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

NORTHROP SERVICES, INC.
P. O. BOX 1484
HUNTSVILLE, ALABAMA 35807
TELEPHONE (205)837-0680
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May 1972
by
Earle L. Bentley

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REVIEWED AND APPROVED BY:

[Signature]
R. E. Bray, Manager
Guidance Theory Branch

[Signature]
W. B. Tucker, Manager
Astro-dynamics and Guidance Theory Section

NORTHROP SERVICES, INC.
HUNTSVILLE, ALABAMA
FOREWORD

This memorandum presents the results of work performed by Northrop Services, Inc. while under contract to the Aero-Astrodynamics Laboratory of the Marshall Space Flight Center (NAS8-21810). This task was conducted in response to the requirements of Appendix E-1, Schedule Order No. 3, Technical Directive No. 1. Technical Coordination was provided by Mr. Wayne Deaton of the Guidance Applications Section (R-AERO-GG).
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>$\Delta T_{L,\phi}$</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 azimuth</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>$\bar{\omega},</td>
<td>\bar{\omega}</td>
</tr>
<tr>
<td>$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

\( \vec{X}_p, \dot{X}_p \)  
State vector position and velocity of orbiter

\( \vec{X}_T, \dot{X}_T \)  
State vector position and velocity of space station

\( T_1 \)  
Time of orbit insertion

\( \beta_{SVPT} \)  
instantaneous angle from the sun's 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>Definition</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, 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 maneuvers 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 (7 100 x 265 n mi)
- Coelliptic impulse (7 260 n mi)

The launch azimuth ($A_2$), inclination ($i$) and node ($\theta_N$) 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 rendezvous 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 establishes 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
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.
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 empirical curve-fit coefficients.
**Section III**

**RENDEZVOUS TARGETING TECHNIQUES**

The procedures for effecting rendezvous includes integration of the space station to the insertion latitude ($\psi$) 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
\[ \phi_{SV} = \pi + \lambda_L - \text{U.T.}|\vec{\omega}| \]

\[ \alpha_{SV} = a \cos(b + c \cdot T_Y) \]

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

\[ x_N = [\phi_L]_3 [A_Z - \frac{[\alpha]}{2}]_1 x_S \]

\[ x_{SV} = [-\alpha_{SV}]_3 [-\phi_{SV}]_2 x_N \]
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 an 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 $\Delta\phi$ 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 ($\Delta T_{L0}$) 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 $\Delta\phi$ 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 ($I_0$) 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 $\Delta \phi_N$. 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 $\Delta T_{L0}$, 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.
Figure 4-1. Inclination Synchronization During Coelliptic Coast-On-Orbit Deck.

Inclination (deg)

Time from Apsidal Rotation (time/sec)

Apsidal Rotation

Space Station

Orbiter

\[ \Delta \phi = \phi_T - \phi_P \]

\[ 3.3^\circ < \Delta \phi < 4.8^\circ \]
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>45°</th>
<th>135°</th>
<th>255°</th>
<th>315°</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABOVE AND RANGE</td>
<td>255°</td>
<td>345°</td>
<td>75°</td>
<td>165°</td>
</tr>
<tr>
<td>ANGLE AHEAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>45°</th>
<th>135°</th>
<th>255°</th>
<th>315°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion</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>Circularization</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>Perigee</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>Constant Delta Height</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>Transfer Phase Initiation</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>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
</tr>
<tr>
<td>Δi (deg)</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>0.29</td>
<td>0.32</td>
<td>0.28</td>
<td>0.24</td>
</tr>
<tr>
<td>ΔΘ_N (deg)</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>-284.7</td>
<td>-226.4</td>
<td>-199.06</td>
<td>-143.6</td>
</tr>
<tr>
<td>ΔΘ_TB (deg)</td>
<td>-0.81</td>
<td>-2.21</td>
<td>-4.43</td>
<td>5.94</td>
</tr>
<tr>
<td>SFN03 (unitless)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>TRUE ANOMALY</td>
<td>45°</td>
<td>135°</td>
<td>225°</td>
<td>315°</td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>ABOVE AND RANGE ANGLE AHEAD</td>
<td>255°</td>
<td>345°</td>
<td>75°</td>
<td>165°</td>
</tr>
<tr>
<td>Insertion</td>
<td>0 hr. 6 m.</td>
<td>11 s.</td>
<td>0 hr. 6 m.</td>
<td>11 s.</td>
</tr>
<tr>
<td>Circularization</td>
<td>0 hr. 50 m.</td>
<td>48 s.</td>
<td>0 hr. 60 m.</td>
<td>4 48 s.</td>
</tr>
<tr>
<td>Perigee</td>
<td>18 hr. 27 m.</td>
<td>36 s.</td>
<td>2 hr. 39 m.</td>
<td>29 s.</td>
</tr>
<tr>
<td>Constant Delta Height</td>
<td>19 hr. 16 m.</td>
<td>59 s.</td>
<td>3 hr. 30 m.</td>
<td>3 s.</td>
</tr>
<tr>
<td>Transfer Phase Initiation</td>
<td>26 hr. 22 m.</td>
<td>50 s.</td>
<td>8 hr. 37 m.</td>
<td>27 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>Δι (deg)</td>
<td>$8.17 \times 10^{-4}$</td>
<td>$2.8 \times 10^{-3}$</td>
<td>$7.9 \times 10^{-3}$</td>
<td>$1.27 \times 10^{-3}$</td>
</tr>
<tr>
<td>Δφ (deg)</td>
<td>-.332</td>
<td>-.256</td>
<td>-.317</td>
<td>-.278</td>
</tr>
<tr>
<td>ΔΘ₂ (deg)</td>
<td>$-1.87 \times 10^{-4}$</td>
<td>$-2.53 \times 10^{-3}$</td>
<td>$-9.3 \times 10^{-3}$</td>
<td>$5.2 \times 10^{-4}$</td>
</tr>
<tr>
<td>ΔT₉₀ (sec)</td>
<td>319.65</td>
<td>190.1</td>
<td>235.9</td>
<td>275.42</td>
</tr>
<tr>
<td>Δφ₉ (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 $\bar{e}$, angular momentum $\bar{h}$ 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>A₀₋₆</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>B₀₋₆</td>
<td>B(7)</td>
<td>(Same as above for southerly launch).</td>
<td>Deg</td>
</tr>
<tr>
<td>C₀₋₆</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>D₀₋₆</td>
<td>D(7)</td>
<td>(Same as above for northerly node).</td>
<td>Deg</td>
</tr>
<tr>
<td>E₀₋₆</td>
<td>E(7)</td>
<td>(Same as above for northerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>F₀₋₆</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>G₀₋₆</td>
<td>G(7)</td>
<td>(Same as above for southerly node)</td>
<td>Deg</td>
</tr>
<tr>
<td>H₀₋₆</td>
<td>H(7)</td>
<td>(Same as above for southerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>Q₀₋₆</td>
<td>Q(7)</td>
<td>Range angle of insertion (northerly).</td>
<td>Deg</td>
</tr>
<tr>
<td>S₀₋₆</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>
<tr>
<td>MATH SYMBOL</td>
<td>FORTRAN ALFA-NUMERIC NAME</td>
<td>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</td>
<td>UNITS</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------</td>
<td>----------------------------------------------------------</td>
<td>-------</td>
</tr>
<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>ENC &lt;sup&gt;1&lt;/sup&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>TNN &lt;sup&gt;1&lt;/sup&gt;</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>XENCS</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 RENDEZVOUS (Concluded)

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_L$</td>
<td>XLMAL</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>SFNO1</td>
<td>SFNO1</td>
<td>Scale factor for the initial orbiter insertion orbit. (Generally $= .5$)</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFNO2</td>
<td>SFNO2</td>
<td>Transfer orbit scale factor for intermediate phasing orbit (SFNO2 $= .5$ for second orbital intersection).</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFNO3</td>
<td>SFNO3</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 $\Delta g = f(\Delta H)$ 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 apogee 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 $A_1, B_1, C_1$ 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 5-2. INPUT LISTING OF DATA

<table>
<thead>
<tr>
<th>CARD</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>
</tr>
<tr>
<td>2</td>
<td>27.785842</td>
<td>.15193435</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16.249967</td>
<td>.069000928</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>106.6733904</td>
<td>-1.2483319</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>113.74390</td>
<td>.81471544</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>361.2315599</td>
<td>.19373362</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>71.972429</td>
<td>1.2579258</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>69.504248</td>
<td>-.842646</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>359.43239</td>
<td>.2231473</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>250.25958</td>
<td>-.43718955</td>
<td></td>
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<td></td>
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<tr>
<td>11</td>
<td>309.06871</td>
<td>.47380784</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1000.0</td>
<td>2000.0</td>
<td>3000.</td>
<td>900.</td>
<td>100.</td>
</tr>
<tr>
<td>13</td>
<td>6878206.0</td>
<td>0.000001</td>
<td>55.0</td>
<td>157.3</td>
<td>150.0</td>
</tr>
<tr>
<td>14</td>
<td>6878206.0</td>
<td>0.000001</td>
<td>55.0</td>
<td>23.9</td>
<td>150.0</td>
</tr>
<tr>
<td>15</td>
<td>28.608</td>
<td>-80.0</td>
<td>110.</td>
<td>23.444</td>
<td>192.4205</td>
</tr>
<tr>
<td>16</td>
<td>0.000074</td>
<td>30.0</td>
<td>10.0</td>
<td>4.0</td>
<td>.5</td>
</tr>
<tr>
<td>17</td>
<td>1.5</td>
<td>0.029</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 trigonometric identity of the cosine of the sum of two angles,

\[ e_S P_p \left( \cos \theta_p \cos \Delta \alpha - \sin \theta_p \sin \Delta \alpha \right) - e_p P_S \cos \theta_p = P_S - P_p \]

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

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

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):

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

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

Letting

$$A = 1$$
$$B = \text{RRP-\text{RAT-RPT}}$$

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

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
NORTHROP SERVICES, INC.

ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT

TIME 2.02093000 CT AT 0.829202000006 ET 1.700000000005 XEVT 0.500000000005 01
THNTO 1.5738E90 02 ALFAO 1.9000000000 02 PHIO 1.3900000000 02

FIRST GUESS TO THE LAUNCH AZIMUTH = 4.09399955 01

THIS IS THE SOLUTION:
INSTANTtes611 LATITUDE OF INSERTION = 3.6139959 01

DESIZED LATITUDE FOR INSERTION = 3.6139959 01

DESIZED VALUE OF INCNATION FOR TARGETING PURPOSE = 5.498229971 01

ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION = 3.6139959 01

STATE VARIABLES OF ORBITER AT INSERTION

AP 6.351490327 02 XP 1.219070555 03 ZP 1.332663905 06
ZXP 1.9551755 03 ZYP 2.9273030 02 ZDP 7.72573693 06

STATE OF SPACE STATION

TIME FROM LIFT-OFF
WAS= 9 4142000000 SEC 3.18836159 01

UNIVERSAL TIME
WAS= 9 4142000000 SEC 3.18836159 01

TIME 2.37163411 03
Y= -6.109699905 06
AA 2.72596049 02
E 5.3306043 01
PHIO 0.5900064 03

THIS IS THE SOLUTION:
STATE VECTORS OF SPACE STATION AT TIME OF ORBITER INSERTION

AT 6.13476053 02 LT 1.76174196 06 ZT 3.15247499 06
XUT= -1.290297123 03 YUT= 3.290297123 02 ZUT= 6.75769940 06
PARAMETERS FOR THE TARGET ORBIT

\[ RRT \times 6.87756324 \times 06 \quad VP \times 7.61364262 \times 06 \quad GANAP \times 2.89517516 \times 06 \quad EP \times 7.10442669 \times 10 \]

\[ \theta = 6.47076600 \times 06 \quad HAP \times 1.00000011 \times 06 \quad HPP \times 4.90999992 \times 01 \quad PHOC \times 6.87566714 \times 02 \]

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

ORBITAL CATCH UP RATE = 9.54155649 E-03

ANGLE OF CATCH UP = 1.40101272 E-01

TIME AT APOGEE OF 50X100 ORBIT = 2.96981135 E-03

FIRST MANEUVER TO CIRCULARIZE 50X100 AT ITS APOGEE:

\[ RUP \times 6.56136667 \times 06 \quad VCP \times 7.92024138 \times 03 \quad \text{TAUCAP} = 5.29175108 \times 03 \quad PDCO \times 6.80350497 \times 02 \]

\[ DLP4 = 1.27294987 \times 03 \quad \text{DELP4} = 1.22379887 \times 03 \quad T4 = 5.53560006 \times 03 \]

SECOND MANEUVER OUT OF 100 NM CIRCULAR TOWARDS COELLPTIC

ORBITAL PERIOD = 2.74601736 E-03

CATCH UP RATE = 2.36135465 E-03

IMPULSE FOR SECOND MANEUVER = 3.67492816 E-01

TIME AFTER FLIGHT = 3.37248776 E-03

\[ DHH4 = 6.443196457 \times 01 \]

COELLPTIC LIMIT PLACEMENT VEHICLE IN 50X100 ORBIT

\[ E4 = 7.34933544 \times 01 \quad GP4 = 6.85625032 \times 06 \quad A4 = 6.48392530 \times 06 \quad AP4 = 6.86527782 \times 06 \]

\[ F4 = 5.90236673 \times 04 \quad \text{TH4} = 1.62508470 \times 03 \quad R4 = 6.96237543 \times 06 \quad V4 = 7.33710346 \times 03 \]

\[ GAN4 = 4.67213064 \times 01 \quad VT4 = 7.61847510 \times 03 \quad \text{GANT4} = 9.24340470 \times 03 \quad \text{DELY4} = 6.70780811 \times 01 \]

THE TPI INCLINATION ANGLE IN RELATION TO THE TARGET = 2.96000000 E-01

THIS SECTION DETERMINES THE CATCH UP RATE IN THE 50X100 ORBIT

IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE FOR THE TOTAL MISSION

\[ \text{TAP4} = 5.45458275 \times 05 \quad \text{TH4} = 1.62508470 \times 03 \quad \text{DPOCO} = 2.89517516 \times 06 \quad \text{DL440} = 3.91219917 \times 00 \]

\[ \text{TPI} = 2.35704741 \times 04 \quad \text{DN40} = 3.66135665 \times 01 \quad \text{DVIT} = 2.11572140 \times 02 \]

C-3
Range Angle of Pursuit: 2.24221587E 02
Range Angle of Target: 8.59509741E 00

Phase Angle Up / Down = 1.4233584E 02
9.0000000000E-01 5.00000000E 01 1.50000000E 00

State of Space Station:

Time from Lift-Off
HRS = 0  MINS = 0  SECS = 1.1836149E 01

Universal Time
HRS = 0  MINS = 0  SECS = 3.1836156E 01

Time 3.1836156E 02
x = 6.1091909E 02  y = 1.76174186E 02  z = 3.15247199E 02  xd = 3.49187794E 03  yd = 3.29287112E 02  zd = 3.79769946E 03

State of Space Station:

Time from Lift-Off
HRS = 11  MINS = 7  SECS = 1.32918492E 01

Universal Time
HRS = 11  MINS = 40  SECS = 3.32918492E 01

Time 4.02332201E 04
x = 5.97918212E 01  y = 3.2867813E 02  z = 3.3459321E 06  xd = 3.71859883E 03  yd = 3.50232201E 02  zd = 3.64589708E 03

Computation for Section 4-A

DPI10 2.26142461E 04  DPI20 1.18443006E 02  DT2 2.56237943E 04  TSST 4.00332201E 04
DT1 1.36372189E 04  DT1 3.71858165E 02  TTEST1 2.76841395E 03  TTEST2 2.86136877E 04

State of Space Station:
TIME FROM LIFT-OFF

HR=11 MIN=24 SEC= 3.24192667E 01

UNIVERSAL TIME

HR=11 MIN=57 SEC= 5.24192667E 01

TIME 4.10724183E 04
x=3.50036764E 06 AA 2.67815336E 02 E 1.02577549E-03
PHIL0 7.37941015E 07
Y0-1.39143907E 05 YD 4.55098656E 03 YD-5.35778389E 02 ZD 6.08630540E 03
R4 0.87423149E 06 RP 6.86170555E 06 P 6.86720152E 06
ENC 5.44679235E 07 TMN 1.55231753E 02 TM 2.37361915E 02 ALFD 1.03578714E 02

COMPUTATION FOR LIGHTING CONDITIONS SECTION 4-19

AO 2.39440000E 01 AO 1.92420000E 02 CD 9.70390400E 01 TY 3.00000000E 02
LANDAO 0.00000000E 01 PHSV0 9.16338477E 01 ALSVD 1.29483511E 01 BSVD 1.10000000E 02

STATE OF SPACE STATION

TIME FROM LIFT-OFF

HR= 0 MIN=46 SEC= 2.98134755E 01

UNIVERSAL TIME

HR= 1 MIN=19 SEC= 4.98134755E 01

TIME 2.78981138E 03
x=4.04065975E 06 AA 2.74426628E 02 E 1.34114858E-03
PHIL0 1.62236007E 02
Y0-3.03268806E 05 YD 6.14938839E 03 YD 2.03655611E 32 ZD 4.50685446E 03
R4 0.84614429E 06 RP 6.86170555E 06 P 6.86720152E 06
ENC 5.49990900E 07 TMN 1.57155695E 02 TM 2.82126231E 01 ALFD 2.10569245E 02

STATE OF ORBITER

TIME FROM LIFT-OFF

HR= 0 MIN=46 SEC= 2.98134755E 01

UNIVERSAL TIME

HR= 1 MIN=19 SEC= 4.98134755E 01

TIME 2.78981138E 03
x=6.35452200E 06 AA 1.02530000E 02 E 4.78126036E 03
PHIL0 3.26552590E 01
Y0-3.20270137E 04 YD 3.04114426E 05 YD 3.23571431E 32 ZD 7.75136349E 03
R4 0.53420000E 00 RP 6.47604229E 06 P 6.91878292E 06
ENC 5.49225199E 07 TMN 1.54868900E 02 TM 1.71219441E 02 ALFD 1.30659820E 02

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STATE OF SPACE STATION

TIME FROM LIFT-OFF
HRS: 0 MIN: 48 SEC: 2.78113475E 01

UNIVERSAL TIME
HRS: 1 MIN: 21 SEC: 4.78113475E 01

TIME 2.00781135E 03  X 4.7405001E 00  Y-7.76728243E 05  ZD 5.50868903E 03
AA 2.7556904E 02  AP 2.64993047E 06  RA 6.86166440E 06
E 1.4064277E-03  C3-9.9447471E 07  ENC 5.90013964E 01
PH10 1.69739246E 02

STATE OF ORBITER

TIME FROM LIFT-OFF
HRS: 0 MIN: 48 SEC: 2.78113475E 01

UNIVERSAL TIME
HRS: 1 MIN: 21 SEC: 4.78113475E 01

TIME 2.00781135E 03  XA-8.9624699E 04  XD 7.25775672E 02
AA 1.0405044E 02  YP 5.09504960E 01  YD-3.12569843E 02
E 7.03643814E-03  C3-6.11565361E 07  TTN 1.38383434E 02
PH10 4.04987772E 01

