02 will be input
and will stay fixed. SFN03 can and will be "bumped" if the isolation results
in orbit coast periods in the coelliptic orbit is less than SFN03 times the
orbital period. That is, when the stay time in final coelliptic orbit between
the constant delta height maneuver and the TPI maneuver is less than SFN03
orbits (Note Page D-14 of the flowcharts), then SFN03 will be bumped by .5
and reinitialized.

A list of sample input data is presented in Table 5-2. It should be
noted that only two coefficients are listed for each surface or polynomial
curve fit variable.
<table>
<thead>
<tr>
<th>CARD</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>27.785842</td>
<td>0.15193435</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>3</td>
<td>16.249967</td>
<td>0.069000928</td>
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<td></td>
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<tr>
<td>4</td>
<td>106.673394</td>
<td>-1.2483319</td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>113.74390</td>
<td>0.81471544</td>
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<td>361.2315599</td>
<td>0.19373362</td>
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<tr>
<td>7</td>
<td>71.972429</td>
<td>1.2579258</td>
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<td>69.504248</td>
<td>-0.842646</td>
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<td>359.43239</td>
<td>0.2231473</td>
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<td>250.25958</td>
<td>-0.43718955</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>11</td>
<td>309.06871</td>
<td>0.47380784</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1000.0</td>
<td>2000.0</td>
<td>3000.0</td>
<td>900.0</td>
<td>100.0</td>
<td>90.0</td>
</tr>
<tr>
<td>13</td>
<td>6678206.0</td>
<td>0.00001</td>
<td>55.0</td>
<td>157.3</td>
<td>150.0</td>
<td>135.0</td>
</tr>
<tr>
<td>14</td>
<td>6678206.0</td>
<td>0.00001</td>
<td>55.0</td>
<td>23.9</td>
<td>150.0</td>
<td>315.0</td>
</tr>
<tr>
<td>15</td>
<td>28.608</td>
<td>-80.0</td>
<td>110.0</td>
<td>23.444</td>
<td>192.4205</td>
<td>0.9703504</td>
</tr>
<tr>
<td>16</td>
<td>0.000074</td>
<td>300.0</td>
<td>10.0</td>
<td>4.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>17</td>
<td>1.5</td>
<td>0.029</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.2 OUTPUT

The sample output (executed listing) presented in Appendix C is for a northerly launch opportunity with lighting considered. The first two pages yield the input values from the tracking station and the "first guess" two-body analysis of the total mission. The last variable printed on the second page, DVIT, gives the delta velocity budget requirement for all on-orbit maneuvers; but, does not include the values for TPI and TPF.

The listing has comment cards throughout, describing each maneuver, and gives on-orbit targeting requirements \((e, \bar{h}, \Delta v)\). Both Universal Time and mission time from lift-off for each maneuver is located at the top of the page, along with the state variables of the orbiter and space station.

The last two pages present the final isolated values at the TPI point; for example, sun angle, \(\Delta \phi\), \(\Delta i\), \(\Delta \theta_N\), and, also, the state vector of the space station in the updated coordinate system at the time of lift-off and orbit insertion. The very last print statement yields the updated time-of-launch.
Appendix A

INTERSECTION OF NEAR-HOHMANN TRANSFER WITH CDH ORBIT

A maneuver at the second orbital intersection of the transfer eclipse with the CDH orbit will place the orbiter coelliptic with the space station. Thus, a method had to be determined to compute the true anomaly of the orbiter at the desired second orbital intersection. A solution to this problem is possible if the two-body polar equations for position of each orbit are equated and then solved for the true anomaly of the intersection. The derivation for determining the intersection point follows.

Considering the equation

$$\Delta \alpha = \alpha_T - \alpha_p$$

where $\alpha_T$ is the argument of perigee of the space station orbit and $\alpha_p$ is the argument of perigee of the orbiter orbit, then

$$\theta_S = \theta_p + \Delta \alpha$$

where $\theta_S$ is the true anomaly of the CDH orbit and $\theta_p$ is the true anomaly of the orbiter at the intersection point.

Then, equating the position equations,

$$\frac{P_p}{1 + e_p \cos \theta_p} = \frac{P_S}{1 + e_S \cos (\theta_p + \Delta \alpha)}$$

or,

$$P_p + e_p P_p \cos(\theta_p + \Delta \alpha) = P_S + e_p P_S \cos \theta_p$$

and

$$e_s P_p \cos(\theta_p + \Delta \alpha) - e_p P_S \cos \theta_p = P_S - P_p$$
Making use of the trigomeric identity of the cosine of the sum of two angles,

\[ e_s P_p (\cos \theta_p \cos \Delta \alpha - \sin \theta_p \sin \Delta \alpha) - e_p P_s \cos \theta_p = P_s - P_p \]

Factoring out \( \cos \theta_p \):

\[ \sin \theta_p (-e_s P_p \sin \Delta \alpha) + \cos \theta_p (e_s P_p \cos \Delta \alpha - e_p P_s) = P_s - P_p \]

Now let

\[ \beta = -e_s P_p \sin \Delta \alpha \]

\[ \Delta = e_s P_p \cos \Delta \alpha - e_p P_s \]

\[ P_o = P_s - P_p \]

then:

\[ \beta \sin \theta_p + \Delta \cos \theta_p = P_o \]

\[ \Delta \cos \theta_p = P_o - \beta \sin \theta_p \]

\[ \Delta^2 \cos^2 \theta_p = P_o^2 - 2P_o \beta \sin \theta_p + \beta^2 \sin^2 \theta_p \]

\[ \cos^2 \theta_p = 1 - \sin^2 \theta_p \]

\[ \Delta^2 (1 - \sin^2 \theta_p) = P_o^2 - 2P_o \beta \sin \theta_p + \beta^2 \sin^2 \theta_p \]

\[ \Delta^2 - \Delta^2 \sin^2 \theta_p = P_o^2 - 2P_o \beta \sin \theta_p + \beta^2 \sin^2 \theta_p \]

and

\[ (-\beta^2 - \Delta^2) \sin^2 \theta_p + 2P_o \beta \sin \theta_p + \Delta^2 - P_o = 0 \]
In order to solve this quadratic, let

\[ A = -\beta^2 - \Delta^2 \]
\[ B = 2P_\beta \]
\[ C = \Delta^2 - P_o^2 \]

and the equation is solved by

\[ \sin \theta_p = \frac{-B + \sqrt{B^2 - 4AC}}{2A} \]

This equation is derived as a sine function instead of a cosine function as in reference 1. The sine function is positive in the second quadrant and negative in the third quadrant. The solution that is negative should be selected and placed in the third quadrant (since the transfer is a near-Hohmann). This will always select the second orbital intersection, that is, select \( \sin \theta_p < 0 \) : \( \theta_p = -\pi - \sin^{-1}(\theta_p) \).
Appendix B

CONSTANT DELTA HEIGHT IMPULSE

The delta velocity for the impulse into the CDH orbit below or above the space station is computed using two-body equations. Forcing the CDH orbit to be coelliptical with the space station can only be achieved by having the same differential height ($\Delta H$) at apogee and perigee. Thus, to insure the $\Delta H$ will be the same at apogee and perigee, the following equation was developed (see reference 1 for complete derivation):

$$
\Delta H^2 + (\text{RRP}-\text{RAT}-\text{RPT})\Delta H + \text{RPT} \cdot \text{RAT} + \frac{\text{RRP}}{2} (\text{RPT}-\text{RAT})
$$

$$
\cos \theta_D - \frac{\text{RRP}}{2} (\text{RAT}+\text{RPT}) = 0
$$

Letting

$$
\begin{align*}
A &= 1 \\
B &= \text{RRP}-\text{RAT}-\text{RPT} \\
C &= \text{RAT} \cdot \text{RPT} + \frac{\text{RRP}}{2} \cdot \cos \theta_D \cdot (\text{RPT}-\text{RAT}) - \frac{\text{RRP}}{2} \cdot (\text{RAT}+\text{RPT})
\end{align*}
$$

Then

$$
A(\Delta H)^2 + B(\Delta H) + C = 0
$$

and

$$
\Delta H = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}
$$

If the coelliptic CDH orbit is above the space station then $B = -B$.

These equations are incorporated into the logic on page D-14 of the flowchart as can be observed from this flowchart, once $\Delta H$ is computed it is utilized to construct the conic parameters of the CDH orbit.
Appendix C

SAMPLE OUTPUT: NORTHERLY LAUNCH
NORTHERLY LAUNCH

ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT

TIME 2.00340000 ST AT 4.8702650000000000 06 ET 1.7000000000000000 05 XEVCTO 5.300000000000000 01
THNTO 1.573460000000000 02 ALFAO 1.500000000000000 02 PHIJO 1.350000000000000 02

FIRST GUESS IN THE LAUNCH AZIMUTH 4.07937855E 01

THIS IS THE SOLUTION
INSTANTANEOUS LATITUDE OF INSERTION 3.61399589E 01

DESIGNED LATITUDE FOR INSERTION 3.61399589E 01

DESIGNED VALUE OF INCLINATION FOR TARGETING PURPOSE 5.40829971E 01

ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION 3.60346512E 01

STATE VARIABLES OF ORBITER AT INSERTION

AP 6.351000000000000 02 XDP 1.99517753E 03
AR 6.88944616E 02 YDP 2.92723639E 02
ZP 1.73299353E 02 ZDP 7.72573935E 03

STATE OF SPACE STATION

TIME FROM LIFT-OFF

WRS# 9 D14:35 SEC 3.18838595E 01

UNIVERSAL TIME

WRS# 9 D14:35 SEC 3.18838595E 01

TIME 2.71173437 03

Y 1.76174190E 05 Z 3.15247196E 06 X 3.48187994E 05
XDP 1.205000000000000 02 AP 6.87514955E 06
YP 2.92723639E 02 AR 6.88944616E 02
ZP 1.73299353E 02 ZDP 7.72573935E 03

PHIJO 2.85346512E 02

THIS IS THE SOLUTION

STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSERTION

AT 6.15946500 ST AT 1.76174190E 05 ZT 3.15247196E 06
XDP 1.205000000000000 02 XDP 1.205000000000000 02
YP 2.92723639E 02 YDP 2.92723639E 02
ZP 1.73299353E 02 ZDP 7.72573935E 03

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PARAMETERS FOR 50X100 NM PHASING ORBIT

RHP 6.41773624E 06 VVP 7.67364623E 03 GAMMAT=2.81049854E+10 EP 7.10422998E 03
AP 6.17086000E 06 HAP 1.00000011E 02 MAP 4.69990282E 01 PHDTP 6.87667146E 02

PARAMETERS FOR THE TARGET ORBIT

RHT 6.89796926E 06 VVT 7.61364302E 03 GAMATO=2.85674250E-02 ET 5.30398490E 04
AT 6.87570526E 06 VAT 2.72659976E 02 HPT 2.68349542E 02 PHOTT 6.34571979E 02

CATCH UP RATE AND ANGLE FOR THE HALF ORBIT OF THE 50X100 NM PHASING ORBIT

ORBITAL CATCH UP RATE= 5.95156949E+03
ANGLE OF CATCH UP= 1.40101412E+01
TIME AT APOLLOE OF 50X100 ORBIT= 2.99991355E 03
FIRST MANEUVER TO CIRCULARIZE 50X100 AT ITS APOLLOE:
RUP 6.56336602E 06 VCP 7.97304310E 04 TAU0P 5.29175108E 03 PDTCO 6.80304997E 02
DLTV 8.67098492E 03 ULTMC 1.23726687E 01 DELV 2.77318951E 02 T3 9.33606689E 03

SECOND MANEUVER TRAVER OUT OF 100 NM CIRCULAR TOWARDS COELLIPTIC

ORBITAL PERIOD= 3.7460173E+03
MEAN ORBITAL RATE= 6.79820736E 02
CATCH UP RATE= 2.35313534E+03
IMPULSE NEW ORBIT= 3.67429581E 01
TIME FOR TRANSFER= 0.37246775E 07
DELV 6.44144647E 01

COELLIPTIC LIMIT PLACEMENT VEHICLE IN COH ORBIT

PDA 6.86536201E 06 RAPA 6.63925306E 06
PDA 6.86527823E 06 RAPA 6.10365306E 06
RAPA 6.63784386E 06 V4 7.33710336E 03
GAMATO 9.24340740E 03 DELLV 6.70769811E 01

THE TPI INITIATION ANGLE IN RELATION TO THE TARGET= 2.90000000E-01
THIS SECTION DETERMINES THE CATCH UP RATE IN THE COH ORBIT
IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE FOR THE TOTAL MISSION
TAPAD= 5.49496292E 03 DNPAD= 6.38620774E 02 DPOPCO 2.38925742E+04 DLPPAD= 3.92219417E 00
TPAI 2.35704741E 04 DNPAD 3.66136695E 01 DTV 2.11572148E 02
RANGE ANGLE OF WARRIOR: 2.29221587E 02
RANGE ANGLE OF TARGET: 1.58569741E 00

PHASE ANGLE UP: 1.423\times10^4E 02
5.06000000E-01 5.00000000E 00

STATE OF SPACE STATION:

TIME FROM LIFT-OFF
HRR: 0 MHN: 6 SEC: 1.1836149E 01

UNIVERSAL TIME
HRR: 0 MHN: 39 SEC: 3.1836156E 01

TIME 3.1836156E 02
V = 6.10196085E 00
A = 2.72768445E 02
C = 5.1316443E 04
PHI10 = 8.8059741E 00

STATE OF SPACE STATION:

TIME FROM LIFT-OFF
HRR: 11 MHN: 7 SEC: 1.3018452E 01

UNIVERSAL TIME
HRR: 11 MHN: 40 SEC: 3.3218452E 01

TIME 4.02538418E 04
V = 6.92770311E 00
A = 2.72768442E 02
C = 5.1316443E 04
PHI10 = 7.1939245E 00

COMPUTATIONS FOR SECTION 4-A

DPH10 2.2513447E 1 J1
DPH21 1.19443006E 02
D12 2.58237943E 04
TEST 4.09332018E 04
DTI 1.38575291E 04
TI 3.1983615E 02
TEST2 2.78011395E 03
TEST2 2.80366776E 04

STATE OF SPACE STATION:
### Time From Lift-Off

**Universal Time**

**Time 4:107:2413E 04**

- HRS= 4 MINS= 13 SEC= 04
- X= 5.26031649E 06
- AA= 2.46759336E 02
- E= 1.69577949E-03
- PHIL= 3.73730168E-01

### Computation for Lighting Conditions Section 4-10

- AO 2.34440000E 01
- AO 1.92240000E 02
- CD 9.70300000E 01
- CD 9.20600000E 01
- DSV 1.29483511E 01
- DSV 1.29483511E 01
- BSPT 1.10000000E 02
- BSPT 1.10000000E 02

### State of Space Station

**Time From Lift-Off**

**Universal Time**

**Time 2:78988113E 03**

- HRS= 2 MINS= 46 SEC= 03
- X= 4.04063973E 06
- AA= 2.75430628E 02
- E= 1.34534185E-03
- PHIL= 1.62266007E 02

### State of Orbiter

**Time From Lift-Off**

**Universal Time**

**Time 2:78988113E 03**

- HRS= 2 MINS= 46 SEC= 03
- X= 4.04063973E 06
- AA= 2.75430628E 02
- E= 1.34534185E-03
- PHIL= 1.62266007E 02

---

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TARGETING VALUES FOR THE COV 100 NM CIRCULARIZATION AT APOGEE

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

TIME FROM LIFT-OFF

HRS 0 MINS 48 SECS 2.78113475E 01

UNIVERSAL TIME

HRS 1 MINS 21 SECS 4.78113475E 01

TIME 2.00781133E 03
X 0.53519535E 06
AA 1.0498944E 02
E 7.0364314E 03
PHI0 4.0697772E 01

Y 8.9624600E 04
AP 5.3050490E 01
C3 -6.1505361E 07
ENC 5.49871015E 01
TMN 1.58583434E 02

TD 7.25775672E 02
PHD 3.12465043E 02
TD -7.72473163E 03
PHD 6.39160608E 06
A 6.9189253E 06

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR
AM(1) 9.0325943E 08
AM(2) 1.1195876E 10
AM(3) 2.1158127E 09

ECCENTRICITY VECTOR
EV(1) 5.8207669E-11
EV(2) 9.0994720E-12
EV(3) 1.8199940E-12

VELOCITY TO BE GAINED VECTOR
VX(1) 2.67735496E 03
VX(2) 1.14439716E 00
VX(3) 2.73115345E 01

STATE OF ORBITER

TIME FROM LIFT-OFF

HRS 8 MINS 42 SECS 5.38091555E 01

UNIVERSAL TIME

HRS 9 MINS 16 SECS 5.38091555E 01

TIME 3.13738092E 04
X 5.16296755E 06
AA 1.06350348E 02
E 7.77949319E-04
PHI0 1.78139160E 02

Y -2.78978799E 05
AP 1.08816893E 02
C3 -6.06763459E 07
ENC 5.50045691E 01
TMN 1.56653152E 02

TD 4.81240419E 03
PHD 2.90786934E 03
TD 6.12486942E 03
PHD 6.56990334E 06
A 6.9598831E 06

STATE OF SPACE STATION

TIME FROM LIFT-OFF

HRS 8 MINS 42 SECS 5.38091555E 01
THIS IS THE SOLUTION.

THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO = 2.29565903E 02
STATE OF ORBIT:

TIME FROM LIFT-ff
HRS = 9 MIN = 5 0/4 = 0.7747397F 01

UNIVERSAL TIME
HRS = 9 MIN = 37 0/4 = 0.7747397F 01

TIME 2.53005740E 04
X 4.12706562E 06
AP 4.77605920E 06
E 1.84790394E -3
PH10 1.51094137E -2

UNIVERSAL TIME
HRS = 9 MIN = 37 0/4 = 0.7747397F 01

TIME 7.38005740E 04
X -4.12706562E 06
AP -4.77605920E 06
E -1.84790394E -3
PH10 1.51094137E -2

STATE OF SPACE STATION

TIME FROM LIFT-ff
HRS = 9 MIN = 6 SEC = 0.7747285E 00

UNIVERSAL TIME
HRS = 9 MIN = 37 0/4 = 0.7747285E 00

TIME 3.33005740E 04
X -4.12706562E 06
AP -4.77605920E 06
E -1.84790394E -3
PH10 1.51094137E -2

STATE OF PHASE:

TIME FROM LIFT-ff
HRS = 9 MIN = 4 0/4 = 0.7747285E 00

UNIVERSAL TIME
HRS = 9 MIN = 37 0/4 = 0.7747285E 00

TIME 7.20005740E 04
X -4.12706562E 06
AP -4.77605920E 06
E -1.84790394E -3
PH10 1.51094137E -2

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TARGETING VALUES FOR THE CON PERIGEE RUN

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

TIME FROM LIFT-OFF

[Data]

UNIVERSAL TIME

[Data]

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR

[Data]

ECCENTRICITY VECTOR

[Data]

VELOCITY TO BE SAWNED VECTOR

[Data]

AFTER PERIGEE RUN AT TIME TTEST2

STATE OF ORBITER

TIME FROM LIFT-OFF

[Data]

UNIVERSAL TIME

[Data]

STATE OF SPACE STATION
STATE OF MATHEMATICIAN

TIME FROM LIFT-OFF
M.R.S. 7 MIN=55 SEC=3.00361934E+01

UNIVERSAL TIME
M.R.S. 8 MIN=29 SEC=4.70289707E-01

TIME 2.877000327E+04
x=-4.962037780E-06
AP 2.159226531E-03
E 2.919797253E-03
P=1.0244072332

TARGETING VALUES FOR THE CON MANEUVER FOR CV
POSITION VECTOR FOR IGNITION

STATE OF MATHEMATICIAN

TIME FROM LIFT-OFF
M.R.S. 7 MIN=50 SEC=3.00361934E+01

UNIVERSAL TIME
M.R.S. 8 MIN=29 SEC=4.70289707E-01

TIME 2.877000327E+04
x=-4.962037780E-06
AP 2.159226531E-03
E 2.919797253E-03
P=1.0244072332

TARGETING VALUES FOR DESIRED ELLIPSE
ANGULAR MOMENTUM VECTOR
AM(1)=4.4246422000E-06 AM(2)=5.2219226600E-10 AM(3)=2.8333203400E+09
ECCENTRICITY VECTOR
Ev(1)=2.6959525844E-03 Ev(2)=4.5001523364E-06 Ev(3)=1.2445878604E+00
VELOCITY TO RF CANTILEVER VECTOR
VG(1)=4.1599539842E+01 VG(2)=5.1599539842E+01 VG(3)=1.6151938000E+01
COM mission accomplished.

State of Space Station:

Time from Lift-Off

Universal Time

Time 2.9770639E-04

Universal Time

Time 2.9770639E-04

Universal Time

Time 2.9770639E-04

C-12
UNIVERSAL TIME FOR TPS

STATE OF SPACE STATION:

TIME FROM LIFT-OFF:
HRS=13 MIN=2 SEC=5.39902945E 01

UNIVERSAL TIME:
HRS=13 MIN=2 SEC=7.44243908E 01

TIME 4.6973903124 X=4.6973903124 Y=0.0000000000 Z=0.0000000000
AA 6.787947962 ZE 1.0259234C+01 PH110 7.4059980371

STATE OF MUFTER:

TIME FROM LIFT-OFF:
HRS=13 MIN=2 SEC=5.39902945E 01

UNIVERSAL TIME:
HRS=13 MIN=2 SEC=7.44243908E 01

TIME 4.497390914 X=4.497390914 Y=0.0000000000 Z=0.0000000000
AA 6.787947962 ZE 1.0259234C+01 PH110 7.3707049471

DTWUE=5.874496294E+04

WATRO 6.911654844 PH110 7.373079445 PH10 7.405998238 PH110 3.951542840 PH110 3.918696971
DELMCO 3.297949311-11

THE SOLAR VECTOR ACHIEVED 1.09900419E 02

STATE VECTOR AT TARGET AT LIFT OFF:

XI-2.916341476 YI 9.362831009 ZI 6.224973196 XI-6.394442168 ZI-1.93938596E 03 XI-1.21989129E 03
TIME FROM LIFT-OFF
HRS: 0  MINS= 9  SEC= 0

UNIVERSAL TIME
HRS: 0  MINS: 24  SEC= 3.6434995E 01

TIME
X=2.3953147E 02  Y=3.249831065E 06  Z=6.224973199E 06  XD=6.49464216E 03  YD=1.93938596E 12  ZD=3.21997129E 03
RAD=2.6775231E 09  RAP=6.8734999E 06  RAE=6.87592518E 06  RF=6.87592518E 06
E=4.15748237E 00  C3=6.7976467E 07  ENC=5.49334592E 01  THM=1.98262908E 02  TM=1.35679948E 12  ALFAD=1.65239544E 02
PH10=3.3044144E 02

STATE VECTOR OF TARGET AT INSERTION

TIME FROM LIFT-OFF
HRS: 0  MINS= 9  SEC= 1.1883149E 01

UNIVERSAL TIME
HRS: 0  MINS: 39  SEC= 4.73177115E 01

TIME
X=5.1642979E 00  Y=1.44197695E 06  Z=4.54001163E 06  XD=5.02720466E 03  YD=2.82498863E 12  ZD=5.71819338E 03
RAD=2.6957836E 02  RAP=6.88044726E 06  RAE=6.87742800E 06  RF=6.87742800E 06
E=2.71920622E 07  C3=5.79494673E 07  ENC=5.5021319E 01  THM=1.9829834E 02  TM=3.0104114E 02  ALFAD=3.07615993E 02
PH10=3.49425591E 02

THE UPDATED TIME OF LAUNCH=1.77543416E 03

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### Appendix D

## PROGRAM MODULES AND DETAILED FLOWCHART

### D.1 PROGRAM MODULES

<table>
<thead>
<tr>
<th>Name</th>
<th>Function or Subroutine</th>
</tr>
</thead>
<tbody>
<tr>
<td>RK713</td>
<td>This is a seventh order Runge-Kutta integration routine which can integrate backward or forward</td>
</tr>
<tr>
<td>RKG</td>
<td>The main routine of the integration package. Integration is variable step-size with an accuracy tolerance of 0.0000005 for the state</td>
</tr>
<tr>
<td>CONIC</td>
<td>Computes orbital parameters given the state. (Only for elliptical orbits.)</td>
</tr>
</tbody>
</table>
| GMAT  | Matrix transformation from space fixed inertial launch coordinate system ($\vec{X}_S$) to the in-plane $\vec{X}'''$ system  

$$
\vec{X}''' = [-i]_1 [-\theta_N]_2 [\phi_L]_3 [A_Z - \frac{\pi}{2}]_1 \vec{X}_S 
$$

| MAROT | Sets up elements of transformation matrix for an angle of rotation about the X, Y, and Z axis |
| ARTAN | Arctangent from 0 to $2\pi$ or $-\pi$ to $\pi$ according to flag |
| POLY  | Evaluates an $n^{th}$ order polynomial given its coefficients |
| ECCV  | Computes eccentricity vector $\vec{e}$  

$$
\vec{e} = \vec{v} \times \frac{\vec{h}}{\mu} - \frac{\vec{r}}{|\vec{r}|} 
$$

| DEG   | Earth's gravitational potential function. Evaluates the acceleration due to gravity for all three components |
| FATT  | Matrix transpose $(3\times3)$ |
| FATMU | Matrix multiplication $(3\times3$ times $1\times3)$ |
| PRINT | Calculates the U.T. in hours, min., sec, adds the U.T. to the mission Time "T", and prints out state and orbital parameters of each vehicle in flight.  
(Note: the program integrates in mission time, thus U.T. of launch is added to mission time from lift-off to obtain instantaneous U.T. time in flight) |
| FATMUL | Matrix multiplication $(3\times3$ times $3\times3)$ |
| TIME  | Determines Keplerian time of flight between two positions on an elliptical orbit |
| RANGA | Computes range to and from descending node w.r.t. equator to the instantaneous radius vector |
| TRUE  | Computes true anomaly from perigee to the instantaneous radius vector |
D.2 FLOWCHART

EPHEMERIS DATA OF SPACE STATION

\[ T_N, a_N, e_N, i_N, \theta_{NN}, \alpha_{PLN}, \phi_N \]
\[ T_S, a_S, e_S, i_S, \theta_{NS}, \alpha_{PLS}, \phi_S \]

\[ \text{JPASS} = 0, \quad \text{KPASS} = 0 \]

YES \[ T_{N-T_S} < 0 \]

YES \[ T_{N-T} \geq \text{TTOL} \]

NO \[ T_{S-T} \geq \text{TTOL} \]

YES \[ \text{TULO} = T_N \]

NORTH = 1

NO \[ \text{TULO} = T_S \]

NORTH = 0

NO \[ \text{TULO} = T_N \]

NORTH = 1

\[ 2-0 \]

FROM PG. D-7

\[ T = T_N \]
\[ a = a_N \]
\[ e = e_N \]
\[ i = i_N \]
\[ \theta_N = \theta_{NN} \]
\[ \alpha_{PL} = \alpha_{PLN} \]
\[ \phi = \phi_N \]

\[ \text{JPASS} = 0 \]

NO \[ 2-1 \]

TO PG. D-3

YES

\[ A_Z = \pi - \sin^{-1} \left( \frac{\cos i_S}{\cos \phi_L} \right) \]

NO

\[ \theta_N - 90 < 0 \]

YES

\[ A_Z = \sin^{-1} \left( \frac{\cos i_N}{\cos \phi_L} \right) \]

2-1

TO PG. D-3

D-2
\[ \phi_T = \phi - \alpha_{PL} \]

\[
[A] = \begin{bmatrix}
\cos \phi_L & \sin \phi_L & \sin A_Z & -\sin \phi_L & \cos A_Z \\
-\sin \phi_L & \cos \phi_L & \sin A_Z & -\cos \phi_L & \cos A_Z \\
0 & \cos A_Z & 0 & 0 & 0
\end{bmatrix}
\]

\[
[B] = \begin{bmatrix}
\cos \theta_N & 0 & -\sin \theta_N \\
\sin \theta_N & \sin i & -\cos \theta_N & \sin i & \cos \theta_N \sin i \\
-\sin \theta_N & \cos i & \sin \theta_N & \sin i & \cos \theta_N \cos i
\end{bmatrix}
\]

\[
[G] = [B] [A]
\]

\[
[\phi_T] = \begin{bmatrix}
\cos \phi_T & 0 & \sin \phi_T \\
0 & 1 & 0 \\
-\sin \phi_T & 0 & \cos \phi_T
\end{bmatrix}
\]

\[
[K] = [\phi_T] [G]
\]

\[
\hat{n} = \sin \phi_L \hat{i} - \cos \phi_L \sin A_Z \hat{j} + \cos \phi_L \cos A_Z \hat{k}
\]

\[
K_{PASS} = 0
\]

\[
R_0 = a(1-e^2)/(1+e \cos \phi)
\]

\[
V_0 = \sqrt{\mu \left( \frac{2}{R_0} - \frac{1}{a} \right)}
\]

\[
Y_0 = \tan^{-1} \left( \frac{e \sin \phi}{1+e \cos \phi} \right)
\]

2-2 TO PAGE D-4
\[
\begin{bmatrix}
X_T \\
Y_T \\
Z_T
\end{bmatrix}
= [K]^{-1}
\begin{bmatrix}
R_0 \\
0 \\
0
\end{bmatrix};
\begin{bmatrix}
\dot{X}_T \\
\dot{Y}_T \\
\dot{Z}_T
\end{bmatrix}
= [K]^{-1}
\begin{bmatrix}
V_0 \sin \gamma_0 \\
0 \\
V_0 \cos \gamma_0
\end{bmatrix}
\]
\[
\Delta T = 100.0, \text{ MPASSI}=0
\]

\[
\begin{align*}
\hat{A}_{MT} &= \bar{X} \times \hat{\bar{X}} / |\bar{X}| \times |\hat{\bar{X}}| \\
\hat{D}_{NT} &= \hat{A}_{MT} \times \hat{\Omega} \\
\hat{E}_{RA} &= \cos \phi_L \hat{i} + \sin \phi_L \sin A_Z \hat{j} - \sin \phi_L \cos A_Z \hat{k} \\
\Psi &= \sin^{-1}(\bar{X} \cdot \hat{\Omega} / |\bar{X}|) \\
\theta_{NT} &= \cos^{-1}[\hat{E}_{RA} \cdot \hat{D}_{NT} / |\hat{D}_{NT}|] \\
I_{NT} &= \tan^{-1}\left[\left(1 - (\hat{\Omega} \cdot \hat{A}_{MT})^2\right)^{1/2} / (\hat{\Omega} \cdot \hat{A}_{MT})\right] \\
A_T &= |\bar{X}| / (2 \mu - |\hat{\bar{X}}|^2 / |\bar{X}|)
\end{align*}
\]
\[
\psi_{DS} = \sum_{M=0}^{6} B_M i_{NT}^M \\
A = (1 - \cos^2 i_{NT}/\cos^2 \psi_{DN})^{1/2} \\
\phi_{LS} = \tan^{-1}\left[\frac{\tan \psi_{DN}}{A}\right] \\
\phi_{LS} = \pi + \phi_{LS} \\
\Delta\phi_R = \phi_{LS} - \phi_T
\]
$$K_{PASS} = 1, \ J_{PASS} = 1$$
$$R_0 = \text{HPER} \times \text{CF} + R$$
$$R_A = \text{HPAR} \times \text{CF} + R$$
$$e = \frac{(R_A - R_0)}{(R_A + R_0)}$$
$$V_o = \sqrt{\mu (1 + e)} / R_0$$
$$a = \frac{(R_A - R_0)}{2}$$
$$\gamma_0 = 0.0$$