C-16
TARGETING VALUES FOR THE CSV 100 NM CIRCULARIZATION AT APGEE

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

TIME FROM LIFT-OFF

HRS= 0  MIN=48  SEC= 2.78113475E 01

UNIVERSAL TIME

HRS= 1  MIN=21  SEC= 4.78113475E 01

TIME 2.00781135E 03
X= -8.2519538E 06  Y= -8.9624680E 04  Z= -6.13475675E 05  XD 7.25775972E 02  YD-1.31955043E 02  ZD-7.72473163E 03
AA 1.00482044E 02  AP 5.0954990E 01  RA 6.364258975E 06  RP 6.47252832E 06  RP 6.15606608E 06
E 7.036439144E 03  CS= -1.11505361E 07  ENC 5.40871015E 01  TMN 1.58583434E 02  TMN 1.79880744E 02
PHI0 4.06567772E 01

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR
AM(1) 9.00352803E 08  AM(2)-5.11660017E 10  AM(3) 2.11583172E 09
ECCENTRICITY VECTOR
EV(1) 5.82076605E-11  EV(2) 9.69494702E-13  EV(3) 1.81999406E 12
VELOCITY TO BE GAINED VECTOR
VG(1) 2.6753496E 03  VG(2)-1.10439716E 00  VG(3)-2.73115345E 01

STATE OF ORBITER

TIME FROM LIFT-OFF

HRS= 8  MIN=42  SEC= 5.38091555E 01

UNIVERSAL TIME

HRS= 9  MIN=16  SEC= 1.38091555E 01

TIME 3.13738092E 04
X 5.16299575E 06  Y= -2.78973799E 05  Z= -4.04947595E 06  XD 4.81240413E 03  YD 2.90706934E 02  ZD 6.12486942E 03
AA 1.06350348E 06  AP 1.10816632E 02  RA 6.57908980E 06  RP 6.36487881E 06  RP 6.56998343E 06
E 7.77941894E-04  CS= -6.10763345E 07  ENC 5.50045691E 01  TMN 1.56653152E 02  TMN 3.36645806E 02
PHI0 1.78139160E 02

STATE OF SPACE STATION

TIME FROM LIFT-OFF

HRS= 8  MIN=42  SEC= 5.38091555E 01
TARGETING VALUES FOR THE CON PERIGEE BURN

POSITION VECTOR FOR INITIATION

STATE OF ORBITER

TIME FROM LIFT-OFF

MINS 7  MIN=2  SEC=4.57478296 00

UNIVERSAL TIME

MINS 7  MIN=37  SEC=3.7098792 E 01

TIME 2.9363574 E 24

AA 1.02532416 02  AP 1.05252106 E 02  RA 6.58505603 E 06

E 1.841791137 04  C3=0.669945317 07  ENC 5.49049508E 01

TARGETING VALUES FOR DESIRED ELLIPSE

ANGLAR MOMENTUM VECTOR

AN(1)=3.419476137 0  AN(2)=9.16759978E 10  AN(3)=2.74236786 E 09

ECCENTRICITY VECTOR

EV(1)=4.21873492 E -1  EV(2)=5.28351639E+02  EV(3)=9.03261466 E 01

VELOCITY TO BE ACHIEVED VECTOR

VG(1)=9.52791241 E 01  VG(2)=1.47664803 E 06  VG(3)=3.79273233 E 01

AFTER PERIGEE BURN AT TIME T TEST2

STATE OF ORBITER

TIME FROM LIFT-OFF

MINS 7  MIN=2  SEC=4.57478296 00

UNIVERSAL TIME

MINS 7  MIN=37  SEC=3.7098792 E 01

TIME 2.9363574 E 24

AA 2.65891584 E 02  AP 1.510241317 02  RA 6.8740344 E 06

E 2.41754517 12  C3=5.93084238 E 07  ENC 5.49049508E 01

STATE OF SPACE STATION

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NORTHROP SERVICES, INC.

STATE OF ORIGIN:

TIME FROM LIFT-OFF
HRS= 7 MIN=59 SEC = 3.00361934E 01

UNIVERSAL TIME
HRS= 8 MIN=29 SEC = 4.70289707E-01

TIME 2.87703427 04
X= 4.96237707 06 Y = 2.97274572 06 Z = 4.69956633 06
A = 2.459263 06 B = 1.06677036 06 C = 5.92859466 07
E = 2.199773 06 ENC = 5.50027232 01
PHI2 = 3.524073 02

TARGETING VALUES FOR THE CM MANUVER FOR COS
POSITION VECTOR FOR IGNITION

STATE OF ORIGIN

TIME FROM LIFT-OFF
HRS= 7 MIN=59 SEC = 3.00361934E 01

UNIVERSAL TIME
HRS= 8 MIN=29 SEC = 4.70289707E-01

TIME 2.87703427 04
X= 4.96237707 06 Y = 2.97274572 06 Z = 4.69956633 06
A = 2.459263 06 B = 1.06677036 06 C = 5.92859466 07
E = 2.199773 06 ENC = 5.50027232 01
PHI2 = 3.524073 02

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR:
AM(1) = 4.4246220 E 06 AM(2) = 5.22190226E 10 AM(3) = 2.0332034E 09

ECCENTRICITY VECTOR:
EV(1) = 2.6999258 E -14 EV(2) = 4.5003252E06 EV(3) = 1.24450788E 04

VELOCITY TO CELESTIAL VECTOR:
VG(1) = 4.73669573 02 VG(2) = 5.15999379E02 VG(3) = 1.015990E 01
COM HAS BEEN ACCOMPLISHED

STATE OF SPACE STATION

TIME FROM LIFTOFF

UNIVERSAL TIME

MARS 7 MIN:29 SEC 3.00361934E 01

MARS 9 MIN:29 SEC 4.70289707E-01

TIME 2.9773432E 04
x 5.7957667E -6
z 2.77366164E 05
2 4.2603594E 06
xd 4.72355605E 03
yd 2.03601474E 02
zd 5.94589195E 03
AA 2.71256337E 02
AP 2.39735740E 02
RA 6.5812777E 06
RP 6.87904986E 06
THN 1.56615196E 02
THN 2.95543631E 02
ALFA 2.98717440E 02

STATE OF OBLITER

TIME FROM LIFTOFF

UNIVERSAL TIME

MARS 7 MIN:59 SEC 3.00361934E 01

MARS 8 MIN:29 SEC 4.70289707E-01

TIME 2.9774632E 04
x 4.9962177E 06
z 2.9727452E 06
2 4.9999633E 06
xd 5.23415085E 03
yd 2.56292183E 02
zd 5.3392934E 03
AA 2.61747127E 02
AP 2.3972357E 02
RA 6.56052127E 06
RP 6.56052127E 06
THN 1.56629234E 02
THN 2.91561118E 32
ALFA 2.98720386E 02
TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME

STATE VECTOR OF TARGET AT INSERTION

THE UPDATED TIME OF LAUNCH 1.77043419E 03

TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME

THE UPDATED TIME OF LAUNCH 1.77043419E 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>
<tr>
<td>GMAT</td>
<td>Matrix transformation from space fixed inertial launch coordinate system ($\vec{X}_G$) to the in-plane $\vec{X}'''$ system $\vec{X}''' = [-i]_1 [-\theta_N]_2 [\phi_L]_3 \left[ A_Z - \frac{\pi}{2} \right]_1 \vec{X}_S$</td>
</tr>
<tr>
<td>MAROT</td>
<td>Sets up elements of transformation matrix for an angle of rotation about the X, Y, and Z axis</td>
</tr>
<tr>
<td>ARTAN</td>
<td>Arctangent from 0 to $2\pi$ or $-\pi$ to $\pi$ according to flag</td>
</tr>
<tr>
<td>POLY</td>
<td>Evaluates an $n$th order polynomial given its coefficients</td>
</tr>
<tr>
<td>ECCV</td>
<td>Computes eccentricity vector $\vec{e}$ $\vec{e} = \frac{\vec{v} \times \vec{r}}{\mu} - \frac{\vec{r}}{</td>
</tr>
<tr>
<td>DEG</td>
<td>Earth's gravitational potential function. Evaluates the acceleration due to gravity for all three components</td>
</tr>
<tr>
<td>FATT</td>
<td>Matrix transpose ($3 \times 3$)</td>
</tr>
<tr>
<td>FATMU</td>
<td>Matrix multiplication ($3 \times 3$ times $1 \times 3$)</td>
</tr>
<tr>
<td>PRINT</td>
<td>Calculates the U.T. in hours, min., sec, adds the U.T. to the mission Time &quot;T&quot;, 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)</td>
</tr>
<tr>
<td>FATMUL</td>
<td>Matrix multiplication ($3 \times 3$ times $3 \times 3$)</td>
</tr>
<tr>
<td>TIME</td>
<td>Determines Keplerian time of flight between two positions on an elliptical orbit</td>
</tr>
<tr>
<td>RANGA</td>
<td>Computes range to and from descending node w.r.t. equator to the instantaneous radius vector</td>
</tr>
<tr>
<td>TRUE</td>
<td>Computes true anomaly from perigee to the instantaneous radius vector</td>
</tr>
</tbody>
</table>
D.2 FLOWCHART

EPHEMERIS DATA OF SPACE STATION

\[ T_N, a_N, e_N, i_N, \theta_N, \alpha_{PLN}, \phi_N \]
\[ T_S, a_S, e_S, i_S, \theta_S, \alpha_{PLS}, \phi_S \]

JPASS = 0, \quad KPASS = 0

\[ T_N - T_S < 0 \]

\[ T_N - T \geq TTOL \]

\[ T_S - T \geq TTOL \]

\[ TULO = T_N, \quad NORTH = 1 \]
\[ TULO = T_S, \quad NORTH = 0 \]
\[ TULO = T_N, \quad NORTH = 1 \]

JPASS = 0

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

\[ \theta_N < 90 \]