$$\bar{x}_p = \bar{x}_T$$
$$\dot{\bar{x}}_p = \dot{\bar{x}}_T$$

$$\bar{x}_0 = \bar{x}_T / \bar{x}_T$$
$$\dot{\bar{x}}_0 = \dot{\bar{x}}_T / \bar{x}_T$$
$$\bar{x}_T = \int_{T}^{T+T1} \dot{\bar{x}}_T \ dt$$
$$\dot{\bar{x}}_T = \int_{T}^{T+T1} \ddot{\bar{x}}_T \ dt$$
\[ \phi_p = 2\pi \left( \frac{A_p}{\mu} \right)^{1/2} \]
\[ \delta_{AP4} = \left( \frac{\mu}{A_p} \right)^{1/2}, \quad \Delta\phi_R = SLM \cdot \Delta H \]
\[ \Lambda\phi_{MR4} = \Lambda\phi_{CU}(\tau_p) (\text{SFN03} + X_N) + \Delta\phi_R \]
\[ TTP1 = T_4 + \tau_p (\text{SFN03} + X_N) \]
\[ \Lambda\phi_{MRT1} = \Lambda\phi_{MR1} + \Lambda\phi_{MR2} + \Lambda\phi_{MR3} + \Lambda\phi_{MR4} \]
\[ \Lambda V_{IT} = \Lambda V_2 + \Lambda V_3 + \Lambda V_4 + \Lambda V_R \]

\[ \phi_{T1} = \phi_{T1} + 2\pi \]
\[ \Delta\phi_{A1} = \phi_{T1} - \phi_{P1} \]

\[ \text{NO} \triangleleft \phi_{T1} - \pi \geq 0 \text{ YES} \rightarrow \Lambda\phi_{A1} = \phi_{T1} - \phi_{P1} \]

\[ \Delta\phi_{A1} = \Delta\phi_{A1} + 2\pi \]

\[ \text{NO} \triangleleft \Lambda\phi_{A1} - \Delta\phi_{MRT1} \geq 0 \text{ YES} \rightarrow \Delta\phi_{A1} = \Delta\phi_{A1} \]

\[ \Delta T_1 = \text{SFN03} \cdot \tau_p + \tau_{p1}/2 + \tau_{p3} (\text{SFN02}) \]
\[ \Delta\phi_1 = \Delta\phi_{MR1} + \Delta\phi_{MR3} + \Delta \phi_{CU} \tau_p (\text{SFN03}) \]
\[ \Delta\phi_2 = \Delta\phi_{A1} - \Delta\phi_1 - \Delta\phi_R, \quad \Delta T_2 = \Delta\phi_2/\Delta\phi_2 \]
\[ TSBST = T_1 + \Delta T_1 + \Delta T_2, \quad \text{TEST1} = T_1 + \tau_{p1}/2 - 200 \]
\[ \text{TTEST2} = T_1 + \tau_{p1}/2 + \Delta T_2 \]

4-2 TO PG. D-10
4-2 FROM PG. D-9

ORBIT INTEGRATION
OF ORBITER AND
SPACE STATION
FROM T₁ TO
TSBST

4-3 TO PG. D-11

4-13 FROM PG. D-17

T = TSBST, \dot{X}_T, \ddot{X}_T
\alpha_{SV} = a + \lambda L + \lambda_B \cdot TULO
\alpha_{SV} = a \cos (b + c \cdot T_f)

\begin{bmatrix}
\cos \theta_{SV} & 0 & \sin \theta_{SV} \\
0 & 1 & 0 \\
-\sin \theta_{SV} & 0 & \cos \theta_{SV}
\end{bmatrix}

\begin{bmatrix}
\cos \phi_{SV} & -\sin \phi_{SV} & 0 \\
-\sin \phi_{SV} & \cos \phi_{SV} & 0 \\
0 & 0 & 1
\end{bmatrix}

\begin{bmatrix}
SV_1 \\
SV_2 \\
SV_3
\end{bmatrix} = [S]^{-1}
\begin{bmatrix}
1 \\
0 \\
0
\end{bmatrix}

JFLAG = 0

NO

TUTP = TSBST

YES

JFLAG = 1

\Delta T = (BSVPD - BSVPT)/BSD

NO

BSVP + BSD (\Delta T) > BSVPD

YES

TUTP = T₁ + \Delta T₁ + \Delta T₂

NO

\Delta T₂ = \Delta t₂/\Delta \theta₂

TTEST₂ = T₁ + \Delta T₁ + \Delta T₂

YES

PRINT LIGHTING ANGLE

TO PAGE D-20

3V = SV₁ \cdot \ddot{X}_T + SV₂ \cdot \dot{X}_T + SV₃ \cdot X_T
\dot{X}_T = \dot{X}_T + \dot{Y}_T + \dot{Z}_T
\ddot{X}_T = \ddot{X}_T + \ddot{X}_T

\ddot{p}_V = \ddot{p}_V \times \dot{SV}_p, \sin(\text{BSVP}) = \ddot{X}_T \cdot \ddot{X}_T / (|\ddot{X}_T| |\ddot{X}_T|)
\cos(\text{BSVP}) = \ddot{X}_T \cdot \ddot{X}_T / (|\ddot{X}_T| |\ddot{X}_T|), \BSD = |\ddot{X}_T| \times |\ddot{X}_T| / (|\ddot{X}_T| |\ddot{X}_T|)

\text{BSVP} = \tan^{-1} \left( \frac{\sin(\text{BSVP})}{\cos(\text{BSVP})} \right)

ORBIT INTEGRATION OF ORBITER AND SPACE STATION FROM T1 TO TTEST1

\[ \ddot{x}_T = \ddot{x}_{TS1} \]

\[ \ddot{\dot{x}}_T = \ddot{\dot{x}}_{TS1} \]

---

\[ \dot{x} = \dot{x}_{TS1} \]

---

**ECCV**

\[ \dot{e}_{EP} \]

**TRUE PTA**

**TIME TGP2**

---

**ORBIT INTEGRATION OF ORBITER AND SPACE STATION** 

\[ \text{NO} \rightarrow \text{TGP2} < 30 \rightarrow \Delta T = 1 \]

\[ \text{YES} \rightarrow \text{TGP2} < 2 \]

\[ R_{AP} = R_{RP} = |\ddot{x}_P|, \quad \nu_C = (\nu/R_{AP})^{1/2}, \quad N_{CPP} = \ddot{x}_P \times \ddot{x}_P \]

\[ \ddot{\dot{v}}_{CP} = \ddot{x}_P \times N_{CPP}/(|\ddot{x}_P \times N_{CPP}|), \quad \ddot{v}_{CP} = \nu_C \ddot{v}_{CP} \]

\[ \ddot{v}_g = \ddot{v}_{CP} - \ddot{x}_P, \quad v_{g1} = |\ddot{v}_g|, \quad \ddot{x}_P = \ddot{v}_{CP} \quad \text{TST1} = T \]

\[ \ddot{x}_{PS} = \ddot{x}_P, \quad \ddot{x}_{PS} = \ddot{x}_P, \quad \ddot{x}_{TS} = \ddot{x}_T, \quad \ddot{x}_{TS} = \ddot{x}_T \]

---

**MAJOR ISOLATION LOOP**

**ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TTEST2**

\[ 4-15 \rightarrow \text{FROM PAGE D-19} \]

\[ 4-4 \rightarrow \text{TO PG. D-12} \]

---

D-11
\[ A_T = \frac{1}{2} \left[ x_T^2 - x_T^2 \right], \quad R_{ATD} = A_T(1 + E_T) - \Delta H_D \]
\[ R_{PTD} = A_T(1 - E_T) - \Delta H_D, \quad A_{TD} = \frac{(R_{ATD} + R_{PTD})}{2} \]
\[ E_{TD} = \frac{(R_{ATD} - R_{PTD})}{(R_{ATD} + R_{PTD})}, \quad P_{TD} = \]
\[ A_{TD}(1 - E_{TD}^2), \quad \text{COSTTAPA} = E_{ET} \cdot \frac{-E_{EP}}{(E_T \cdot E_P)} \]
\[ R_{TD} = \frac{P_{TD}}{(1 + E_{TD} \cdot \text{COSTTAPA})} \]
\[ \text{DRTEST} = R_{AP} - R_{TD} - 100.0, \quad \text{IPASSI} = 0 \]

\[
\begin{align*}
A_{MP} & = x_P \times x_P, \quad A_{MT} = x_T \times x_T, \\
\bar{D}_{NT} & = A_{MI} \times \bar{A}, \quad D_{NP} = A_{MP} \times \bar{A} \\
\bar{D}_{NAMP} & = D_{NP} \times \bar{A}_{MP}, \quad \bar{D}_{NAMT} = \bar{D}_{NT} \times \bar{A}_{MT} \\
\sin \alpha_T & = E_{ET} \cdot \frac{D_{NAMT}}{[E_T \cdot D_{NAMT}]}, \quad \cos \alpha_T = E_{ET} \cdot \frac{D_{NT}}{[E_T \cdot D_{NT}]} \\
\alpha_T & = \tan^{-1}(\sin \alpha_T / \cos \alpha_T) \\
\sin \alpha_P & = \bar{D}_{NAMP} / [E_P \cdot \bar{D}_{NAMP}] \\
\cos \alpha_P & = \bar{D}_{NP} / [E_P \cdot \bar{D}_{NP}] \\
\alpha_P & = \tan^{-1}(\sin \alpha_P / \cos \alpha_P) \\
\Delta \alpha & = \alpha_T - \alpha_P, \quad D = E_{TD}(PP). \\
\cos(\Delta \alpha) - P_{TD}(E_P), \quad E = -E_{TD} \cdot (PP) \sin(\Delta \alpha), \quad F = P_{TD} - PP, \\
A & = -(E^2 + D^2), \quad B = 2FE, \quad C = D^2 - F^2 \\
\text{RAD} & = B^2 - 4AC, \quad \text{STI} = (-B - \sqrt{\text{RAD}})/2A \\
\text{STII} & = (-B + \sqrt{\text{RAD}})/2A
\end{align*}
\]
LIFT-OFF TIME CORRECTION

\[ A_T = |\bar{x}_T| u/(2u^2 - |\bar{x}_T|^2|\bar{x}_T|) \]
\[ E_T = |\bar{E}_T|, \quad \bar{N}_{PCET} = \bar{x}_p \times \bar{x}_p \]
\[ \bar{N}_{CTCT} = \bar{E}_T \times \bar{N}_{PCET} \]
\[ \text{COSTTAPP} = \bar{E}_T \cdot \bar{x}_p/[E_T|\bar{x}_p|] \]
\[ \text{SINTTAPP} = \bar{N}_{CTCT} \cdot \bar{x}_p/[|\bar{N}_{CTCT}|\bar{x}_p|] \]
\[ P_T = A_T(1 - E_T^2) \]
\[ R_{RT} = P_T/(1 + E_T \text{ COSTTAPP}) \]
\[ \Delta R_1 = R_{RT} - |\bar{x}_p|, \quad B = |\bar{x}_p| - R_{AT} - R_{PT} \]

\[ \Delta R_1 > 0 \quad \text{NO} \quad B = -B \]

\[ C = R_{AT}(R_{PT}) + (|\bar{x}_p|/2)(\text{COSTTAPP}(R_{PT} - R_{AT}) - (R_{AT} + R_{PT})) \]
\[ \Delta H_1 = [(-B + (B^2 - 4C)^{1/2})/2], \quad \Delta H_2 = [(-B - (B^2 - 4C)^{1/2})/2] \]
\[ \Delta R = |\Delta R_1|, \quad DRT_1 = |\Delta R - \Delta H_1|, \quad DRT_2 = |\Delta R - \Delta H_2| \]

\[ \Delta H_D = \Delta H_1 \quad \text{YES} \]
\[ DRT_1 \leq DRT_2 \quad \text{NO} \]
\[ \Delta H_D = \Delta H_2 \]

\[ \Delta R_1 > 0 \quad \text{NO} \]
\[ \Delta H_D = -\Delta H_D \quad \text{YES} \]

\[ R_{PP} = R_{PT} - \Delta H_D', \quad R_{AP} = R_{AT} - \Delta H_D', \quad E_P = (R_{AP} - R_{PP})/(R_{AP} + R_{PP}) \]
\[ A_P = (R_{PP} + R_{AP})/2, \quad p_p = A_p(1 - E_p^2), \quad V_p = [(u/p_p)(1 + E_p^2 + 2E_p \text{ COSTTAPP})]^{1/2} \]
\[ V_p = \text{TAN}^{-1}[(E_p \text{ SINTTAPP})/(1 + E_p \text{ COSTTAPP})], \quad \bar{N}_{CPP} = \bar{x}_p \times \bar{x}_p \]
\[ \bar{V}_{pp} = \bar{x}_p \times \bar{N}_{CPP}/(|\bar{x}_p| \times \bar{N}_{CPP}|), \quad \bar{x}_p = \bar{x}_p/|\bar{x}_p|, \quad \bar{V}_p = V_p \cos \phi \bar{V}_{pp} + V_p \sin \phi \bar{x}_p, \quad \bar{V}_g3 = \bar{V}_p - \bar{x}_p, \quad V_g3 = |\bar{V}_g3|, \quad \bar{x}_p = \bar{V}_p \]
\[ \text{ICOR} = \text{ICOR} + 1 \]
LIFT-OFF TIME CORRECTION

4-11 FROM PG. D-14

TCDH-TUTP +SSFNO3
*T4-1000.
>0

YES

TULO = TULOS
DT = DTS

SFNO3 = SFNO3 + .5
\hat{x}_T = \hat{x}_{TS1}
\dot{x}_T = \dot{x}_{TS1}
\hat{x}_P = \hat{x}_{PS1}
\dot{x}_P = \dot{x}_{PS1}

NO

\bar{A}_{MP} = \bar{x}_P \times \bar{\dot{x}}_P, \quad \bar{A}_{MT} = \bar{x}_T \times \bar{\dot{x}}_T
\bar{N}_{TP} = \bar{A}_{MP} \times \bar{A}_{MT}
W_{ATP} = \cos^{-1} \left( \frac{\bar{A}_{MP} \cdot \bar{A}_{MT}}{||\bar{A}_{MP}|| ||\bar{A}_{MT}||} \right)

\cdot RANGA

\phi_p

\cdot RANGA

\phi_T

\bar{N}_{CXT} = \bar{x}_T \times \bar{N}_{TP}, \quad \bar{N}_{CTCT} = \bar{N}_{TP} \times \bar{N}_{CXT}
SIN \phi_{NT} = [\bar{N}_{CTCT} \cdot \bar{x}_T/(||\bar{N}_{CTCT}|| \cdot ||\bar{x}_T||)]
COS \phi_{NT} = [\bar{N}_{PT} \cdot \bar{x}_T/(||\bar{N}_{TP}|| ||\bar{x}_T||)]
\phi_{NT} = \tan^{-1} (\sin \phi_{NT}/\cos \phi_{NT})
\bar{N}_{CXP} = \bar{x}_P \times \bar{N}_{TP}, \quad \bar{N}_{CPCP} = \bar{N}_{TP} \times \bar{N}_{CXP}, \quad \sin \phi_{NP} =
\bar{N}_{CPCP} \cdot \bar{x}_P/(||\bar{N}_{CPCP}|| ||\bar{x}_P||), \quad \cos \phi_{NP} = \bar{N}_{TP} \cdot \bar{x}_P
/||N_{TP}|| ||x_p||, \quad \phi_{NP} = \tan^{-1} (\sin \phi_{NP}/\cos \phi_{NP})
\hat{E}_{RA} = \cos \phi_L \hat{i} + \sin \phi_L \sin A_z \hat{j} - \sin \phi_L \cos A_z \hat{k}
\theta_{NT} = \cos^{-1} (\hat{E}_{RA} \cdot \hat{\bar{\delta}}_{NT}/||\bar{\delta}_{NT}||), \quad \theta_{NP} = \cos^{-1} (\hat{E}_{RA} \cdot \hat{\bar{\delta}}_{NP}/||\bar{\delta}_{NP}||)
\Delta_\theta_E = \theta_{NT} - \theta_{NP}

TO PG. D-8

4-10

TO PG. D-16

4-12

D-15
\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \phi_{NP} = \phi_{NP} + 2\pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NT} = \phi_{NT} + 2\pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ \phi_{NP} > \pi \]

\[ \phi_{NT} > \pi \]

\[ \Delta \phi = \phi_{NT} - \phi_{NP} \]

\[ |\Delta \phi| < \pi \]
\[
\Delta \phi_E = \Delta \phi - \Delta \phi_R
\]

4-17 FROM PG. D-18

4-18

YES

\[ |\Delta \phi_E| > .05 \]

NO

\[ |\Delta \phi_E| > .02 \]

NO

YES

LAST PASS NODE CORRECTION

\[ \Delta T_{LO} = \Delta \phi_E/(\Delta \phi_R) \]
\[ \hat{x}_{TR1} = \hat{x}_{TS} \]
\[ T = TSTI, \quad \hat{x}_T = \hat{x}_{TS}, \quad \hat{\chi}_T = \hat{\chi}_{TS} \]
\[ TULO = TULO + \Delta T_{LO}, \quad \Delta T_{LOT} = TULOS - TULO, \quad TUTP = TUTP - \Delta T_{LO}, \quad TULOSS = TULO + TULOS \]

4-16 FROM PG. D-18

THIS IS THE SOLUTION
RECYCLE AND PRINT
OUT ISOLATED TIMELINE
AND TARGETING PARAMETERS

4-21 TO PAGE D-20

ISOLAS = 0

YES

ACUMULATED VALUE*
OF LAUNCH TIME CORRECTION

\[ \hat{x}_T = \hat{x}_{TS}, \quad \hat{\chi}_T = \hat{\chi}_{TS} \]
\[ \hat{R}_P = \hat{R}_{PS}, \quad \hat{\chi}_P = \hat{\chi}_{PS} \]
\[ T = TSTI \]
\[ *\Delta T_{LOT} = TULO - TULOS \]

4-19 TO PAGE D-18

SPACE STATION ORBIT INTEGRATION (ONLY)
FROM \( T = TSTI \) TO \( T = TSTI + \Delta T_{LO} \)
(IF \( \Delta T_{LO} < 0 \) INTEGRATE BACKWARDS)

\[ x_{TR2} = x_T \theta T = TSTI + \Delta T_{LO} \]
\[ \Delta \phi_{LOC} = \cos^{-1} \left( \frac{x_{TR2}}{x_{TR1}} \right) \]
\[ \Delta \phi_{LOC} = \left( \frac{\Delta T_{LO}}{\Delta T_{LO}} \right) \Delta \phi_{LOC} \]
\[ \Delta T_{TI} = \Delta \phi_{LOC} - \Delta \phi_{CU}/\Delta \phi_{2} \]
\[ TTEST2 = TTEST2 + \Delta T_{TI} \]

4-15 TO PG. D-11

MAJOR ISOLATION LOOP

D-19
\[ \ddot{x}_T = \ddot{x}_{TLO}, \quad \dot{x}_T = \dot{x}_{TLO} \]

Space Station Integration from \( T = TULO \) to \( T = TULO + \Delta T_{LOT} \)

\[ \Delta \theta_E = \omega \cdot \Delta T_{LOT} \]

KINS = 0

JINS = 1

---

\[ \ddot{x}_T = \ddot{x}_{TSI}, \quad \dot{x}_T = \dot{x}_{TSI} \]

Space Station Orbit Integration from \( T = TULOS \) to \( T = TULOS + \Delta T_{LO} \)

KINS = 1

---

Stop read another case
D.3 SUBROUTINES

\[ \bar{A}_M = \bar{X} \times \dot{\bar{X}} \]
\[ \bar{e} = -\left\{ \frac{\bar{X}}{|\bar{X}|} + \frac{\bar{A}_M \times \dot{\bar{X}}}{\mu} \right\} \]

RETURN
TRUE

\[ \text{TRUE} \]

\[ \vec{N}_{EC} = \vec{x} \times \vec{y}, \quad \vec{N}_{CEC} = \vec{e} \times \vec{N}_{EC} \]

\[ \text{COS}(TA) = \vec{e} \cdot \vec{y} / (|\vec{e}| |\vec{y}|) \]

\[ \text{SIN}(TA) = \vec{N}_{CEC} \cdot \vec{y} / (|\vec{N}_{CEC}| |\vec{y}|) \]

\[ TA = \text{TAN}^{-1} \left[ \frac{\text{SIN}(TA)}{\text{COS}(TA)} \right] \]

RETURN

RANGA

\[ \vec{A}_{M} = \vec{x} \times \vec{\dot{x}}, \quad \vec{D}_{N} = \vec{A}_{M} \times \vec{\dot{n}}, \quad \vec{D}_{CH} = \vec{A}_{M} \times \vec{D}_{N} \]

\[ \text{SIN} \phi = \vec{D}_{CH} \cdot \vec{y} / (|\vec{D}_{CH}| |\vec{y}|) \]

\[ \text{COS} \phi = \vec{D}_{N} \cdot \vec{y} / (|\vec{D}_{N}| |\vec{y}|) \]

\[ \phi = \text{TAN}^{-1} (\text{SIN} \phi / \text{COS} \phi) \]

RETURN

D-22
Appendix E

PROGRAM LISTING
PROGRAM TARG

DIMENSION XP(3), XDP(3), XT(3), XDT(3), XTR1(3), XTR2(3), TEMP1(3)
1 TEMP2(3), TEMP3(3), TEMP4(3), TEMP5(3), XOMEGA(3), AAA(3,3), BBB
2(3,3), CCC(3,3), DDD(3,3), XPS(3), XDPS(3), XTS(3), XDTS(3), EV(3)
3 AM(3), XTS1(3), XDT1(3), XDP1(3), XPS1(3)
DIMENSION XTLO(3), XDTLO(3)

CFL=1052,
GHC=396032E15
RE=6370166,
GH2=7972064E15
OMEGA=729211585E-04
P3=6.2831092
P1=3.1415926
ZERO=0.0
ONE=1.
TWO=2.0
Cnv=57.2957951
MATOL=1.0/Cnv
KPASS=0
JPASS=0
READ 1750, ISURF, ILIG
READ 1760, A, B, C, D, E, F, G, H, O, S
READ 2100, T, TN, TS, TTOL, HAP, HPER
READ 2100, AN, EN, XENCN, THNN, ALFAN, PHIN
READ 2100, AS, ES, XENS, THNS, ALFAS, PHIS
READ 2100, PHI, XLAMAL, BSVD, A1, B1, C1, TOLE, TY, DLHD, DLHB, SFNO1, SFNO2,
SFNO3 A SLH
JINS=0
D16=5.0
D7=20.0
D12=20.0
SFNO3=SFNO3
JLIGHT=0
DTS=DT
PHI=PHI
AZ=AZ
DELTH=DLHD
DLHD=DLHD*CF
DLHB=DLHB*CF
PHI=PHI/Cnv
AZ=AZ/Cnv
XLAMAL=XLAMAL/Cnv
BSVD=BSVD/Cnv
A1=A1/Cnv
B1=B1/Cnv
C1=C1/Cnv
XENCN=XENCN/Cnv
THNN=THNN/Cnv
THNN=THNN/Cnv
PROGRAM TARG

**A** 51
ALFAN = ALFAN / CNV

**A** 52
PHIN = PHIN / CNV

**A** 53
XENCS = XENCS / CNV

**A** 54
THNS = THNS / CNV

**A** 55
ALFAS = ALFAS / CNV

**A** 56
PHIS = PHIS / CNV

IF (TN - TS) 20, 50, 50

**A** 57
20 IF ((TN - T) - TTOL) 40, 30, 30

**A** 58
30 NORTH = 1

**A** 59
TULO = TN

**A** 60
PRINT 1770

**A** 61
GO TO 60

**A** 62
40 NORTH = 0

**A** 63
TULO = TS

**A** 64
PRINT 1780

**A** 65
GO TO 60

**A** 66
50 IF ((TS - T) - TTOL) 30, 40, 40

**A** 67
60 IF (NORTH = 1) 80, 70, 80

**A** 68
70 T = TN

**A** 69
AT = AN

**A** 70
ET = EN

**A** 71
XENCT = XENCN

**A** 72
THNT = THNN

**A** 73
ALFAT = ALFAN

**A** 74
PHII = PHIN

**A** 75
GO TO 90

**A** 76
80 T = TS

**A** 77
AT = AS

**A** 78
ET = ES

**A** 79
XENCT = XENCN

**A** 80
THNT = THNN

**A** 81
ALFAT = ALFAN

**A** 82
PHII = PHIN

**A** 83
GO TO 90

**A** 84
90 IF (JPASS = 1) 100, 140, 140

**A** 85
100 IF (THNT - PI/2, ) 110, 110, 120

**A** 86
110 AZL = PI - ARSIN(COS(XENCN) / COS(PHI))

**A** 87
AZO = AZL - CNV

**A** 88
AZ = AZL

**A** 89
GO TO 130

**A** 90
120 AZL = ARSIN(COS(XENCN) / COS(PHI))

**A** 91
AZ = AZL

**A** 92
AZO = AZL - CNV

**A** 93
130 PRINT 1800

**A** 94
PHII = PHII - CNV

**A** 95
ALFAT = ALFAT - CNV

**A** 96
XENCN = XENCN - CNV

**A** 97
THNT = THNT - CNV

**A** 98
PRINT 1790, T, AT, ET, XENCN, THNT, ALFAT, PHII, PHII

**A** 99
PRINT 1810, AZO

**A** 100
140 PHIT = PHII - ALFAT

E-3
PROGRAM TARG

CALL MAROT (AAA, AZ-PI/2., 1, 1)
CALL MAROT (BBB, PHI, 3-1)
CALL MAMUL (CCC, BBB, AAA)
CALL MAROT (AAA, THNT, 2, 1)
CALL MAROT (BBB, XENTRY, 1, -1)
CALL MAMUL (DDD, BBB, AAA)
CALL MAROT (AAA, DDD, CCC)
CALL MAROT (BBB, THNT, 2, 1)
CALL MAMUL (CCC, BBB, AAA)
CALL FATT (DDD, CCC)

XOMEGA(1) = SIN(PHI)
XOMEGA(2) = COS(PHI)*SIN(AZ)
XOMEGA(3) = COS(PHI)*COS(AZ)

IF (KPASS = 1) 150, 160, 150

150 RO = AT*(ONE-ET*ET)/(ONE-ET*COS(PHI))
VO = SQRT(GM*(TWO/RO-ONE/AT))
GAMMO = ARCTAN(ET*SIN(PHI), ONE+ET*COS(PHI), 1)

160 CONTINUE

TEMP1(1) = RO
TEMP1(2) = ZERO
TEMP1(3) = ZERO
TEMP2(1) = VO*SIN(GAMMO)
TEMP2(2) = ZERO
TEMP2(3) = VO*COS(GAMMO)
CALL FATMU (XT, DDD, TEMP1)
CALL FATMU (XDT, DDD, TEMP2)

MPASS = 0

IF (JPASS = 1) 170, 370, 170

170 CALL RANGE (XT, XDT, XOMEGA, PHI)
CALL VCROSS (TEMP1, XT, XDT)
CALL VCROSS (TEMP2, TEMP1, XOMEGA)

RRT = VMAG(XT)

PSI = ARSIN(VDOT(TEMP1, XOMEGA)/RRT)
PSIO = PSI*CNV

TEMPS(1) = COS(PHI)
TEMPS(2) = SIN(PHI)*SIN(AZ)
TEMPS(3) = SIN(PHI)*COS(AZ)
THNT = ARCOS(VDOT(TEMPS, TEMP2)/VMAG(TEMP2))

CALL VUNIT (TEMP4, TEMP1)

DUM1 = VDOT(XOMEGA, TEMP4)
DUMDUM1 = DUM1

XENC = ARCTAN(SQRT(ONE-DUM), DUM1, 1)

AT = RRT*GM/(TWO*GM-VDOT(XDT, XDT)*RRT)

XENC = XENC*CNV
PHITO = PHIT*CNV
THNTQ = THNT*CNV
PRINT 1700, PSIO

IF (MPASS = 1) 180, 300, 180

180 IF (THNT = PI/2) 200, 190, 190
PROGRAM TARG

190 NORTH=1
GO TO 210

200 NORTH=0
SOUTHERNLY LAUNCH COEFFICIENTS
210 IF (NORTH=1) 220, 230, 230
220 PSIDO=POLY(B,XENCO,6)
PSID=PSIDO/CNV
DUM=COS(XENC)/COS(PSID)
AA=SQRT(ONE-DUM*DUM)
PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
PHILS=PI2-PHILS
DPHRR=PHILS-PHIT
GO TO 240

NORTHERNLY LAUNCH COEFFICIENTS
230 PSIDO=POLY(A,XENCO,6)
PSID=PSIDO/CNV
DUM=COS(XENC)/COS(PSID)
AA=SQRT(ONE-DUM*DUM)
PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
PHILS=PI2-PHILS
DPHRR=PHILS-PHIT
240 CONTINUE
DPHRR=DPHRR*CNV
PRINT 1710, PSIDO
IF (PHIT=PI) 290, 290, 250
250 IF (DPHRR) 290, 290, 260
260 PHID=SQRT(GM/(AT*AT*AT))
TGR=DPHRR/PHID
IF (TGR-100.0) 270, 270, 290
270 DTT3=10.0
IF (TGR-20.0) 280, 280, 290
280 DTT3=TGR
MPASSI=1
290 TF=T+DTT3
CALL RKG (PHIO,AZO,XT,XDT,T,TF)
T=TF
TULOD=0,0
PRINT 2210
CALL PRINT (TF,XT,XDT,AZ,PHI,TULOD)
GO TO 170
300 PRINT 1840
PRINT 1820, PSIO
PRINT 1830, PSID0
XIDO=XENC0
PRINT 1850, XENC0
IF (ISURF-1) 310, 330, 310
THIS IS WHERE THE STEADY STATE SHOULD BE PROGRAMED IN THE FUTURE
310 DO 320 I=1,3
XP(I)=0,0
320 XP(DP(I))=0,0
PROGRAM TARG