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

FROM PG. D-7

TO PG. D-3

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

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

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

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

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

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

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

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

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

\[ \gamma_0 = \tan^{-1} \left( \frac{e \sin \phi}{1+e \cos \phi} \right) \]
\[
\begin{bmatrix}
X_T \\
Y_T \\
Z_T
\end{bmatrix} = [K]^{-1}
\begin{bmatrix}
R_0 \\
0 \\
0
\end{bmatrix} ;
\begin{bmatrix}
\dot{X}_T \\
\dot{Y}_T \\
\dot{Z}_T
\end{bmatrix} = [K]^{-1}
\begin{bmatrix}
V_0 \sin \gamma_0 \\
0 \\
V_0 \cos \gamma_0
\end{bmatrix}
\]

\[\Delta T = 100.0, \text{MPASSI}=0\]

\[J_{\text{PASS}} = 0 \quad \text{NO} \quad \text{YES} \quad \text{TO PAGE D-7}\]

\[K_{\text{PASS}} = 0 \quad \text{NO} \quad \text{YES} \quad \text{TO PAGE D-7}\]

\[\text{DNT} = \text{AMT} \times \text{ERA} = \cos \theta - [\text{ERA}] / \text{DNT} \]

\[\text{INT} = \tan^{-1} \left\{ \frac{1. - (\hat{\omega} \cdot \hat{A}_M)^2}{(\hat{\omega} \cdot \hat{A}_M)} \right\}^{1/2} \]

\[A_T = |\vec{x}_T| \mu / (2 \mu - |\vec{x}_T|^2 / |\vec{x}_T|)\]
\[ \psi_{DN} = \sum_{M=0}^{6} B_M I_{NT}^M \]
\[ A = (1 - \cos^2 I_{NT}/\cos^2 \psi_{DS})^{1/2} \]
\[ \phi_{LS} = \tan^{-1} \left( \frac{\tan \psi_{DS}}{A} \right) \]
\[ \phi_{LS} = \pi + \phi_{LS} \]
\[ \Delta \phi_{R} = \phi_{LS} - \phi_{T} \]

\[ \psi_{DS} = \sum_{M=0}^{6} B_M I_{NT}^M \]
\[ A = (1 - \cos^2 I_{NT}/\cos^2 \psi_{DS})^{1/2} \]
\[ \phi_{LS} = \tan^{-1} \left( \frac{\tan \psi_{DS}}{A} \right) \]
\[ \phi_{LS} = 2\pi - \phi_{LS} \]
\[ \Delta \phi_{R} = \phi_{LS} - \phi_{T} \]
FROM PAGE D-5

ISURF = 1

STEADY STATE TRAJ. COMP.

TO PAGE D-7

3-5

INSERTION CONDITIONS FOR NORTHERNLY LAUNCH

YES

NORTH = 1

NO

INSERTION CONDITIONS SOUTHERNLY FOR LAUNCH

\[ A_{ZN} = \sum_{N=0}^{6} C_N I_N^N \]
\[ \theta_{NNP} = \sum_{N=0}^{6} D_N I_N^N \]
\[ T_{1N} = \sum_{N=0}^{6} E_N I_N^N \]
\[ \phi_{PN} = \sum_{N=0}^{6} Q_N I_N^N \]
\[ \alpha_{PL} = 0.0 \]

\[ A_{ZS} = \sum_{N=0}^{6} F_N I_N^N \]
\[ \theta_{NSP} = \sum_{N=0}^{6} G_N I_N^N \]
\[ T_{1S} = \sum_{N=0}^{6} H_N I_N^N \]
\[ \phi_{PS} = \sum_{N=0}^{6} S_N I_N^N \]
\[ \alpha_{PL} = 0.0 \]

YES

NORTH = 1

NO

\[ \phi = \frac{\phi_{PN}}{CNV} \]
\[ \theta_N = \frac{\theta_{NNP}}{CNV} \]
\[ A_Z = \frac{A_{ZN}}{CNV} \]
\[ T_1 = T_{1N}, i = I_D \]
\[ AZO = A_Z \]

\[ \phi = \frac{\phi_{PS}}{CNV} \]
\[ \theta_N = \frac{\theta_{PS}}{CNV} \]
\[ A_Z = \frac{A_{ZS}}{CNV} \]
\[ T_1 = T_{1S}, i = I_D \]
\[ AZO = A_Z \]

3-2

TO PAGE D-7

D-6
KPASS = 1, JPASS = 1
R_o = HPER * CF + R_o
R_a = HAP * CF + R_a
\( e = \frac{R_a - R_o}{R_a + R_o} \)
\( V_o = \frac{\sqrt{\mu(1 + e)}}{R_o} \)
a = \frac{(R_a - R_o)}{2}
\( \gamma_o = 0.0 \)
\[ \tau_{p4} = 2\pi \left( \frac{A_{p4}}{\mu} \right)^{1/2}, \quad \delta_{AP4} = \left( \frac{A_{p4}}{A_3} \right)^{1/2}, \quad \Delta \phi_R = SLM \cdot \Delta H \]
\[ \Delta \phi_{MR4} = \Delta \phi_{CU}(\tau_{p4})(SFNO3 + X_N) + \Delta \phi_{t}\]
\[ TTPI_{T4} = T_{p4}(SFNO3 + X_N) \]
\[ \Delta \phi_{MRT1} = \Delta \phi_{MR1} + \Delta \phi_{MR2} + \Delta \phi_{MR3} + \Delta \phi_{MR4} \]
\[ \Delta V_{IT} = \Delta V_2 + \Delta V_3 + \Delta V_4 + \Delta V_R \]

**RANGA**

\[ \phi_{T1} \]

**RANGA**

\[ \phi_{T1} \]

\[ \phi_{T1} = \phi_{T1} + 2\pi, \quad \Delta \phi_{A1} = \phi_{T1} - \phi_{p1} \]

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

\[ \Delta \phi_{A1} = \Delta \phi_{A1} - \Delta \phi_{MRT1} \leq 0 \]

\[ \Delta T_{1} = SFNO3 \cdot \tau_{p4} + \tau_{p1}/2 + \tau_{p3}(SFNO2) \]
\[ \Delta \phi_{1} = \Delta \phi_{MR1} + \Delta \phi_{MR3} + \Delta \psi_{CU} \tau_{p4}(SFNO3) \]
\[ \Delta \phi_{2} = \Delta \phi_{A1} - \Delta \phi_{R}, \quad \Delta T_{2} = \Delta \phi_{2}/\Delta \phi_{2} \]
\[ T_{BST} = T_{1} + \Delta T_{1} + \Delta T_{2}, \quad T_{TEST1} = T_{1} + \tau_{p1}/2 - 200 \]
\[ T_{TEST2} = T_{1} + \tau_{p1}/2 + \Delta T_{2} \]

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

JFLAG = 1

NO

TUP = TTSBST

JFLAG = 1

YES

ΔT = (BSVPD - BSVPT)/BSD

NO

BSVP + BSD (ΔT) > BSVPO

YES

JFLAG = 1

NO

SPACE STATION ORBIT INTEGRATION

JLIGHT = YES

PRINT LIGHTING ANGLE

4-21 TO PAGE D-20

4-13 FROM PG. D-17

YES

ILIG = 1

NO

T = TSBST, \( \dot{x}_T, \dot{\dot{x}}_T \)

\( \alpha_{SV} = \pi + \alpha_{DB} - TULO \)

\( \alpha_{SV} = \cos(b + c \cdot T) \)

\( [-\alpha_{SV}]_2 = \begin{bmatrix} \cos \alpha_{SV} & \sin \alpha_{SV} \\ 0 & 1 & 0 \end{bmatrix} \)

\( [-\alpha_{SV}]_3 = \begin{bmatrix} \sin \alpha_{SV} & \cos \alpha_{SV} & 0 \\ 0 & 1 \end{bmatrix} \)

\( [S] = [-\alpha_{SV}] [-\alpha_{SV}] [A] \)

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

JFLAG = 0

3V = SV_1 \hat{i} + SV_2 \hat{j} + SV_3 \hat{k}, x_T = \dot{x}_T + SV_2 \hat{i} + Z \hat{k}, \dot{A}_{MT} = \dot{x}_T \times \dot{x}_T

\( \tilde{p}_V = \tilde{A}_{MT} \times 3V, \tilde{p}_p = \tilde{p}_V \times \tilde{A}_{MT}, \sin(BSVPT) = \tilde{x}_T \times \tilde{3V}/(|\tilde{x}_T||\tilde{3V}|) \)

\( \cos(BSVPT) = \tilde{x}_T \times \tilde{3V}/(|\tilde{x}_T||\tilde{3V}|), \BSD = |\tilde{x}_T \times \tilde{3V}|/(\tilde{x}_T \cdot \tilde{x}_T) \)

BSVP = \tan^{-1} \left( \frac{\sin(BSVPT)}{\cos(BSVPT)} \right)
FROM PG. D-10

\[
\begin{align*}
\dot{x}_T &= \dot{x}_{TS1} \\
\ddot{x}_T &= \ddot{x}_{TS1}
\end{align*}
\]

ORBIT INTEGRATION OF ORBITER AND SPACE STATION FROM \( T_1 \) TO \( T_{TEST1} \)

\[
\begin{align*}
\Delta T &= 1 \\
\text{ECCV} &\rightarrow \tilde{\epsilon}_{EP} \\
\text{TRUE} &\rightarrow \text{PTA} \\
\text{TIME} &\rightarrow \text{TGP2}
\end{align*}
\]

ORBIT INTEGRATION OF ORBITER AND SPACE STATION

\[
R_{AP} = R_{RP} = |\dddot{x}_P|, V_C = (n/R_{AP})^{1/2}, \tilde{N}_{CPP} = \ddot{x}_P \times \dddot{x}_P
\]

\[
\begin{align*}
\tilde{v}_{CP} &= \dddot{x}_P \times \tilde{N}_{CPP}/(|\dddot{x}_P \times \tilde{N}_{CPP}|), \\
\tilde{v}_{CP} &= V_C \tilde{v}_{CP} \\
\tilde{v}_g &= \tilde{v}_{CP} - \dddot{x}_P, v_g &= |\tilde{v}_g|, \dddot{x}_p &= \tilde{v}_{CP}, TSTI = T
\end{align*}
\]

\[
\begin{align*}
\dddot{x}_{PS} &= \dddot{x}_P, \dddot{x}_{TS} &= \dddot{x}_P, \dddot{x}_{TS} &= \dddot{x}_T
\end{align*}
\]

MAJOR ISOLATION LOOP

FROM PAGE D-19

ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO \( T_{TEST2} \)

FROM PG. D-12
\[
A_T = \mu |\ddot{x}_T|/(2\mu - |\dddot{x}_T|^2)|\ddot{x}_T|, \quad R_{ATD} = A_T(1 + E_T) - \Delta H_D
\]
\[
R_{PTD} = A_T(1 - E_T) - \Delta H_D, \quad A_T = (R_{ATD} + R_{PTD})/2
\]
\[
E_T = (R_{ATD} - R_{PTD})/(R_{ATD} + R_{PTD}), \quad P_T =
\]
\[
A_T(1 - E_T^2), \quad \text{COSTTAPA} = \bar{e}_{ET} \cdot (-\bar{e}_{EP})/(E_T E_P)
\]
\[
R_T = P_T/(1 + E_T \text{ COSTTAPA})
\]
\[
\text{DRTEST} = R_{AP} - R_{TD} - 100.0, \quad \text{IPASSI} = 0
\]

\[
\tilde{A}_{MP} = \ddot{x}_P \times \dot{x}_P, \quad \tilde{A}_{MT} = \ddot{x}_T \times \dot{x}_T
\]
\[
\tilde{D}_{NT} = \tilde{A}_{MT} \Omega, \quad \tilde{D}_{NP} = \tilde{A}_{MP} \Omega
\]
\[
\tilde{D}_{NAMP} = \tilde{D}_{NP} \times \tilde{A}_{MP}, \quad \tilde{D}_{NAMT} = \tilde{D}_{NT} \times \tilde{A}_{MT}
\]
\[
\sin \alpha_T = \bar{e}_{ET} \cdot \tilde{D}_{NAMT}/[E_T \tilde{D}_{NAMT}], \quad \cos \alpha_T = \bar{e}_{ET} \cdot \tilde{D}_{NT}/[E_T \tilde{D}_{NT}]
\]
\[
\alpha_T = \tan^{-1}(\sin \alpha_T / \cos \alpha_T)
\]
\[
\sin \alpha_P = \bar{e}_{EP} \cdot \tilde{D}_{NAMP}/[E_P \tilde{D}_{NAMP}], \quad \cos \alpha_P = \bar{e}_{EP} \cdot \tilde{D}_{NP}/[E_P \tilde{D}_{NP}]
\]
\[
\alpha_P = \tan^{-1}(\sin \alpha_P / \cos \alpha_P)
\]
\[
\Delta \alpha = \alpha_T - \alpha_P, \quad D = E_T (PP)
\]
\[
\cos(\Delta \alpha) = P_{TD}(E_P), \quad E = -E_{TD} - (PP)\sin(\Delta \alpha), \quad F = P_{TD} - PP
\]
\[
A = -(E^2 + D^2), \quad B = 2FE, \quad C = D^2 - F^2
\]
\[
\text{RAD} = B^2 - 4AC, \quad \text{STI} = (-B - \sqrt{\text{RAD}})/2A
\]
\[
\text{STII} = (-B + \sqrt{\text{RAD}})/2A
\]
LIFT-OFF TIME CORRECTION

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

\[ C = R_{AT}(R_{PT}) + (|\hat{x}_p|/2)(\text{COSTTAPP}(R_{PT} - R_{AT}) - (R_{AT} + R_{PT})) \]
\[ \Delta H_1 = [-B + (B^2 - 4C)^{1/2}] / 2 \]
\[ \Delta H_2 = [-B - (B^2 - 4C)^{1/2}] / 2 \]
\[ \Delta R = |\Delta R_1|, \text{DRT1} = |\Delta R - \Delta H_1|, \text{DRT2} = |\Delta R - \Delta H_2| \]

\[ \Delta H_D^* = \Delta H_1 \]
\[ \text{DRT1} \leq \text{DRT2} \]
\[ \Delta H_D^* = \Delta H_2 \]

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

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

\[ R_{PP} = R_{PT} - \Delta H_D^* \]
\[ R_{AP} = R_{AT} - \Delta H_D^* \]
\[ E_P = (R_{AP} - R_{PP}) / (R_{AP} + R_{PP}) \]
\[ A_P = (R_{PP} + R_{AP}) / 2, P_P = A_P(1 - E_P^2), V_P = [(u/P_P)(1 + E_P^2 + 2E_P \text{COSTTAPP})]^{1/2} \]
\[ V_P = \tan^{-1}[(E_P \text{SINTTAPP}) / (1 + E_P \text{COSTTAPP})], \hat{N}_{CPP} = \hat{x}_P \times \hat{N}_{CPP} \]
\[ \hat{v}_{pp} = \hat{x}_P \times \hat{N}_{CPP} / (|\hat{x}_P| \times \hat{N}_{CPP}), \hat{x}_p = \hat{x}_P / |\hat{x}_P|, \hat{v}_p = V_P \cos \theta_P \hat{v}_{pp} \]
\[ + V_P \sin \theta_P \hat{x}_p, \hat{g}_3 = \hat{v}_p - \hat{x}_p, \hat{v}_g = |\hat{g}_3| \times \hat{x}_p = \hat{v}_p \]
\[ \text{ICOR} = \text{ICOR} + 1 \]

To PG. D-15

ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TUTP

From PG. D-12

D-14
\[ SFNO3 = SFNO3 + 0.5 \]
\[ x_T = \dot{x}_{TS1} \]
\[ \dot{x}_T = \dot{x}_{TS1} \]
\[ \dot{x}_P = \dot{x}_{PS1} \]
\[ \dot{x}_P = \dot{x}_{PS1} \]
\[ TULO = TULOS \]
\[ DT = DTS \]

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

\[ N_{CXT} = x_T \times N_{TP}, \quad N_{CTCT} = N_{TP} \times N_{CXT} \]
\[ \sin \phi_{NT} = \left[ N_{CTCT} \cdot \hat{x}_T / \{ N_{CTCT} \cdot |x_T| \} \right] \]
\[ \cos \phi_{NT} = \left[ N_{PT} \cdot \hat{x}_T / \{ N_{TP} \cdot |x_T| \} \right] \]
\[ \phi_{NT} = \tan^{-1} (\sin \phi_{NT} / \cos \phi_{NT}) \]
\[ \bar{N}_{CXP} = \bar{x}_P \times \bar{N}_{TP}, \quad \bar{N}_{CPCP} = \bar{N}_{TP} \times \bar{N}_{CXP}, \quad \sin \phi_{NP} = \]
\[ \bar{N}_{CPCP} \cdot \hat{x}_P / \{ \bar{N}_{CPCP} \cdot |\bar{x}_P| \}, \quad \cos \phi_{NP} = \bar{N}_{TP} \cdot \bar{x}_P / \{ N_{TP} \cdot |x_P| \}, \quad \phi_{NP} = \tan^{-1} (\sin \phi_{NP} / \cos \phi_{NP}) \]
\[ \hat{E}_{RA} = \cos \phi_L \hat{i} + \sin \phi_L \sin A_z \hat{j} - \sin \phi_L \cos A_z \hat{k} \]
\[ \theta_{NT} = \cos^{-1} (\hat{E}_{RA} \cdot \bar{\delta}_{NT} / |\bar{\delta}_{NT}|), \quad \theta_{NP} = \cos^{-1} (\hat{E}_{RA} \cdot \bar{\delta}_{NP} / |\bar{\delta}_{NP}|) \]
\[ \Delta \theta_E = \theta_{NT} - \theta_{NP} \]
4-12 FROM PG. D-15

WATP > WATOL

YES

\( \phi_{NT} > \pi \)

NO

\( \phi_{NP} > \pi \)

YES

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

NO

\( |\Delta \phi| < \pi \)

YES

\( \phi_{NP} = \phi_{NP} + 2\pi \)

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

NO

\( |\Delta \phi| < \pi \)

YES

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

NO

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

Philadelphia

D-16

4-13 TO PG. D-17

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

\( \phi_{NP} > \pi \)

YES

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)

\( \phi_{NT} = \phi_{NT} + 2\pi \)

\( \Delta \phi = \phi_{NT} - \phi_{NP} \)
LAST PASS NODE CORRECTION

\[ \Delta T_{LO} = \Delta \phi_e (\Delta \phi / \Delta \phi_e) \]
\[ \bar{\chi}_{TR1} = \bar{\chi}_{TS} \]
\[ T = TSTI, \bar{x}_T = \bar{x}_{TS}, \bar{\chi}_T = \bar{\chi}_{TS} \]
\[ TULOS = TULO + \Delta T_{LO}, \Delta T_{LOT} = \]
\[ TULOS - TULO, TUTP = TUTP - \Delta T_{LO}, TULOS + TULO \]

SPACE STATION ORBIT INTEGRATION (ONLY)

FROM

\[ X_{T} = TSTI \]
\[ T = TSTI + \Delta T_{LO} \]

(\text{IF } \Delta T_{LO} < 0 \text{ INTEGRATE BACKWARDS})

\[ \bar{x}_{TR2} = \bar{x}_T \Theta T = TSTI + \Delta T_{LO} \]
\[ \Delta \phi_{LOC} = \cos^{-1} \left[ \bar{x}_{TR2}/(|\bar{x}_{TR1}| \bar{x}_{TR2}) \right] \]
\[ \Delta T_{TI1} = \Delta \phi_{LOC} - (\Delta \phi_{LOC} \Delta \phi_{CU}/\Delta \phi_e) \]
\[ TTEST2 = TTEST2 + \Delta T_{TI1} \]

\[ \Delta \phi_e = \Delta \phi - \Delta \phi_R \]

4-17 FROM PG. D-18

\[ \text{YES} \]

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

\[ \text{NO} \]

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

\[ \text{YES} \]