PRINT 1860
Go TO 400

330 IF (NORTH = 1) 350, 340, 350
340 AZN = POLY(C, XIDO, 6)
  AZO = AZN
  THNNP = POLY(D, XIDO, 6)
  T1N = POLY(E, XIDO, 6)
  PHIPN = POLY(Q, XIDO, 6)
  PHII = PHIPN/CNV
  ALFAT = 0, 0
  THNT = THNNP/CNV
  AZ = AZN/CNV
  T1 = T1N
  GO TO 360
350 AZS = POLY(F, XIDO, 6)
  AZO = AZS
  THNSP = POLY(G, XIDO, 6)
  T1S = POLY(H, XIDO, 6)
  PHIPS = POLY(S, XIDO, 6)
  PHII = PHIPS/CNV
  ALFAT = 0, 0
  THNT = THNSP/CNV
  AZ = AZS/CNV
  T1 = T1S
360 XENCT = XIDO/CNV
PRINT 1870, AZO
KPASS = 1
JPASS = 1
RO = HPER*CF*RE
RA = MAP*CF*RE
ETD = (RA-RO)/(RA+RO)
ATE = (RA-RO)/TWO
VO = SORT(GM*ONE+ET)/RO
GAMMO = 0, 0
GO TO 140
370 IF (KPASS = 1) 410, 380, 380
380 DO 390 I = 1, 3
  XP(I) = XT(I)
390 XP(I) = XD(I)
400 KPASS = 0
PRINT 1880, XP, XDP
PUNCH 2350, XP, XDP
JPASS = 1
GO TO 60
410 TF = T + T1
DO 420 I = 1, 3
  XTL0(I) = XT(I)
420 XDTL0(I) =XD(T(I)
PRINT 2320
CALL RKG (PHIO, AZO, XT, XDT, T, TF)
CALL PRINT (TF,TX,TXT,AZ,PHI,TULOD)
PRINT 1840
PRINT 1890, XT,XDT
TULOS=TULO
DO 430 I=1,3
XTS(I)=XT(I)
XDT(I)=XDT(I)
XPS(I)=XP(I)
430 XDPS(I)=XDP(I)
440 RRP=SQR(T(VDOT(XP,XP))
VVP=SQR(T(VDOT(XDP,XDP))
AP=GM*RRP/(GM2*VVP*VVP*RRP)
RRT=SQR(T(VDOT(XT,XT))
VVT=SQR(T(VDOT(XDT,XDT))
AT=GM*RRT/(GM2*VVT*VVT*RRT)
PDP1=SQR(T(GM/(AP*AP*AP))
PDTA1=SQR(T(GM/(AT*AT*AT))
DLPD1=PDPA1-PDTA1
DLMR1=DLPD1+PI*SQR(T(AP*AP*AP/GM))
GAMAP=ARSIN(VDOT(XP,XDP)/(RRP*VVP))
HP=RRP*VVP*COS(GAMAP)
EP=SQR(T(ONE+HP/HP/(GM*AP))
RRP=AP*(ONE-EP)
RAP=AP*(ONE+EP)
VAP=SQR(T(GM/AP)*SQR(T((ONE+EP)/(ONE+EP)))
GAMAT=ARSIN(VDOT(XT,XDT)/(RRT*VVT))
HT=RRT*VVT*COS(GAMAT)
ET=SQR(T(ONE+HT/HT/(GM*AT))
RAT=AT*(ONE+ET)
RPT=AT*(ONE-ET)
TAUP1=PI/2*SQR(T(AP*AP*AP/GM))
T2=T1+TAUP1/TWO
DRT=RAT-RPT
GAMAP0=GAMAP-CNVT
HAT=(RAT-RE)/CF
PHDOTP=PDPA1-CNVT
HPT=(RPT-RE)/CF
PHDOTT=PDTA1-CNVT
HAP=(RAP-RE)/CF
DLPD10=DLPD1-CNVT
HPP=(RRP-RE)/CF
GAMATO=GAMAT-CNVT
DLMR10=DLMR1-CNVT
PRINT 2110
PRINT 2120, RRP,VVP,GAMAP0,EP,AP,HAP,HPP,PHDOTP
PRINT 2130
PRINT 2140, RRT,VVT,GAMATO,ET,AT,HAT,HPT,PHDOTT
PRINT 2150
PRINT 2160, DLPD10,DLMR10,T2
PROGRAM TARG

RCP*RAP
VCP=SQRRT(GM/RCP)
DUM=SQRRT(RCP*RCP*GM)
TAUCP=PI2*DUM
PDOTCP=ONE/DUM
DLPD2=PDOTCP-PDTA1
DLMR2=SFNO1*DLPD2*TAUCP
DELV2=VCP*VAP
T3=T2*SFNO1*TAUCP
PDOTCO=PDOTCP*CNV=DLMR2=DLMR2*CNV
PRINT 2170
PRINT 2180, RCP, VCP, TAUCP, PDOTCO, DLPD2, DLMR20, DELV2, T3
IF (ILIG=1) 450, 460, 450

450 XN=ZERO
GO TO 470

460 XN=ONE
CONTINUE

470 RPP3=RCP
RAP3=RPT-DLHD+DLHB
AP3=(RPP3*RAP3)/TWO
DUM=SQRRT(AP3*AP3*AP3/GM)
TAUP3=PI2*DUM
PDPA3=ONE/DUM
DLPD3=PDPA3-PI2
DLMR3=SFNO2*DLPD3*TAUP3
T4=T3*SFNO2*TAUP3
VPP3=SQRRT(GM2*RAP3/RPP3)
DELV3=VPP3-VCP
PRINT 2190
PRINT 2190
PDPA30=PDPA3*CNV=DLPD30=DLPD3*CNV
DLMR30=DLMR3*CNV
DLMR30=DLMR3*CNV
PRINT 2200, TAUP3, PDPA30, DLPD30, DELV3, T4, DLMR30
CONTINUATION AT CDH ALTITUDE
RPP3=RAT-DLHD+DLHB
AP3=(RPP3*RAP3)/TWO
EP3=(RAP3*RPP3)/(RPP3*RPP3)
RPP4=RPT-DLHD
RAP4=RAT-DLHD
AP4=(RPP4*RAP4)/TWO
EP4=(RPP4*RAP4)/(RPP4*RPP4)
P3=AP3*(ONE-EP4*EP3)
TH4=ARCCOS(P3-P4)/(EP3*P4*EP4*P3)
R4=AP4/(ONE-EP4*COS(TH4))
V4=SQRRT((GM2*AP3/R4-GM)/AP3)
GAMA4=ARTAN(R4*EP3*SIN(TH4), P3, -1)
VT4=SQRRT((GM2*AP4/R4-GM)/AP4)
GAMT4=ARTAN(R4*EP4*SIN(TH4), P4, -1)
DELV4=SQRRT(VT4*VT4+V4*V4-TWO*VT4*V4*COS(GAMT4-GAMA4))
TH40=TH4*CNV
GAMA40=GAMA4*CNV
GAMT40=GAMT4*CNV
PRINT 2210
DUM=SORT(AP4*AP4*AP4/GM)
TAUP4=PI2*DUM
PDPA4=ONE/DUM
PDPA40=PDPA4*CNV
DPDCU=PDPA4-PDTA1
DPHO=SLM*DELTH
DPHR=DPHO/CNV
PRINT 2230, DPHO
DELVR=0.0
DLMR4=DPDCU*TAUP4*(SFNO3*XN)*DPHR
TPPI=T4+TAUP4*(SFNO3*XN)*DPHR/DPDCU
DPDCU0=DPDCU*CNV
DVI1=DELV2*DELV3*DELV4*DELVR
DLMR40=DLMR4*CNV
DPHT1=DLMR1+DLMR2+DLMR3+DLMR4
DMTO=DPHT1*CNV
PDPA40=PDPA4*CNV
DPDCU0=DPDCU*CNV
PRINT 2240
PRINT 2250
PRINT 2260, TAUP4, PDPA40, DPDCU0, DLMR40, TTP1, DMTO, DVI
CALL RANGA (XP, XDP, XOMEGA, PHIP1)
CALL RANGA (XT, XDT, XOMEGA, PHIT1)
ISOLAS=0
ICOR=0
PHIP10=PHIP1*CNV
PHIT10=PHIT1*CNV
PRINT 2270, PHIP10, PHIT10
IF (PHIT1-P1) 480,490,490
480 PHIT1=PHIT1-P12
490 DPA1=PHIT1-PHII1
GO TO 500
500 IF (DPA1-DPHRT1) 510,520,520
510 DPA1=DPA1+P12
GO TO 530
520 DPA1=DPA1
530 DT1=SFNO3*TAUP4+TAUP1/TH2+TAUP3*SFNO2
DPHI1=DLMR1+DLMR3*DPDCU+TAUP4*SFNO3
DPA10=DPA1*CNV
PRINT 1910, DPA10
DPH2=DPA1-DPH1-DPHR
DT2=DPH2/DPH2
TTTEST1=TI+TAUP1/TH0=200.
PROGRAM TARG

TTEST2 = T1 * TAUP1 / TWO + DT2
TBSST  = T1 + DT1 + DT2
PRINT 1920, SFNO1, SFNO2, SFNO3
PRINT 2320
CALL PRINT (T1, XT, XDT, AZ, PH1, TULO)
CALL RKG (PH1O, AZO, XT, XDT, T1, TBSST)
PRINT 2320
CALL PRINT (TBSST, XT, XDT, AZ, PH1, TULO)
PRINT 2280
DPH1O = DPH1 * CNV
DPH2O = DPH2 * CNV
PRINT 2290, DPH1O, DPH2O, DT2, TBSST, DT1, T1, TTEST1, TTEST2
IF (ILIG = 1) 630, 540, 630
TULO = SHUTTLE LIFT-OFF TIME IN SECONDS UNIVERSAL TIME
TY = NUMBER OF DAYS PAST JAN. 1 OF LAUNCH YEAR
LAMDA, L = LONGITUDE OF LAUNCH SITE
Al, Bi, C1 = INPUT CONSTANTS
OMEGA = EARTH'S ROTATION

540 T = TBSST
550 DUM = PI * XLAMAL - OMEGA * TULO
PHSV = DUM
CALL MAROT (AAA, DUM, 2, -1)
DUM = A1 * COS (B1 * C1 * TY)
ALSV = DUM
CALL MAROT (BBB, DUM, 3, -1)
CALL MAMUL (CCC, BBB, AAA)
CALL MAROT (AAA, AZ, PI / THO, 1, 1)
CALL MAROT (BBB, PHI, 3, 1)
CALL MAMUL (DDD, BBB, AAA)
CALL MAMUL (AAA, CCC, DDD)
CALL FATT (BBB, AAA)

TEMP1(1) = ONE
TEMP1(2) = ZERO
TEMP1(3) = ZERO
CALL FATHU (TEMP2, BBB, TEMP1)
JFLAG = 0

CALL VCROSS (TEMP3, XT, XDT)
BSVPT = VRAG (TEMP3) / VDOT (XT, XT)
CALL VUNIT (TEMP4, TEMP3)
CALL VCROSS (TEMP5, TEMP4, TEMP2)
CALL VUNIT (TEMP5, TEMP5)
CALL VCROSS (TEMP2, TEMP5, TEMP4)
BSVPT = ARTAN (VDOT (XT, TEMP5), VDOT (XT, TEMP2), 1)
IF (JLIGHT = 1) 570, 1450, 570
IF (BSVPT = BSV) = 0, 001) 580, 580, 610
IF (JFLAG = 1) 590, 620, 590
CHECK = BSVPT * BSD * DT
IF (CHECK = BSV) 610, 600, 600
JFLAG = 1
DT = (BSV - BSVPT) / BSD
**PROGRAM TARG**

610 T2=T+DT
CALL RKG (PHIO, AZO, XT, XDT, T, T2)
T=T2
GO TO 560

620 PRINT 2320
CALL PRINT (T2, XT, XDT, AZ, PHI, TULO)
PRINT 2300
PWSVO=PHSV*CNV
ALSVO=ALSV*CNV
BSVP=BSVPT*CNV
AO=A1*CNV$BO=B1*CNVSOC=C1*CNV
XLAMDO=XLAMAL*CNV
PRINT 2310, AO, BO, CO, TY, XLAMDO, PWSVO, ALSVO, BSVPTO
TUTP=T
DT3=T-TSBNST
DPH1=DPH1+DPDCU+DT3
DPH2=PA1+DPH1+DPH2
DT2=DPH2/DLPD2
TTEST2=T1+TAUDP1+DT2
GO TO 640

630 TUTP=TSBNST
640 DO 650 I=1,3
XT(I)=XTS1(I)
XDT(I)=XTS1(I)
CALL RKG (PHIO, AZO, XT, XDT, T, T1, TTEST1)
CALL RKG (PHIO, AZO, XP, XDP, T, T1, TTEST1)
PRINT 2320
CALL PRINT (TTEST1, XT, XDT, AZ, PHI, TULO)
PRINT 2330
CALL PRINT (TTEST1, XP, XDP, AZ, PHI, TULO)
T=TTEST1

660 CALL ECCV (GM, XP, XDP, TEMP3)
CALL TRUE (XP, XDP, TEMP3, PTA)
EP=VMAG(TEMP3)
RPM=VMAG(XP)
AP=RPM*GM/(GM2-VDOT(XDP, XDP)*RPM)
CALL TIME (AP, EP, PTA, PI, GM, PI, TGP2)
IF (TGP2<30.,0.) 670, 670, 680

670 DT12=ONE
IF (TGP2<TWO) 690, 690, 680

680 T12=T+DT12
CALL RKG (PHIO, AZO, XT, XDT, T, T12)
CALL RKG (PHIO, AZO, XP, XDP, T, T12)
T=T12
GO TO 660

690 RAP=VMAG(XP)
PRINT 2320
CALL PRINT (T12, XT, XDT, AZ, PHI, TULO)
PRINT 2330
CALL PRINT (T12, XP, XDP, AZ, PHI, TULO)
PROGRAM TARG

TST= T
VC=SQRT(GM/RAp)
CALL VCRoss (TEMP1, XDP, XP)
CALL VCRoss (TEMP2, XP, TEMPP1)
CALL VUNIT (TEMP2, TEMPP1)
DO 700 I=1, 3
700 TEMP3(I)=VC*TEMP2(I)
DO 710 I=1, 3
710 TEMPP1(I)=TEMP3(I)*XDP(I)
VC=VMAG(TEMP1)
PRINT 1990
PRINT 2000
PRINT 2330
CALL PRINT (TST, XP, XDP, AZ, PHI, TULO)
CALL VCRoss (AM, XP, TEMPP3)
CALL ECCV (GM, XP, TEMPP3, EV)
PRINT 2010, AM(1), AM(2), AM(3), EV(1), EV(2), EV(3), TEMP1(1), TEMP1(2), TEMP1(3)
DO 720 I=1, 3
720 XP(I)=TEMP3(I)
DO 730 I=1, 3
730 XDP(I)=XP(I)
XDP(S(I))=XDP(S(I))
XT(S(I))=XT(S(I))
740 CALL RKG (PHIO, AZO, XT, XDT, TST, TTEST2)
CALL RKG (PHIO, AZO, AM, TST, TTEST2)
PRINT 2330
CALL PRINT (TTEST2, XP, XDP, AZ, PHI, TULO)
CALL PRINT (TTEST2, XT, XDT, AZ, PHI, TULO)
TO TTEST2
CALL ECCV (GM, XT, XDT, TEMPP3)
RT=VMAG(XT)
AT=RT=GM/(GM*VDOT(XDT, XDT)*RM)
ET=VMAG(TEMP3)
RPP=VMAG(XP)
RAT=AT((ONE+ET)-DLHD
RPTD=AT((ONE+ET)-DLHD
ETDP=(RATD+RPTD)/(RATD+RPTD)
DO 750 I=1, 3
750 TEMP2(I)=XP(I)
RPP=VMAG(XP)
CTYP=VDOT(TEMP3, TEMPP2)/(ET*RPP)
RAP=TH0=RATD+RPTD/((RATD+RPTD)*(RATD+RPTD)*CTYPA+DLHB
EP0(RAP+RPP)/(RAP+RPP)
VPP=SQRT((GM/RPP)*(ONE+EP))
PRINT 2330
CALL PRINT (YTEST2, XP, XDP, AZ, PHI, TULO)
PRTN 2930
PROGRAM TARG

CALL VCROSS (TEMP1, XDP, XP)
CALL VCROSS (TEMP3, XP, TEMP1)
CALL VUNIT (TEMP3, TEMP3)
Do 760 I=1,3

760 TEMP2(I)=VPP*TEMP3(I)
Do 770 I=1,3

770 TEMP1(I)=TEMP2(I)-XDP(I)
VQ2=VMAG(TEMP1)
IF (ISOLAS-1) 790, 780, 780

780 PRINT 2020
PRINT 2000
PRINT 2330
CALL PRINT (TTEST2, XP, XDP, AX, PHIL, TULO)
CALL VCROSS (AM, XP, TEMP2)
CALL ECCV (GM, XP, TEMP3, EV)
PRINT 2010, AM(1), AM(2), AM(3), EV(1), EV(2), EV(3), TEMP1(1), TEMP1(2), TEMP1(3)
CONTINUE