4-16 FROM PG. D-18

THIS IS THE SOLUTION

RECYCLE AND PRINT
OUT ISOLATED TIMELINE
AND TARGETING PARAMETERS

ISOLAS = 0

NO

YES

4-21

TO PAGE D-20

ACCUMULATED VALUE*

OF LAUNCH TIME CORRECTION

\[ \bar{x}_T = \bar{x}_{TS}, \bar{x}_T' = \bar{x}_{TS}' \]
\[ \bar{x}_P = \bar{x}_{PS}, \bar{x}_P' = \bar{x}_{PS}' \]
\[ T = TSTI \]
\[ ^\Delta T_{LOT} = TULO - TULOS \]

ISOLAS = ISOLAS + 1

4-15

MAJOR ISOLATION LOOP

TO PG. D-11

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

**SPACE STATION ORBIT INTEGRATION FROM**
**T = TULOS TO T = TULOS + \Delta T_{\text{LO}}**

\[ \Delta \theta_E = \omega \cdot \Delta T_{\text{LO}} \]

**KINS = 0**

**JINS = 1**

---

**FROM PG. D-18**

**KINS = 0**

**YES**

**STOP**

**READ**

**ANOTHER**

**CASE**

**FROM PG. D-19**

**4-21 FROM PAGE D-19**

**4-19 TO PAGE D-18**

**4-19 TO PAGE D-18**

---

**D-20**
\[ \bar{\mathbf{A}}_M = \bar{\mathbf{x}} \times \dot{\bar{\mathbf{x}}} \]
\[ \bar{\mathbf{e}} = -\left( \frac{\dot{\bar{\mathbf{x}}}}{|\bar{\mathbf{x}}|} + \frac{\bar{\mathbf{A}}_M \times \dot{\bar{\mathbf{x}}}}{\mu} \right) \]
TRUE

\[ N_{EC} = \hat{x} \times \bar{x}, \quad \bar{N}_{EC} = \hat{e} \times \bar{N}_{EC} \]
\[ \cos(TA) = \hat{e} \cdot \bar{x}/(|\hat{e}| \bar{x}|) \]
\[ \sin(TA) = \bar{N}_{EC} \cdot \bar{x}/(|\bar{N}_{EC}| \bar{x}|) \]
\[ TA = \tan^{-1}\left[ \frac{\sin(TA)}{\cos(TA)} \right] \]

RETURN

RANGA

\[ \bar{A}_{M} = \bar{x} \times \hat{x}, \quad \bar{D}_N = \bar{A}_{M} \times \hat{\Omega}, \quad \bar{D}_{CH} = \bar{A}_{M} \times \bar{D}_N \]
\[ \sin(\phi) = \bar{D}_{CH} \cdot \bar{x}/(|\bar{D}_{CH}| \bar{x}|) \]
\[ \cos(\phi) = \bar{D}_N \cdot \bar{x}/(|\bar{D}_N| \bar{x}|) \]
\[ \phi = \tan^{-1}(\sin(\phi)/\cos(\phi)) \]

RETURN
Appendix E

PROGRAM LISTING
PROGRAM TARG

DIMENSION XP(3), XDP(3), XT(3), XDT(3), XTR1(3), XTR2(3), TEMP1(3)
DIMENSION TEMP2(3), TEMP3(3), TEMP4(3), TEMP5(3), XOMEGA(3), AAA(3,3), BBB
DIMENSION CCC(3,3), DDD(3,3), XPS(3), XDPS(3), XTS(3), XDTS(3), EV(3)
DIMENSION AM(3), XTS1(3), XDT(3), XDPS1(3), XPS1(3)
DIMENSION XTLO(3), XDTLO(3)

CF=1852,
GH=3900032E15
RE=6370166,
GH2o,7972064E15
OMEGA=72921158E-04
P12o6.2831852
P13.415926
ZERO=0.0
ONE=1,
TWO=2.0
CNV=57.29577951
MATOL=.1/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, XENCN, THNS, ALFAS, PHIS
READ 2100, PHI, XLAMAL, BSVD, A1, B1, C1, TOLE, TY, DLHD, DLHB, SFNO1, SFNO2,
SFNO3, SLH
JINS=0
DT1=8.5, 0
DT2=200,
DT12=20.0
SSFNO3=SFNO3
JLIGHT=0
DT5=DT
PHI=PHI
AZ0=AZ
DELTH=DLHD
DLHD=DLHD*CF
DLHB=DLHB*CF
PHI=PHI/CNV
AZ0=AZ/CNV
XLAMAL=XLAMAL/CNV
BSVD=BSVD/CNV
A1=A1/CNV
B1=B1/CNV
C1=C1/CNV
XENCN=XENCN/CNV
THNN=THNN/CNV

E-2
PROGRAM TARG

ALFAN=ALFAN/CNV
PHIN=PHIN/CNV
XENCN=XENCN/CNV
THNS=THNS/CNV
ALFAS=ALFAS/CNV
PHIS=PHIS/CNV

IF (TN-TS) 20,50,50
20 IF ((TN-T)-TTOL) 40,30,30

30 NORTH=1
TULO=TN
PRINT 1770
GO TO 60

40 NORTH=0
TULO=TS
PRINT 1780
GO TO 60

50 IF ((TS-T)-TTOL) 30,40,40
60 IF (NORTH=1) 80,70,80

70 T=TN
AT=AN
ET=EN
XENCN=XENCN
THNT=THNS
ALFAT=ALFAN
PHII=PHIN
GO TO 90

80 T=TS
AT=AS
ET=ES
XENCN=XENCN
THNT=THNS
ALFAT=ALFAS
PHII=PHIS
GO TO 130

90 IF (JPASS=1) 100,140,140
100 IF (THNT-PI/2) 110,110,120

110 AZL=PI-ARSIN(COS(XENCN)/COS(PHI))
AZO=AZL-CN
AZ=AZL
GO TO 130

120 AZL=ARSIN(COS(XENCN)/COS(PHI))
AZ=AZL
AZO=AZL-CN

130 PRINT 1800
PHII=PHII-CN
ALFAT=ALFAT-CN
XENCN=XENCN-CN
THNS=THNS-CN
PRINT 1790, T, AT, ET, XENCN, THNS, ALFAT, PHII
PRINT 1810, AZO

140 PHII=PHII-ALFAT
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, XENCT, 1, -1)
CALL MAMUL (DDD, BBB, AAA)
CALL MAMUL (AAA, DDD, CCC)
CALL MAROT (BBB, PHIT, 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)
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 (XT, DDD, TEMP2)
DTY3 = 100, 0
MPASS1 = 0

160 IF (JPASS = 1) 170, 370, 170
CALL RANGA (XT, XDT, XOMEGA, PHIT)
CALL VCROSS (TEMP1, XT, XDT)
CALL VCROSS (TEMP2, TEMP1, XOMEGA)
RRT = VMAG( XT)
PSI = ARSIN(VDOT( XT, 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)
DUM2 = VDOT(XOMEGA, TEMP4)
DUM3 = DUM1 * DUM1
XENC = ARCTAN(SQR(ONE - DUM2), DUM1, 1)
AT = RRT * GM / (TWO * GM - VDOT( XDT, XDT) * RRT)
XENC = XENC * CNV
PHITO = PHIT * CNV
THNTO = THNT * CNV
PRINT 1700, PSIO
IF (MPASSI = 1) 180, 300, 180
200 IF (THNT = PI / TWO) 200, 190, 190
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=ARCTAN((SIN(PSID)/COS(PSID)),AA,-1)
PHILS=PI2-PHILS
DPHRR=PHILS-PHIT
GO TO 240

230 NORTHERNLY LAUNCH COEFFICIENTS

230 PSIDO=POLY(A,XENCO,6)
PSID=PSIDO/CNV
DUM=COS(XENC)/COS(PSID)
AA=SQRT(ONE-DUM*DUM)
PHILS=ARCTAN((SIN(PSID)/COS(PSID)),AA,-1)
PHILS=PI2-PHILS
DPHRR=PHILS-PHIT
GO TO 240

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, PSIDO
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 XDP(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
THN=POLY(G,XIDO,6)
T1S=POLY(H,XIDO,6)
PHIPS=POLY(S,XIDO,6)
PHII=PHIPS/CNV
ALFAT=0,0
THNT=THNPS/CNV
AZ=AZS/CNV
T1=T1S

360 XENCT=XIDO/CNV
PRINT 1870, AZO
KPASS=1
JPASS=1
RO=HPER*CF*RE
RA=HPA*CF*RE
ETD=(RA-RO)/(RA+RO)
ATD=(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)
XD(I)=XDT(I)
400 KPASS=0
PRINT 1880, XP,XD
PUNCH 2350, XP,XD
JPASS=1
GO TO 60

420 TF=T+T1
DO 420 I=1,3
XTLO(I)=XT(I)
420 XDTLO(I)=XDT(I)
PRINT 2320
CALL RKG (PHIO,AZO,XT,XDT,T,TF)
CALL PRINT (TF, XT, XDT, AZ, PHI, TULOD)
PRINT 1840
PRINT 1890, XT, XDT

TUL0=TUL0
DO 430 I=1,3
XTS1(I)=XT(I)
XDT1(I)=XDT(I)
XPS1(I)=XP(I)
430 XDPS1(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)
PDPA1=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))
RPP=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=PI2*SQR(T(AP*AP*AP/GM))
T2=T1+TAUP1/TWO
DR1=RAT-RPT
GAMAP0=GAMAP*CNV
HAT=(RAT-RE)/CF
PHDOTP=PDPA1*CNV
HPT=(RPT-RE)/CF
PHDOTT=PDTA1*CNV
HAP=(RAP-RE)/CF
DLPD10=DLPD1*CNV
HPP=(RPP-RE)/CF
GAMATO=GAMAT*CNV
DLMR10=DLMR1*CNV
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
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PROGRAM TARG

RCP = RAP
VCP = SQRT(GM/RCP)
DUM = SQRT(RCP*RCP/RCP/GM)
TAUCP = PI2*DUM
PDOTCP = ONE/DUM
DLPD2 = PDOTCP*PD1A1
DLMR2 = SFNO1*DLPD2*TAUCP
DELV2 = VCP * VAP
T3 = T2 * SFNO1 * TAUCP
PDOTCO = PDOTCP * CNV * DLMR20 = DLMR2 * CNV
PRINT 2170
PRINT 2180, RCP, VCP, TAUCP, PDOTCO, DLPD2, DLMR20, DELV2, T3
IF (ILIG = 1) 450, 460, 450
450 X:\=ZERO
GO TO 470
460 X:\=ONE
470 CONTINUE
RPP3 = RCP
RAP3 = RPT - DLHD * DLHB
AP3 = (RPP3 * RAP3) / TWO
DUM = SQRT(AP3 * AP3 * AP3/GM)
TAUP3 = PI2*DUM
PDPA3 = ONE/DUM
DLPD3 = PDPA3 * PD1A1
DLMR3 = SFNO2 * DLMR3 * TAUP3
T4 = T3 * SFNO2 * TAUP3
VPP3 = SQRT(GM2 * RAP3/(RPP3 * RAP3 * RPP3))
DELV3 = VPP3 * VCP
PRINT 2190
PDPA30 = PDPA3 * CNV * DLMR30 = DLMR3 * CNV
DLMR30 = DLMR3 * CNV
PRINT 2200, TAUP3, PDPA30, DLMR30, DELV3, T4, DLMR30
CONTINUATION AT CDH ALTITUDE
RAP3 = RAT - DLHD * DLHB
AP3 = (RPP3 * RAP3) / TWO
EP3 = (RAP3 * RPP3) / (RAP3 * RPP3)
RPP4 = RPT - DLHD
RAP4 = RAT - DLHD
AP4 = (RPP4 * RAP4) / TWO
EP4 = (RAP4 * RPP4) / (RAP4 * RPP4)
P3 = AP3 * (ONE - EP3 * EP3)
TH4 = ARCCOS((P3 - P4) / (EP3 + P4 * EP4))
R4 = P4 / (ONE + EP4 * COS(TH4))
V4 = SQRT((GM2 * AP3 / R4 - GM) / AP3)
GAMA4 = ARCTAN((R4 * EP3 * SIN(TH4) + P3 - 1)
VT4 = SQRT((GM2 * AP4 / R4 - GM) / AP4)
GAMT4 = ARCTAN((R4 * EP4 * SIN(TH4) + P4 - 1)
DELV4 = SQRT(VT4 * VT4 + V4 * V4 - TWO * VT4 * V4 * COS(GAMT4 - GAMA4))
TH40=TH4*CNV
GAMA40=GAMA4*CNV
GAMT40=GAMT4*CNV
PRINT 2210
PRINT 2230, DPH0
DELVR=0.0
DPMR4=DPDCU*TAUP4*(SFNO3*XN)*DPHR
TTPI=TAUP4*(SFNO3*XN)*DPHR/DPDCU
DPDCU0=DPDCU*CNV
DVIT=DELV2*DELV3*DELV4*DELVR
DLMR40=DLMR4*CNV
DPMRT1=DLMR1+DLMR2+DLMR3+DLMR4
DMPRT0=DPMRT1*CNV
PDPA4=PDPA4*CNV
DPDCU0=DPDCU*CNV
PRINT 2240
PRINT 2250
PRINT 2260, TAUP4, PDPA40, DPDCU0, DLMR40, TTPI, DMRTO, DVIT
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=PHIT10*PI2
GO TO 500
490 DPA1=PHIT1-PHIP1
GO TO 500
500 IF (DPA1-DPMRT1) 510, 520, 520
510 DPA1=DPA1*PI2
GO TO 530
520 DPA1=DPA1
530 D1=SFNO3*TAUP4+TAUP1/THO+TAUP3*SFNO2
DPH1=DLMR1+DLMR3+DPDCU*TAUP4*SFNO3
DPA10=DPA1*CNV
PRINT 1910, DPA10
DPHR2=DPA1-DPH1-DPHR
DT2=DPHR2/DLPD2
TTEST1=T1+TAUP1/THO=200.
PROGRAM TARG

TTEST2=T1+TAUP1/TWO+DT2
TSBST=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, TSBST)
PRINT 2320
CALL PRINT (TSBST, XT, XDT, AZ, PH1, TULO)
PRINT 2280
DPH1O=DPH1*CNV
DPH2O=DPH2*CNV
PRINT 2290, DPH1O, DPH2O, DT2, TSBST, 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=TSBST
550 DUM=PIXLAML-OMEGA*TULO
PHSV=DUM
CALL MAROT (AAA, DUM, 2, 1)
DUM=A1*COS(B1*C1*TY)
ALS=V1
CALL MAROT (BBB, DUM, 3, 1)
CALL MAMUL (CCC, BBB, AAA)
CALL MAROT (AAA, AZ-P1/THO, 1, 1)
CALL MAROT (BBB, PH1, 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

360 CALL VCROSS (TEMP3, XT, XDT)
BSD=VMAG(TEMP3)/VDOT(XT, XT)
CALL VUNIT (TEMP4, TEMP3)
CALL VCROSS (TEMP5, TEMP4, TEMP2)
CALL VUNIT (TEMP5, TEMP5)
CALL VCROSS (TEMP2, TEMP5, TEMP4)
BSVPT=ARCTAN(VDOT(XT, TEMP5), VDOT(XT, TEMP2), 1)
IF (JLIGHT=1) 570, 1450, 570
570 IF ((BSVPT-BSVD)>.0001) 580, 580, 610
580 IF (JFLAG=1) 590, 620, 590
390 CHECK=BSVPT*BSD*DT
IF (CHECK-BSVD) 610, 600, 600
300 JFLAG=1
DT=(BSVD-BSVPT)/BSD
610 \text{T2}=T+DT
\text{CALL RKG (PHIO, AZO, XT, XDT, T, T2)}
T=T2
\text{GO TO 560}

620 \text{PRINT 2320}
\text{CALL PRINT (T2, XT, XDT, AZ, PHI, TUL0)}
\text{PRINT 2300}
PHSVO=PHSV*CNV
ALSVO=ALSV*CNV
BSVPTO=BSVPT*CNV
AO=AI*CNV$BO=81*CNV$C0=C1*CNV
XLAMDO=XLAMAL*CNV
\text{PRINT 2310, AO, BO, CO, TY, XLAMDO, PHSVO, ALSVO, BSVPT0}
\text{TUTP}=T
\text{DT3}=T-TSBST
\text{DPH1}=DPH1+DPDCU+DT3
\text{DPH2}=DPH2+DPH2+DPHR
\text{DT2}=DPH2/DLDP2
\text{TTEST2}=T1+TAUP1+DT2
\text{GO TO 640}

630 \text{TUTP}=TBSBT
640 \text{DO 650 I=1,3}
\text{XT(I)=XTS1(I)}
\text{XDT(I)}=XDTS1(I)
\text{CALL RKG (PHIO, AZO, XT, XDT, T, T1, TTEST1)}
\text{CALL RKG (PHIO, AZO, XP, XDP, T1, TTEST1)}
\text{PRINT 2320}
\text{CALL PRINT (TTEST1, XT, XDT, AZ, PHI, TUL0)}
\text{PRINT 2330}
\text{PRINT 2330}
\text{T=TTEST1}

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

670 \text{DT12}=ONE
\text{IF (TGP2-TWO) 690,690,680}
680 \text{T12}=T+DT12
\text{CALL RKG (PHIO, AZO, XT, XDT, T, T12)}
\text{CALL RKG (PHIO, AZO, XP, XDP, T, T12)}
T=T12
\text{GO TO 660}

690 \text{RAP=VMAG(XP)}
\text{PRINT 2320}
\text{CALL PRINT (T12, XT, XDT, AZ, PHI, TUL0)}
\text{PRINT 2330}
\text{CALL PRINT (T12, XP, XDP, AZ, PHI, TUL0)}