Do 800 I=1,3

800 XDP(I)=TEMP2(I)
PRINT 1940
PRINT 2330
CALL PRINT (TTEST2, XP, XDP, AZ, PHIL, TULO)
AP=(RPP*RAP)/TWO
TAUP2=PI/2*SQRT(AP*AP*AP/GM)
TTEST3=T+(TAUP2*SPNO2)-250.
JPAS=0
KPAS=0
CALL RKG (PHIO, AZO, XT, XDT, TTEST2, TTEST3)
CALL RKG (PHIO, AZO, XP, XDP, TTEST2, TTEST3)
PRINT 2320
CALL PRINT (TTEST3, XT, XDT, AZ, PHIL, TULO)
PRINT 2330
CALL PRINT (TTEST3, XP, XDP, AZ, PHIL, TULO)
DT22=5.0
T=TTEST3

810 CALL ECCV (GM, XP, XDP, TEMP1)
EP=VMAG(TEMP1)
CALL ECCV (GM, XT, XDT, TEMP4)
ET=VMAG(TEMP4)
RMT=VMAG(XP)
AP=RMT*GM/(GM2-VDOT(XDP,XDP)*RMT)
RAP=AP*(ONE*EP)
DRTEST=RAP-VMAG(XT)*DLHD-100.
CALL TRUE (XP, XDP, TEMP1, PTA)
IF (ET-TOLE) 820, 840, 840

820 IF (DRTEST) 830, 900, 900
830 IF (PTA=PI) 840, 870, 870
840 CALL TIME (AP, EP, PTA, PI, GM, PI, TG3)
PRINT 1720, TG3
IF (TG3=10.) 860, 850, 850

050 T18=T+DT22
CALL RKG (PHIO, AZO, XP, XDP, T, T18)
CALL RKG (PHIO, AZO, XT, XDT, T, T18)
T=T18
IF (JPAS=1) 810, 870, 810

860 DT22=TG3
JPAS=1
GO TO 850

870 RCP=VMAG(XP)
PRINT 1730
VCP=SQRT(GM/RCP)
CALL VCROSS (TEMP1, XDP, XP)
CALL VCROSS (TEMP4, XP, TEMP1)
CALL VUNIT (TEMP4, TEMP4)
DO 880 I=1, 3

880 TEMP2(I)=VCP*TEMP4(I)
DO 890 I=1, 3

890 TEMP3(I)=TEMP2(I)-XDP(I)
V03=VMAG(TEMP3)
GO TO 1140

900 RS=VMAG(XT)-DLHD
PTASI=-ARCOS((PP-RS)/(EP*RS))*PI2
PRINT 1900
CALL ECCV (GM, XP, XDP, TEMP1)
CALL TRUE (XP, XDP, TEMP1, PTA)
PHST=PTASI-PTA
IF (PHST) 870, 910, 910

10 CALL TIME (AP, EP, PTA, PTASI, GM, PI, TG3)
PRINT 1740, TG3
IF (TG3=10.) 930, 920, 920

20 T18=T+DT22
CALL RKG (PHIO, AZO, XT, XDT, T, T18)
CALL RKG (PHIO, AZO, XP, XDP, T, T18)
T=T18
IF (KPAS=1) 810, 870, 810

930 DT22=TG3
KPAS=1
GO TO 920

940 RMT=VMAG(XT)
AT=RMT*GM/(GM2-VDOT(XDT, XDT)*RMT)
RATD=AT*(ONE+ET)-DLHD
RPTD=AT*(ONE+ET)-DLHD
ATD=(RATD*RPTD)/TWO
STD=(RATD*RPTD)/(RATD*RPTD)
PTD=ATD*(ONE+ETD+ETD)
DO 950 I=1, 3

950 TEM1P2(I)=TEMP1(I)
GYPAR=VDOT(TEMP2, TEMP4)/(ET*EP)
**PROGRAM TARG**

RTD = PTD (/ ONE + ETD * CTAPA)

DRTEST = RAP - RTD = 100.0

IPASS1 = 0

IF (DRTEST) 1020, 960, 960

960 CALL VCROSS (TEMP2, XP, XDP)

CALL VCROSS (TEMP3, TEMP2, XOMEGA)

CALL VCROSS (TEMP5, TEMP3, TEMP2)

SINAP = VDOT (TEMP1, TEMP5) / (EP * VMAG (TEMP5))

COSAP = VDOT (TEMP1, TEMP3) / (EP * VMAG (TEMP3))

ALFAP = ARTAN (SINAP, COSAP, 1)

CALL VCROSS (TEMP2, XT, XDT)

CALL VCROSS (TEMP3, TEMP2, XOMEGA)

CALL VCROSS (TEMP5, TEMP3, TEMP2)

SINAT = VDOT (TEMP4, TEMP5) / (ET * VMAG (TEMP5))

COSAT = VDOT (TEMP4, TEMP3) / (ET * VMAG (TEMP3))

ALFAT = ARTAN (SINAT, COSAT, 1)

DELAL = ALFAT - ALFAP

DEL = ETD * PP * COS (DELAL) - PTD * EP

E = ETD * PP * SIN (DELAL)

F = PTD * PP

A = (E * E + D * D)

B = TWO * F * E

C = D * F * F

RAD = (B + B - 4 * A * C)

STI = (-B - SQRT (RAD)) / (TWO * A)

STII = (-B + SQRT (RAD)) / (TWO * A)

IF (STI) 970, 970, 980

970 PTASI = -PI - ARSIN (STI)

GO TO 990

980 PTASI = -PI - ARSIN (STII)

990 CALL TIME (AP, EP, PTA, PTASI, GM, PI, TG3)

IF (TG3 < 10.) 1000, 1000, 1010

1000 DT22 = TG3

IPASS1 = 1

1010 T18 = T + DT22

CALL RKG (PHIO, AZO, XP, XDP, T, T18)

CALL RKG (PHIO, AZO, XT, XDT, T, T18)

T = T18

IF (IPASS1 = 1) 810, 1040, 810

1020 IF (PTA = PI) 1030, 1030, 1040

1030 PTASI = PI

GO TO 990

1040 RPM = VMAG (XP)

PRINT 2320

CALL PRINT (T18, XT, XDT, AZ, PHI, TULO)

PRINT 2330

CALL PRINT (T18, XP, XDP, AZ, PHI, TULO)

CALL ECCV (GM, XT, XDT, TEMP1)

RTM = VMAG (XT)

AT = RTM * GM / (GH2 - VDOT (XDT, XDT) * RTM)
ET=VMAG(TEMP1)
RAT=AT*(ONE-ET)
RPT=AT*(ONE-ET)
CALL VCROSS (TEMP2,XDP,XP)
CALL VCROSS (TEMP3,TEMP1,TEMP2)
CTTAPP=VDOT(TEMP1,XP)/(RPM*ET)
STTAPP=VDOT(TEMP3,XP)/(VMAG(TEMP3)*RPM)
PT=AT*(ONE-ET)
RRT=PT/(ONE-ET-CTTAPP)
DELR1=RRT-RPM
0=RPM-RAT-RPT
IF (DELR1) 1050,1050,1060
1050 B=b
1060 C=RAT-RPT/RPM/TWO*(CTTAPP*(RPT=RAT)-(RAT*RPT))
DLH1=ABS((-B+SORT(B*B-4.*C))/TWO)
DLH2=ABS((-B-SORT(B*B-4.*C))/TWO)
DELR=ABS(DELR1)
DRT1=ABS(DELR-DLH1)
DRT2=ABS(DELR-DLH2)
IF (DRT1=DRT2) 1070,1070,1080
1070 DLHDP=DLH1
GO TO 1090
1080 DLHDP=DLH2
1090 IF (DELR1) 1100,1100,1110
1100 DLHDP=-DLHDP
1110 RPP=RPT-DLHDP
RAT=RAT-DLHDP
EP=(RPP=RAP)/(RPP+RPP)
AP=(RAP=RPP)/TWO
GAMMP=ARTAN(EP*STTAPP,ONE+EP+CTTAPP,-1)
CALL VCROSS (TEMP1,XDP,XP)
CALL VCROSS (TEMP2,XP,TEMP1)
CALL VUNIT (TEMP3,TEMP2)
CALL VUNIT (TEMP1,XP)
DO 1120 I=1,3
1120 TEMP2(I)=VP*COS(GAMMP)*TEMP3(I)*VP*SIN(GAMMP)*TEMP1(I)
DO 1130 I=1,3
1130 TEMP1(I)=TEMP2(I)-XDP(I)
V63=VMAG(TEMP1)
1140 IF (ISOLAS-1) 1160,1150,1150
1150 PRINT 2030
PRINT 2000
PRINT 2330
CALL PRINT (T18,XP,XDP,AZ,PHI,TULO)
CALL VCROSS (AM,XP,TEMP2)
CALL ECV (GH,XP,TEMP2,EV)
PRINT 2010, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2),
TEMP1(3)
1160 CONTINUE
1170 XDP(I) = TEMP2(I)
      ICOR = ICOR + 1
      T = T18
      PRINT 2040
      PRINT 2320
      CALL PRINT (T18, XT, XDT, AZ, PHI, TUL0)
      PRINT 2330
      CALL PRINT (T18, XP, XDP, AZ, PHI, TUL0)
      CALL RKG (PHIO, AZO, XT, XDT, T, TUTP)
      CALL RKG (PHIO, AZO, XP, XDP, T, TUTP)
      PRINT 2050
      PRINT 2320
      CALL PRINT (TUTP, XT, XDT, AZ, PHI, TUL0)
      PRINT 2330
      CALL PRINT (TUTP, XP, XDP, AZ, PHI, TUL0)
      IF (T18 - TUTP + SFNO3 * TAUP4 - 1000.0 > 1200, 1200, 1180
1180 SFNO3 = SFNO3 - .5
      DO 1190 I = 1, 3
      XT(I) = XTS1(I)
      XDT(I) = XDT1S1(I)
      XP(I) = XPS1(I)
      XDP(I) = XDP1S1(I)
      PRINT 1950
      TUL0 = TULOS
      DT = DTS
      GO TO 440
1200 CALL VCROSS (TEMP1, XP, XDP)
      CALL VCROSS (TEMP2, XT, XDT)
      CALL VCROSS (TEMP3, TEMP1, TEMP2)
      WATP = ARCSOS (VDOT (TEMP1, TEMP2) / VMAO (TEMP1) * VMAO (TEMP2))
      CALL RANGA (XP, XDP, XOMEGA, PH1P)
      CALL RANGA (XT, XDT, XOMEGA, PHI1)
      CALL VCROSS (TEMP1, XT, TEMP5)
      CALL VCROSS (TEMP2, TEMP5, TEMP1)
      SINPNT = VDOT (TEMP2, XT) / VMAO (TEMP2) * VMAO (XT)
      COSPNT = VDOT (TEMP5, XT) / VMAO (TEMP5) * VMAO (XT)
      PHINT = ARCSOS (SINPNT, COSPNT, 1)
      CALL VCROSS (TEMP1, XP, TEMP5)
      CALL VCROSS (TEMP3, TEMP2, TEMP5)
      SINP = VDOT (TEMP2, XP) / VMAO (TEMP2) * VMAO (XP)
      COSP = VDOT (TEMP5, XP) / VMAO (TEMP5) * VMAO (XP)
      PHINP = ARCSOS (SINP, COSP, 1)
      TEMP1(1) = COS (PH1)
      TEMP1(2) = SIN (PH1) * SIN (AZ)
      TEMP1(3) = - SIN (PH1) * COS (AZ)
      CALL VCROSS (TEMP2, XT, XDT)
      CALL VCROSS (TEMP3, TEMP2, XOMEGA)
      THINT = ARCSOS (VDOT (TEMP1, TEMP3) / VMAO (TEMP1) * VMAO (TEMP3))
CALL VCROSS (TEMP2, XP, XDP)
CALL VCROSS (TEMP3, TEMP2, XOMEGA)
THNP=ARCS(CDOT(TEMP1, TEMP3)/VMAG(TEMP1)*VMAG(TEMP3))
DTHE=THINT-THNP
DTHEO=DTHE*CNV
PRINT 2060, DTHEO
IF (WATP-WATOL) 1210, 1210
IF (PHINT-PI) 1220, 1220, 1270
IF (PHINP-PI) 1240, 1240, 1230
DELPH=PHINT-PHIP
GO TO 1420
DELPH=PHINT-PHIP
IF (ABS(DELPH)-PI) 1260, 1260, 1250
PHINP=PHINP-PHIP
DELPH=PHINT-PHIP
GO TO 1420
DELPH=PHINT-PHIP
GO TO 1420
IF (PHINT-PI) 1290, 1290, 1280
DELPH=PHINT-PHIP
GO TO 1420
DELPH=PHINT-PHIP
IF (ABS(DELPH)-PI) 1300, 1300, 1310
DELPH=PHINT-PHIP
GO TO 1420
PHINT=PHINT+PI2
DELPH=PHINT-PHIP
GO TO 1420
IF (PHIT-PI) 1330, 1330, 1370
DELPH=PHIT-PHIP
IF (PHIP-PI) 1340, 1340, 1340
IF (ABS(DELPH)-PI) 1350, 1360, 1360
DELPH=PHIT-PHIP
GO TO 1420
DELPH=PHIT-PHIP
GO TO 1420
IF (PHIT-PI) 1380, 1380, 1410
DELPH=PHIT-PHIP
IF (ABS(DELPH)-PI) 1390, 1400, 1400
DELPH=PHIT-PHIP
GO TO 1420
PHIP=PHIP+PI2
DELPH=PHIT-PHIP
GO TO 1420
DELPH=PHIT-PHIP
DELPH=DELPH*CNV
WATPO=WATP*CNV
PHIPO=PHIP*CNV
PHITO=PHIT*CNV
PROGRAM TARG

PHINTO=PHINT*CNV
PHINPO=PHINP*CNV
PRINT 1970, WATPO,PHIPO,PHITO,PHINTO,PHINPO
PRINT 2070, DELPHO
IF (ILIG-1) 1460,1430,1460
1430 IF (ISOLAS-1) 1460,1440,1460
1440 JLIGHT=1
GO TO 550
1450 BSVPAO=BSVPT*CNV
PRINT 1960, BSVPAO
GO TO 1650
1460 CONTINUE
PRINT 2080, ICOR
IF (ICOR-2) 1470,1530,1460
1470 IF (ABS(DTHE)-.02/CNV) 1530,1480,1480
1480 DLTLO=DTHE/OMEGA
TULO=TULO+DLTLO
T=TSTI
PRINT 1980, DLTLO
TUTP=TUTP+DLTLO
DO 1490 I=1,3
XTR(I)=XTS(I)
XT(I)=XTS(I)
1490 XDT(I)=XDT(I)
DpHEE=DELPH-DPHR
TDLO=TDLO
CALL RKG (PHIO,AZO,XT,XDT,TSTI,TDTLO)
PRINT 2320
CALL PRINT (TDTLO,XT,XDT,AZ,PHI,TULO)
DO 1500 I=1,3
1500 XTR2(I)=XT(I)
DLPLOC=ARCS(VMAG(XTR1,XTR2)/VMAG(XTR1)*VMAG(XTR2))
DLPLOC=(DLTLO/ABS(DLTLO))*DLPLOC
DLTT1=(DLPLOC-(DLPLOC*DPDCU)/DLPD2)-DLTLO*DPDCU)/DLPD2
DLTT2=DPHEE/(DLPD2-DPDCU)
DLTTT2=DLTT1+DLTT2
TTEST2=TTEST2+DLTTT2
1510 CALL RANGA (XT,XDT,XOMEGA,PHITT)
CALL VCROSS (TEMP1,XT,XDT)
CALL VCROSS (TEMP2,TEMP1,XOMEGA)
CALL VUNIT (TEMP4,TEMP1)
DUM1=VDOT(XOMEGA,TEMP4)
DUM=DUM1*DUM1
XINT=ARTAN(SORT(ONE-DUM),DUM1,1)
TEMP1(1)=COS(PHI)
TEMP1(2)=SIN(PHI)*SIN(AZ)
TEMP1(3)=-SIN(PHI)*COS(AZ)
THTNT=ARCOS(VDOT(TEMP1,TEMP2)/(VMAG(TEMP2)))
THTNE=THTNT-DTHE
CALL MAROT (AAA,AZ-P1/2,1,1)
CALL MRO (BBB, PHI, 3, 1)
CALL MMU (CCC, BBB, AAA)
CALL MRO (AAA, THTNE, 2, -1)
CALL MRO (BBB, XINT, 1, -1)
CALL MMU (DDD, BBB, AAA)
CALL MMU (AAA, DDD, CCC)
CALL MRO (BBB, PHITT, 2, -1)
CALL MMU (CCC, BBB, AAA)
CALL FATT (DDD, CCC)
RRTP=VMAG(XT)
VVT=VMAG(XDT)
GAMMA=ARSIN(VDOT(XT, XDT)/(RRTP*VVT))
TEMP1(1)=RRTP
TEMP1(2)=ZERO
TEMP1(3)=ZERO
CALL FAMU (XT, DDD, TEMP1)
TEMP1(1)=VVT*SIN(GAMMA)
TEMP1(2)=ZERO
TEMP1(3)=VVT*COS(GAMMA)
CALL FAMU (XDT, DDD, TEMP1)
T=TST
DO 1520 I=1,3
XDP(I)=XDP(I)
XT(I)=XT(I)
XDT(I)=XDT(I)
1520 XP(I)=XPS(I)
TU=T=TULO
IF (JINS) 1670, 740, 1670
1530 DPHEE=DELPH-DPHR
IF (ABS(DPHEE)=.05/CNV) 1580, 1580, 1540
1540 DTTT2=DPHEE/(DLPD2-DPDCU)
T=TST
DO 1550 I=1,3
XP(I)=XPS(I)
XDP(I)=XDP(I)
XT(I)=XTS(I)
1550 XDT(I)=XDT(I)
TU=TST=TULO
TTST2=TTST2+DTTT2
GO TO 740
1560 DPHEE=DELPH-DPHR
IF (ABS(DPHEE)=.05/CNV) 1570, 1570, 1540
1570 IF (ABS(DTUE)>.02/CNV) 1580, 1610, 1610
1580 PRINT 2090
IF (ISOLAS-1) 1590, 1650, 1650
1590 ISOLAS=1
DTULOT=TULO-TULOS
PRINT 1980, DTULOT
T=TST
DO 1600 I=1,3
```
PROGRAM TARG

XP(I)=XPS(I)
XDP(I)=XDPS(I)
XT(I)=XTS(I)

1600 XDT(I)=XDT(I)
    GO TO 740

1610 DTL0=DTHE/OMEGA
    DO 1620 I=1,3
        XTR(I)=XTS(I)
        XT(I)=XTS(I)
    1620 XDTS(I)
        TULO=TULO+DLTLO
        T=TST
        PRINT 1980, DLTLO
        DO 1630 I=1,3
            XTR(I)=XTS(I)
            XT(I)=XTS(I)
        1630 XDT(I)=XDT(I)
            TF=TST+DLTLO
            CALL RKG (PHIO, ARO, XT, XDT, TST, TST, TF)
            PRINT 2320
            CALL PRINT (TF, XT, XDT, ARA, TULO)
            DO 1640 I=1,3
        1640 XTR2(I)=XT(I)
            DLPLOC+AROS(VDOT(XTR1, XTR2)/(VMAG(XTR1)*VMAG(XTR2)))
            DLPLOC(DLPLOC/ABS(DLTLO)*DLTLO)
            DLT1=(DLPLOC*(DLPLOC+DPDCU)/DLPD2-DLTLO*DPDCU)/DLPD2
            TTEST2=TTEST2+DLT1
            GO TO 1510

1650 TIMLAU=TULOS+DTULOT
    TIMIN=TULOS+DTULOT+T1
    CALL RKG (PHIO, ARO, XT, XDTLO, TULOS, TIMLAU)
    DO 1660 I=1,3
        XT(I)=XTLO(I)
    1660 XDTS(I)
        JINS=1
        KINS=0
        DTHE=OMEGA+DTULOT
        GO TO 1510

1670 IF (KINS) 1680, 1690, 1680

1680 PRINT 2340
    PUNCH 2350, XT, XDT
    PUNCH 2350, XT, XDT
    PUNCH 2100, XT, XDT
    CALL PRINT (T1, XT, XDT, ARO, TULO, DTULOT)
    GO TO 1710

1690 CALL RKG (PHIO, ARO, XTS1, XDTS1, TULOS+T1, TIMIN)
    KINS=1
```
PROGRAM TARG

PRINT 2370
PRINT 2360, XT, XDT
CALL PRINT (0.0, XT, XDT, AZ, PHI, TIMLAU)
DO 1700 I=1,3
XT(I)=XTS(I)
3700 XDT(I)=XDTS(I)
GO TO 1510
1710 PRINT 2380, TIMLAU

3720 FORMAT (1E16,8//)
3730 FORMAT (32H CIRCULARIZE W/O C D H EQUATIONS//)
3740 FORMAT (1E16,8//)
3750 FORMAT (212)
3760 FORMAT (5E15.8/2E15.8)
3770 FORMAT (17H NORTHERLY LAUNCH//)
3780 FORMAT (17H SOUTHERLY LAUNCH//)
3790 FORMAT (7H TIME15.8,7H ATE15.8,7H ETE15.8,7H XENCTOE15.8/ 18/7H THNTOE15.8,7H ALFATOE15.8,7H PHIIOE15.8,7H)
3800 FORMAT (49H ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT//)
3810 FORMAT (35H FIRST GUESS ON THE LAUNCH AZIMUTH=E15.8//)
3820 FORMAT (38H INSTANTANEOUS LATITUDE OF INSERTION=E15.8//)
3830 FORMAT (32H DESIRED LATITUDE FOR INSERTION=E15.8//)
3840 FORMAT (21H THIS IS THE SOLUTION)
3850 FORMAT (52H DESIRED VALUE OF INCLINATION FOR TARGETING PURPOSE=E15.8//)
3860 FORMAT (61H INSERTION CONDITIONS DETERMINED FROM STEADY STATE TRAJEC TORY//)
3870 FORMAT (46H ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION=E15.8//)
3880 FORMAT (40H STATE VARIABLES OF ORBITER AT INSERTION/7H XPE15.8/ 17H YPE15.8,7H ZPE15.8,7H XDPE15.8,7H YDPE15.8,7H)
2 7ZDPE15.8,7H)
3890 FORMAT (59H STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSERTION/7H XTE15.8,7H YTE15.8,7H ZTE15.8,7H XDTE19.8,7H YDTE15.8,7H ZDTE15.8,7H)
3900 FORMAT (39H INTERSECTION ASSUMING CIRCULAR ORBIT=E15.8//)
3910 FORMAT (18H PHASE ANGLE DPA1=E15.8//)
3920 FORMAT (3E16.8//)
3930 FORMAT (35H BEFORE PERIGEE BURN AT TIME TTEST2//)
3940 FORMAT (35H AFTER PERIGEE BURN AT TIME TTEST2//)
3950 FORMAT (72H1SFG03 HAS BEEN BUMPED BY .5 BECAUSE THE TIME OF TPI OCCURRED BEFORE CDH//)
3960 FORMAT (33H THE SOLAR VECTOR ANGLE ACHIEVED=E15.8//)
3970 FORMAT (7H WATPOE15.8,7H PHIPOE15.8,7H PHITOPE15.8,7H PHINTPOE15.8,7H)
3980 FORMAT (50H THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO=E15.8 1)
3990 FORMAT (62H1TARGETING VALUES FOR THE C0V 100 NM CIRCULARIZATION AT
1 APOGEE//)
2000 FORMAT (29H POSITION VECTOR FOR IGNITION//)
2010 FORMAT (37H TARGETING VALUES FOR DESIRED ELLIPSE/24H ANGULAR MOMEN
PROGRAM TARG

1. TUM VECTOR/7H AM(1)E15.8,7H AM(2)E15.8,7H AM(3)E15.8/20H ECCENT
2. RICITY VECTOR/7H EV(1)E15.8,7H EV(2)E15.8,7H EV(3)E15.8/29H VEL
3. CITY TO BE GAINED VECTOR/7H VG(1)E15.8,7H VG(2)E15.8,7H VG(3)E15.8,7H

2020 FORMAT (42H TARGETING VALUES FOR THE COV PERIGEE BURN//)
2030 FORMAT (46H TARGETING VALUES FOR THE CDH MANUVER FOR COV/)
2040 FORMAT (26H CDH HAS BEEN ACCOMPLISHED:///)
2050 FORMAT (23H UNIVERSAL TIME FOR TPI:///)
2060 FORMAT (6H DTHEO15.8/)
2070 FORMAT (7H DELPHOE15.8/)
2080 FORMAT (32H BEGIN NEXT ISOLATION LOOP ICOR=112)
2090 FORMAT (21H THIS IS THE SOLUTION///)
2100 FORMAT (6E13,8)
2110 FORMAT (42H PARAMETERS FOR 90X100 N.M. PHASING ORBIT//)
2120 FORMAT (7H RRPE15.8,7H VVPE15.8,7H GAMMAPE15.8,7H EPE15.8,7H APE15.8,7H HAPE15.8,7H HPPE15.8,7H PHDOTPE15.8/)
2130 FORMAT (32H PARAMETERS FOR THE TARGET ORBIT//)
2140 FORMAT (7H RRTE15.8,7H VVTE15.8,7H GAMATE15.8,7H ETE15.8,7H ATE15.8,7H HATE15.8,7H HPTE15.8,7H PHDOTTE15.8/)
2150 FORMAT (74H CATCH UP RATE AND ANGLE FOR THE HALF ORBIT OF THE 50X1)
2160 FORMAT (7H RCPE15.8,7H VCPE15.8,7H TAUCPE15.8,7H DDLOE15.8,7H DELV2E15.8,7H T3E15.8/)
2170 FORMAT (7H ORBITAL CATCH UP RATE=15.8/19H ANGLE OF CATCH UPEE15.8,7H TIME AT APOGEE OF 50X100 ORBIT=E15.8,7H)
2180 FORMAT (5H FIRST MANUVER TO CIRCULARIZE 80X100 AT ITS APOGEE//)
2190 FORMAT (6H SECOND BURN TRANSFER OUT OF 100 NM CIRCULAR TOWARDS Ai077)
2200 FORMAT (16H ORBITAL PERIOD=E15.8/19H MEAN ORBITAL RATE=E15.8/15H CATCH UP RATE=E15.8/21H IMPULSE REQUIREMENT=E15.8/18H TIME INTO FLI)
2210 FORMAT (45H COELLIPIC ORBIT PLACING VEHICLE IN CDH ORBIT//)
2220 FORMAT (7H EP3E15.8,7H RPP4E15.8,7H AP4E15.8,7H PH4E15.8,7H TH4E15.8,7H R4E15.8,7H V4E15.8,7H)
2230 FORMAT (50H THE TPI IGNITION ANGLE IN RELATION TO THE TARGET=E15.8,7H)
2240 FORMAT (61H THIS SECTION DETERMINES THE CATCH UP RATE IN THE CDH)
2250 FORMAT (7H IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE 1 ORBIT//)
2260 FORMAT (7H TAUP4E15.8,7H PBPA4E15.8,7H DPDCUE15.8,7H DLMR4E15.8,7H TTP1E15.8,7H)
2270 FORMAT (24H RANGE ANGLE OF PURSUIT=E15.8/23H RANGE ANGLE OF TARGET T=E15.8/)
2280 FORMAT (29H COMPUTATIONS FOR SECTION 4-8//)
2290 FORMAT (7H DPH1OE15.8,7H DPH2OE15.8,7H DT2E15.8,7H TSBSTER)
2300 FORMAT (50H COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10//)
2310 FORMAT (7H AOE15.8,7H B0E15.8,7H COE15.8,7H TYE15.8)
PROGRAM TARG

18/7H LAMDAE15.8,7H PHSVOE15.8,7H ALSVOE15.8,7H BSVPTOE15.8,

2320 FORMAT (23H STATE OF SPACE STATION//)

2330 FORMAT (17H STATE OF ORBITER//)

2340 FORMAT (36H STATE VECTOR OF TARGET AT INSERTION//)

2350 FORMAT (6E13.6)

2360 FORMAT (7H XTE15.8,7H YTE15.8,7H ZTE15.8,7H XDTE15,

18.7H YDTE15.8,7H ZDTE15.8,7H)

2370 FORMAT (35H STATE VECTOR OF TARGET AT LIFT OFF//)

2380 FORMAT (28H THE UPDATED TIME OF LAUNCH=E15.8//)

END
SUBROUTINE RK713 (TO, TF, TOL, XI, X, N, KT, M, BETA, ALPH, CH, TI, AB)

SEVENTH ORDER RUNGE-KUTTA INTEGRATION WITH STEPSIZE CONTROL
TF CAN BE GREATER THAN TI OR LESS THAN TI AND RK713 WILL WORK
M IS THE NUMBER OF STEPS NEEDED
N IS THE NUMBER OF DIFFERENTIAL EQUATIONS
KT IS MAX NUMBER OF ITERATIONS
ARRAY F STORES THE 13 EVALUATIONS OF THE DIFFERENTIAL EQUATIONS
SUBSCRIPTS FOR ALPHA, BETA, AND CH ARE +1 GREATER THAN FEHLBERG'S
F(0) IN FEHLBERG'S REPORT IS IN F(1, J)
F(I) IS IN F(I+1, J)
FEHLBERG'S REPORT REFERENCED IS NASA TR R-287
PARAMETERS FOR DEQ SUBROUTINE MUST BE STORED IN COMMON
DIMENSIONS MUST AGREE WITH NUMBER OF DIFFERENTIAL EQUATIONS AND
NUMBER OF CONSTANTS IN THE PARTICULAR FEHLBERG FORMULA USED
DIMENSION F(13, 6), XDUM(6), TE(6), XI(6), ALPH(13), BETA(13, 12), X
1(6), CH(13), AB(3), ACCO(3)

T=T0
DT=TF-T0
M=0
DO 10 I=1, N
10 X(I)=XI(I)
20 CALL DEQ (X, T, TE, AB, TI)
30 DO 40 I=1, N
30 F(I, I)=TE(I)
40 DO 50 K=2, 13
40 XDUM(I)=X(I)
50 DO 60 J=1, NN
60 F(I, J)=TE(I)
70 CONTINUE
80 XDUM(I)=X(I)
90 DO 100 L=1, 13
100 X(I)=X(I)+DT*CH(L)*F(L, I)
EPS=1.
DO 120 I=1, N
120 IF ALL THE VARIABLES BEING INTEGRATED HAVE MAGNITUDES WHOSE
ABSOLUTE VALUES ARE ALWAYS MUCH LESS THAN 1., THEN A VALUE
OF EPS LESS THAN ONE MAY NEED TO BE USED TO ACHIEVE AN ACCURACY
AS SPECIFIED BY TOL.
IF (ABS(XDUM(I))< EPS) 100, 110, 110
A=EPS
GO TO 120
SUBROUTINE RK713 (TO, TF, TOL, XI, X, N, KT, M, BETA, ALPH, CH, TI, AB)

110 A = XDUM(I)
120 TE(I) = DT *(F(1, I) + F(11, I) - F(12, I) - F(13, I)) * 41 / 840 / A
130 ER = ABS(TE(I))
140 DO 140 I = 2, N
145 IF (ABS(TE(I)) - ER) 140, 140, 130
140 CONTINUE
150 DT1 = DT
160 M = M + 1
170 AK = 8
180 DT = AK * DT1 ** (TOL / ER) ** 1.25
190 IF (ER - TOL) 150, 150, 180
150 T = T + DT1
200 IF (ABS(DT) - ABS(TF - T)) 170, 170, 160
210 DT = TF - T
220 CONTINUE
230 GO TO 240
240 DO 190 I = 1, N
250 X(I) = XDUM(I)
260 IF (M - KT) 210, 220, 220
270 IF (T - TF) 20, 230, 20
280 TF = T
290 RETURN
END
SUBROUTINE RKG (PHIL, AZ, XI, DXI, TI, TF)

DIMENSION X(6), DX(6), ALPH(13), BETA(13,12), CH(13), AB(3), XI(3)

DO 10 I=1,3
   X(I)=XI(I)
10 X(I*3)=DXI(I)

GM=3.9860319E14
RCONV=1.745329252E-01
RPHI=PHIL*RCONV
HAZ=AZ*RCONV
AC3=COS(RPHI)
AB(2)=-AC3*SIN(RAZ)
AB(3)=AC3*COS(RAZ)
DO 30 I=1,13
   DO 20 J=1,12
      BETA(I,J)=0.
      ALPH(I)=0.
30 CH(I)=0.
   CH(6)=34./105.
   CH(7)=9./35.
   CH(8)=CH(7)
   CH(9)=9./280.
   CH(10)=CH(9)
   CH(12)=41./840.
   CH(13)=CH(12)
   ALPH(2)=2./27.
   ALPH(3)=1./9.
   ALPH(4)=1./6.
   ALPH(5)=5./12.
   ALPH(6)=5.
   ALPH(7)=5./6.
   ALPH(8)=1./6.
   ALPH(9)=2./3.
   ALPH(10)=1./3.
   ALPH(11)=1.
   ALPH(13)=1.
   BETA(2,1)=2./27.
   BETA(3,1)=1./36.
   BETA(4,1)=1./24.
   BETA(5,1)=5./12.
   BETA(6,1)=.05
   BETA(7,1)=-25./108.
   BETA(8,1)=31./300.
   BETA(9,1)=2.
   BETA(10,1)=-91./108.
   BETA(11,1)=23./4100.
   BETA(12,1)=3./205.
   BETA(13,1)=-1777./4100.
   BETA(3,2)=1./12.
SURROUTINE RKG (PHI, AZ, XI, DXI, TI, TF)

BETA(4,3) = 1./8.
BETA(5,3) = -25./16.
BETA(5,4) = -BETA(5,3)
BETA(6,4) = .25
BETA(7,4) = 125./108.
BETA(9,4) = -53./6.
BETA(10,4) = 23./108.
BETA(11,4) = -341./164.
BETA(13,4) = BETA(11,4)
BETA(6,5) = .2
BETA(7,5) = -65./27.
BETA(8,5) = 61./225.
BETA(9,5) = 704./45.
BETA(10,5) = 976./135.
BETA(11,5) = 4496./1025.
BETA(13,5) = BETA(11,5)
BETA(7,6) = 125./54.
BETA(8,6) = -2./9.
BETA(9,6) = -107./9.
BETA(10,6) = 311./54.
BETA(11,6) = -301./82.
BETA(12,6) = 6./41.
BETA(13,6) = -249./82.
BETA(8,7) = 13./900.
BETA(9,7) = 67./90.
BETA(10,7) = -19./60.
BETA(11,7) = 2133./4100.
BETA(12,7) = 3./205.
BETA(13,7) = 2193./4100.
BETA(9,8) = 3.
BETA(10,8) = 17./6.
BETA(11,8) = 45./82.
BETA(12,8) = 3./41.
BETA(13,8) = 51./82.
BETA(10,9) = -1./12.
BETA(11,9) = 45./164.
BETA(12,9) = 3./41.
BETA(13,9) = 33./164.
BETA(11,10) = 1H./41.
BETA(12,10) = 6./41.
BETA(13,10) = 12./41.
BETA(13,12) = 1.
CALL N=EQ (X, TI, DX, AB, TI)
TOL = .5E-06
T=TI
CALL RK713 (TO, TF, TOL, X, 6, 2000, M, BETA, ALPH, CH, TI, AB)
CALL N=EQ (X, TF, DX, AB, TI)
UN 40 I = 1, 3
XI(1) = X(1)
40 DXI(I) = X(I+3)
SURROUNTE RKG (PHIL, AZ, XI, DXI, TI, TF)

RETURN
END
SUBROUTINE CONIC (R, V, AZ, PHI, AA, AP, ENC, THTN, TH, E, P, A, ALFAD, RA, RP, C)


W(1) = SIN(PHI)
W(2) = COS(PHI) * SIN(AZ)
W(3) = COS(PHI) * COS(AZ)
CALL VUNIT (RU, R)
CALL VCROSS (H, P, V)
CALL VUNIT (HU, H)
CALL VCROSS (THNV, H, W)
CALL VUNIT (THNU, THNV)
CALL VCROSS (QU, HU, RU)
GM = 3.986031979E14
RM = SQRT(VDOT(R, R))
P = VDOT(H, H)/GM
RD = VDOT(V, RU)
A = GM*RM/(2.0*GM-RM*VDOT(V, V))
TEST = (lo-P/A)
IF (TEST) 20, 20, 10
E = SQRT(TEST)
GO TO 30
20 E = 0.0
30 CONTINUE
COSTH = (P*RM)/(E*RM)
SINTH = (RD/E)*SQRT(P/GM)
DO 40 I = 1, 3
40 XI(I) = RU(I) * COSTH = QU(I) * SINTH
ALFAD = ARTAN(VDOT(XI, PU), VDOT(XI, THNU), 1)
TH = ARTAN(SINTH, COSTH, 1)
CALL VCROSS (CU, HU, THNU)
PHII = ARTAN(VDOT(CU, RU), VDOT(THNU, RU), 1)
T(1) = COS(PHI)
T(2) = SIN(AZ) * SIN(PHI)
T(3) = -COS(AZ) * SIN(PHI)
CALL VCROSS (SU, W, T)
THTN = ARTAN(VDOT(THNU, SU), VDOT(THNUM, T), 1)
CALL VCROSS (R, W, THNU)
ENC = ARTAN(VDOT(HU, B), VDOT(HU, W), 1)
RE = 6378166.0
CNV = 1852.0
C3 = GM/A
RA = A*(1.0+E)
RP = A*(1.0+E)
AA = (RA-RE)/CNV
AP = (RP-RE)/CNV
RETURN
END
SUBROUTINE GMAT (PHI, AZI, THTN, ENC, G, PI)

DIMENSION AA(3,3), B(3,3), C(3,3), D(3,3), TE(3,3), G(3,3)
CALL MAROT (AA, AZI - PI/2, 1, 1)
CALL MAROT (B, PHI, 3, 1)
CALL MAROT (C, THTN, 2, -1)
CALL MAROT (D, ENC, 1, -1)
CALL MAMUL (G, B, AA)
CALL MAMUL (TE, C, G)
CALL MAMUL (G, D, TE)
RETURN
END
SUBROUTINE MAROT (A, ANGLE, K, L)

DIMENSION A(3,3), C(3,3)
SANG = SIN(ANGLE)
CANG = COS(ANGLE)

DO 10 I = 1, 3
DO 10 J = 1, 3
10 A(I,J) = 0

M = (-3*K**2+11*K-4)/2
N = (3*K**2-13*K+16)/2
A(K,K) = 1.0
A(M,M) = CANG
A(N,N) = CANG
A(M,N) = SANG
A(N,M) = SANG

IF (L) 20, 20, 50
20 DO 30 I = 1, 3
DO 30 J = 1, 3
30 C(I,J) = A(J,I)
DO 40 I = 1, 3
DO 40 J = 1, 3
40 A(I,J) = C(I,J)
50 RETURN
END
FUNCTION ARTAN (SANG, CANG, ISW)

This subroutine uses the sine and cosine of the function and places the angle in the proper quadrant.

If ISW = 1, the angle is put between 0 and 2π.
If ISW = -1, the angle is put between -π and +π.

π = 3.14159265

IF (SANG) 1, 7, 10
1 IF (CANG) 2, 3, 4
2 ARTAN = -PI + ATAN(SANG/CANG)
   GO TO 5
3 ARTAN = -PI/2,
   GO TO 5
4 ARTAN = ATAN(SANG/CANG)
5 IF (ISW) 14, 14, 6
6 ARTAN = 2 * PI + ARTAN
   GO TO 14
7 IF (CANG) 8, 9, 9
8 ARTAN = PI
   GO TO 14
9 ARTAN = 0,
   GO TO 14
10 IF (CANG) 11, 12, 13
11 ARTAN = PI + ATAN(SANG/CANG)
   GO TO 14
12 ARTAN = PI/2,
   GO TO 14
13 ARTAN = ATAN(SANG/CANG)
14 RETURN

END

( BLANK CARD )
FUNCTION POLY (C, X, N)

C IS THE COEFFICIENT ARRAY
X IS THE INDEPENDENT VARIABLE
N IS THE DEGREE OF THE POLYNOMIAL
DIMENSION C(1)

POLY = 0.0
K = N + 1

10 POLY = C(K) * POLY * X
K = K - 1
IF (K .GT. 0) 10, 20
20 RETURN
END
SUBROUTINE ECCV(GM, XP, XDP, TEMP1)
DIMENSION XP(3), XDP(3), TEMP1(3), TEMP2(3), TEMP3(3)
CALL VCROSS (TEMP1, XP, XDP)
CALL VUNIT (TEMP2, XP)
CALL VCROSS (TEMP3, TEMP1, XDP)
DO 360 I=1, 3
360 TEMP1(I)=-(TEMP2(I)+TEMP3(I))/GM
RETURN
END

FORTRAN DIAGNOSTIC RESULTS FOR ECCV
SUBROUTINE DEQ(X,T,DX,AB,TA)

DIMENSION X(6), DX(6), AB(3), XDUM(6), ACCO(3)

GM=3.9860319E14
AA=6378166E+07
FJ=1.62345E-03
FH=-5.75E-06
FD=7.875E-06
DO 20 I=1,3

DX(I)=X(I+3)

R2=X(I)*X(I)+X(2)*X(2)+X(3)*X(3)
R=SQRT(R2)
RI=1./R
R21=1./R2
B=AA*AA*R21
BB=AA*RI
A=(AB(I)*X(I)+AB(2)*X(2)+AB(3)*X(3))*RI
A2=A*A
A4=A2*A2
GR=B*(FJ*(1.-5.*A2)+3.*FD*(1./7.-2.*A2+3.*A4)*B+FH*BB*A*(3.-7.*A2)
1)
GP=B*(2.*FJ*A+4.*FD*A*(3./7.+A2)*B+3.*FH*BB*(A2-1./5.))
DO 30 I=1,3

DX(I+3)=-GM*R21*(1.+GR)*X(I)*RI+GP*AB(I))
RETURN
END
SUBROUTINE FATT (BBB, AAA)

DIMENSION BRH(3,3), AAA(3,3)
DO 10 L = 1, 3
DO 10 M = 1, 3
10 BRH(L,M) = 0.
DO 20 J = 1, 3
DO 20 I = 1, 3
20 BBB(J, I) = AAA(I, J)
RETURN
END

E-37
SUBROUTINE FATMU (EEE,AAA,DDD)

DIMENSION EEE(3), AAA(3,3), DDD(3)

DO 10 L=1,3
10 EEE(L)=.0

DO 20 I=1,3
20 EEE(I)=EEE(I)+AAA(I,J)*DDD(J)

RETURN
END
SUBROUTINE PRINT (T, RI, VI, AZ, PH, TULO)

DIMENSION RI(3), VI(3)
TULO=TULO*T

T=*
ICOR=0

10 HR=T/3600.
IHR=HR
XMIN=(T-IHR*3600.)/60.
MIN=XMIN
SEC=T-IHR*3600.-MIN*60.

IF (ICOR=1) 20,30,30

20 PRINT 40, IHR, MIN, SEC
T=TULO
ICOR=1
GO TO 10

30 PRINT 50, IHR, MIN, SEC
CNV=57.295779513
CALL CONIC (RI, VI, AZ, PH, AA, AP, ENC, THN, TH, E, P, A, ALF, RA, RP, C3, PII)
ENC=ENC*CNV
THN=THN*CNV
TH=TH*CNV
ALF=ALF*CNV
PHII=PHII*CNV
PRINT 60, T, RI, VI, AA, AP, RA, RP, P, A, E, C3, ENC, THN, TH, ALF, PHII
RETURN

40 FORMAT (2X,19H TIME FROM LIFT-OFF/5H HRS=,I2,3X,5H MIN=,I2,3X,5H SEC=,E15.8//)

50 FORMAT (2X,15H UNIVERSAL TIME/5H HRS=,I2,3X,5H MIN=,I2,3X,5H SEC=,E15.8//)

60 FORMAT (/3X,4HTIME,E15.8/5X,2H X,E15.8,6X,1HY,E15.8,6X,1HZ,E15.8,5X,1X,2HZD,E15.8,5X,2HYD,E15.8,5X,2HHD,E15.8,5X,2HZD,E15.8,4X,3H AA,E15.8,4X,3H AP,E215.8,4X,3H RA,E15.8,4X,3H RP,E15.8,5X,2H P,E15.8,2X,5H A,E15.8,3/5X,2H E,E15.8,4X,3H C3,E15.8,4X,3H ENC,E15.8,4X,3H THN,E15.8,5X,2H TH4H,E15.8,2X,5HALFAD,E15.8/7H PHII0E15.8//)

END
SUBROUTINE FATML (CCC, BBB, AAA)

DIMENSION CCC(3,3), BBB(3,3), AAA(3,3)

DO 10 L=1,3
DO 10 M=1,3
10 CCC(L, M) = 0.

DO 20 J=1,3
DO 20 I=1,3
DO 20 K=1,3
20 CCC(I, J) = CCC(I, J) + BBB(I, K) * AAA(K, J)

RETURN
END
SUBROUTINE TIME (A, E, THA, THB, GM, PI, TF)

DIMENSION TH(2), SINE(2), COSE(2), ECA(2), XM(2)

TH(1) = THA
TH(2) = THB

DO 10 I = 1, 2
  SINE(I) = SQRT(1 - E**2) * SIN(TH(I)) / (1 + E*COS(TH(I)))
  COSE(I) = (E+COS(TH(I)))/(1 + E*COS(TH(I)))
  ECA(I) = ARTAN(SINE(I), COSE(I))

  XM(I) = ECA(I) - E*SIN(ECA(I))

10 XMTR = XM(2)

ET1 = ECA(1)
ET2 = ECA(2)

T = SQRT(A**3/GM)
TFA = T*XM(1)
TFB = T*XM(2)

IF (TFB - TFA) 20, 30, 30

20 TFB = TFB + 2*PI*T
30 TF = TFB - TFA

RETURN

END
SUBROUTINE HANGA(XT, XDT, OMEGA, PHIT)
DIMENSION TEMP1(3), TEMP2(3), TEMP3(3), OMEGA(3), XT(3), XDT(3)

CALL VCROSS (TEMP1, XT, XDT) A 119
CALL VCROSS (TEMP2, TEMP1, OMEGA) A 120
CALL VCROSS (TEMP3, TEMP1, TEMP2) A 121
RRT=VMAG(XT) A 122
SINPHIT=VDOT(TEMP3, XT)/(VMAG(TEMP3)*RRT) A 123
COSPHT=VDOT(TEMP2, XT)/(VMAG(TEMP2)*RRT) A 124
PHIT=ARTAN(SINPHIT, COSPHT, 1)
RETURN
END

FORTRAN DIAGNOSTIC RESULTS FOR RANGA
3200 FORTRAN (3.0)/RTS

SUBROUTINE TRUE(XP,XDP,TEMP1,PTA)
DIMENSION XP(3),XDP(3),TEMP1(3),TEMP2(3),TEMP3(3)

EP=VMAG(TEMP1)
RMP=VMAG(XP)

CALL VCROSS (TEMP2,XDP,XP)  A 549
CALL VCROSS (TEMP3,TEMP1,TEMP2)  A 550

COSPTA=VDOT(TEMP1,XP)/(EP*RMP)  A 551
SINPTA=VDOT(TEMP3,XP)/(VMAG(TEMP3)*RMP)  A 552

PTA=ARTAN(SINPTA,COSPTA,1)  A 553

RETURN
END

FORTRAN DIAGNOSTIC RESULTS FOR TRUE