E-11
PROGRAM TARG

TSTI=T
VC=SQRT(GM/RAP)
CALL VCROSS (TEMP1,XDP,XP)
CALL VCROSS (TEMP2,XP,TEMP1)
CALL VUNIT (TEMP2,TEMP2)
DO 700 I=1,3
700 TEMP3(I)=VC*TEMP2(I)
DO 710 I=1,3
710 TEMP1(I)=TEMP3(I)*XDP(I)
    VC=VMAG(TEMP1)
    PRINT 1990
    PRINT 2000
    PRINT 2330
    CALL PRINT (TSTI,XP,XDP,AZ,PHI,TULO)
    CALL VCROSS (AM,XP,TEMP3)
    CALL ECCV (GM,XP,TEMP3,ET)
    PRINT 2100, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2)
    DO 720 I=1,3
720 XP(I)=TEMP3(I)
    DO 730 I=1,3
730 XDTS(I)=XDT(I)
740 CALL RKG (PHIO,AZ,XT,XDT,TSTI,TTEST2)
    CALL RKG (PHIO,AZ,XP,XDP,TSTI,TTEST2)
    CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
    CALL PRINT (TTEST2,XT,XDT,AZ,PHI,TULO)
    CALL PRINT (TTEST2)
    CALL ECCV (GM,XT,XDT,TEMP3)
    RT=VMAG(CT)
    AT=THETA(GM2=VDOT(XDT,XDT)*RTM)
    ET=VMAG(TEMP3)
    RPP=VMAG(XP)
    RATD=AT0(ONE+ET)=DLHD
    RPTD=AT0(ONE+ET)=DLHD
    ETDP=(RATD+RPTD)/(RATD+RPTD)
    DO 750 I=1,3
750 XP(I)=XP(I)
    RPP=VMAG(XP)
    CTTAPA=VDOT(TEMP3,TEMP2)/(ET+RPP)
    RAPOTH=RAP+RPTD/((RATD+RPTD)*(RATD+RPTD)*CTTAPA)+DLHD
    EP=(RAP+RPP)/(RAP+RPP)
    VPP=SQRT((GM/RPP)*(ONE+EP))
    PRINT 2330
    CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
    PRINT 2190
    END
CALL VCROSS (TEMP1, XDP, XP)
CALL VCROSS (TEMP3, XP, TEMP1)
CALL VUNIT (TEMP3, TEMP3)
DO 760 1 = 1, 3
760 TEMP2(I) = TEMP3(I)
      DO 770 1 = 1, 3
770 TEMP1(I) = TEMP2(I) - XDP(I)
      V2 = Vmag(TEMP1)
      IF (ISOLAS = 1) 790, 780, 780
780 PRINT 2020
      PRINT 2000
      PRINT 2330
      CALL PRINT (TTEST2, XP, XDP, AZ, PHI, TULO)
      CALL VCROSS (AM, XP, TEMP2)
      CALL ECCV (GM, XP, TEMP3, EV)
      PRINT 1000, AM(1), AM(2), AM(3), EV(1), EV(2), EV(3), TEMP1(1), TEMP1(2), TEMP1(3)
790 CONTINUE
      DO 800 1 = 1, 3
800 XDP(I) = TEMP2(I)
      PRINT 1940
      PRINT 2330
      CALL PRINT (TTEST2, XP, XDP, AZ, PHI, TULO)
      AP = (RPP * RAP) / TWO
      TAUP2 = PI^2 * SQRT((AP * AP * AP) / GM)
      TTEST3 = T + (TAUP2 * SPFNO2) - 250.
      JPAS = 0
      KPAS = 0
      CALL RKG (PHID, AZO, XT, XDT, TTEST2, TTEST3)
      CALL RKG (PHID, AZO, XP, XDP, TTEST2, TTEST3)
      PRINT 2320
      CALL PRINT (TTEST3, XT, XDT, AZ, PHI, TULO)
      PRINT 2330
      CALL PRINT (TTEST3, XP, XDP, AZ, PHI, 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 / (GM^2 - VDOT(XDP, XDP) * RMT)
      RAP = AP * (ONE + EP)
      DRTEST = RAP * Vmag(XT) * DLHD = 100.
      CALL TRUE (XP, XDP, TEMP1, PTA)
      IF (ET - TOLE) 820, 940, 940
820 IF (DRTEST) 830, 830, 900
830 IF (PTA = PI) 840, 870, 870
840 CALL TIME (AP, EP, PTA, PI, GM, PI, TG3)

E-13
PROGRAM TARG

PRINT 1720, TG3
IF (TG3-10.) 860, 850, 850

850 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=SG3
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=-ARCS((PP-RS)/(EP*RS))*PI2
PRINT 1900
CALL ECCV (GM, XP, XDP, TEMP1)
CALL TRUE (XP, XDP, TEMP1, PTA)
PHTST=PTASI-PTA
IF (PHTST) 870, 910, 910

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

920 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=SG3
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 TEMP2(I)=TEMP1(I)
CYAPA=VDOT(TEMP2, TEMP4)/(ET*EP)
RTD=PTD/(ONE+ETD*CTAPA)
DRTEST=RAP-RTD-100.0
IPASSI=0
IF (DRTEST) 1020,960,960
960 CALL VCROSS (TEMP2,XP,XDP)
CALL VCROSS (TEMP3,TEMP2,XOEGA)
CALL VCROSS (TEMP5,TEMP3,TEMP2)
SNAP=VDOT(TEMP1,TEMP5)/(EP*VMAG(TEMP5))
COSAP=VDOT(TEMP1,TEMP3)/(EP*VMAG(TEMP3))
ALFAP=ARTAN(SNAP,COSAP,1)
CALL VCROSS (TEMP2,XT,XDT)
CALL VCROSS (TEMP3,TEMP2,XOEGA)
CALL VCROSS (TEMP5,TEMP3,TEMP2)
SNAT=VDOT(TEMP4,TEMP5)/(ET*VMAG(TEMP5))
COSAT=VDOT(TEMP4,TEMP3)/(ET*VMAG(TEMP3))
ALFAT=ARTAN(SNAT,COSAT,1)
DELAL=ALFAT-ALFAP
D=ETD*PP*COS(DELAL)-PTD*EP
E=ETD*PP*SIN(DELAL)
F=PTD*PP
A=(E*E+D*D)
B=2*E+F
C=D-D-F+F
RAD=(B+B-4,-A*C)
STI=-(B-SQRT(RAD))/(TWO*A)
STII=-(B+SQR(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,P,T,G3)
IF (TG3=10.) 1000,1000,1010
1000 DT22=TG3
IPASSI=1
1010 T18=T+DT22
CALL RKG (PHIO,ATO,XP,XDP,T,T18)
CALL RKG (PHIO,ATO,XT,XDT,T,T18)
T=T18
IF (IPASSI=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 ECV (GM,XT,XDT,TEMP1)
RTM=VMAG(XT)
AT=RTM*GM/(GH2*VDOT(XDT,XDT)*RTM)
PROGRAM TARG

\[
\begin{align*}
ET &= VMAG(TEMP1) \\
RAT &= AT*(ONE*ET) \\
RPT &= AT*(ONE*ET) \\
\text{CALL VCROSS (TEMP2, XDP, XP)} \\
\text{CALL VCROSS (TEMP3, TEMP1, TEMP2)} \\
CTTAPP &= VDOT(TEMP1, XP)/(RPM*ET) \\
STTAPP &= VDOT(TEMP3, XP)/(VMAG(TEMP3)*RPM) \\
P\gamma &= AT*(ONE*ET*ET) \\
RRT &= PT/(ONE*ET*CTTAPP) \\
DELR1 &= RRT - RPM \\
0 &= RPM - RAT - RPT \\
\text{IF (DELR1) 1050, 1050, 1060} \\
S &= B \\
C &= RAT * RPT * RPM / TWO * (CTTAPP * (RPT = RAT) * (RAT + RPT)) \\
DLH1 &= ABS((-B + SQRT(B*B - 4,*C))/TWO) \\
DLH2 &= ABS((-B - SQRT(B*B - 4,*C))/TWO) \\
DELR &= ABS(DELR1) \\
DRT1 &= ABS(DLR = DLH1) \\
DRT2 &= ABS(DLR = DLH2) \\
\text{IF (DRT1 = DRT2) 1070, 1070, 1080} \\
DLHDP &= DLH1 \\
\text{GO TO 1090} \\
DLHDP &= DLH2 \\
\text{IF (DELR1) 1100, 1100, 1110} \\
DLHDP &= -DLHDP \\
\text{RPP = RPT - DLHDP} \\
RAT &= DLHDP \\
EP &= (RAP = RPP) / (RAP * RPP) \\
\text{AP = (RAP = RPP) / TWO} \\
PP &= AP * (ONE = EP) \\
\text{VP = SORT(GM/PP) * SORT(ONE = EP) * TWO = EP = CTTAPP) } \\
\text{GAMMP = ARTAN(EP * STTAPP, ONE = EP * CTTAPP, -1) } \\
\text{CALL VCROSS (TEMP1, XDP, XP)} \\
\text{CALL VCROSS (TEMP2, XP, TEMP1)} \\
\text{CALL VUNIT (TEMP3, TEMP2)} \\
\text{CALL VUNIT (TEMP1, XP)} \\
\text{DO 1120 I = 1, 3} \\
\text{TEMP2(I) = VP * COS(GAMMP) * TEMP3(I) - VP * SIN(GAMMP) * TEMP1(I)} \\
\text{DO 1130 I = 1, 3} \\
\text{TEMP1(I) = TEMP2(I) - XDP(I)} \\
\text{V63 = VMAG(TEMP1)} \\
\text{IF (ISOLAS = 1) 1160, 1150, 1150} \\
\text{PRINT 2030} \\
\text{PRINT 2000} \\
\text{PRINT 2330} \\
\text{CALL PRINT (T10, XP, XDP, AZ, PRI, TULO)} \\
\text{CALL VUNIT (AM, XP, TEMP2)} \\
\text{CALL ECCV (GH, XP, TEMPP2, EV)} \\
\text{PRINT 2010, AM(1), AM(2), AM(3), EV(1), EV(2), EV(3), TEMP1(1), TEMP1(2), TEMP1(3)} \\
\end{align*}
\]
1160 CONTINUE
1170 XDP(I)=TEMP2(I)
      ICOR=ICOR+1
      T=T18
      PRINT 2040
      PRINT 2320
      CALL PRINT (T18,XT,XDT,AZ,PHI,TULO)
      PRINT 2330
      CALL PRINT (T18,XP,XDP,AZ,PHI,TULO)
      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,TULO)
      PRINT 2330
      IF (T18-TUTP+SSFN03*TAUP4=1000.) 1200,1200,1180
      SFN03=SFN03+.5
      DO 1190 I=1,3
         XT(I)=XTS1(I)
         XDT(I)=XDTS1(I)
         XP(I)=XPS1(I)
      1190 XDP(I)=XDPS1(I)
      PRINT 1950
      TULO=TULOS
      DT=DTS
      GO TO 440
1200 CALL VCROSS (TEMP1,XP,XDP)
      CALL VCROSS (TEMP2,XT,XDT)
      CALL VCROSS (TEMP5,TEMP1,TEMP2)
      WATP=ARCOS (VDOT(TEMP1,TEMP2)/(VMAG(TEMP1)*VMAG(TEMP2)))
      CALL RANGA (XP,XDP,XOMEGA,PHIP)
      CALL RANGA (XT,XDT,XOMEGA,PHIT)
      CALL VCROSS (TEMP1,XT,TEMP5)
      CALL VCROSS (TEMP2,TEMP5,TEMP1)
      SINPNT=VDOT (TEMP2,XT)/(VMAG(TEMP2)*VMAG(XT))
      COSPNT=VDOT (TEMP5,XT)/(VMAG(TEMP5)*VMAG(XT))
      PHINT=ARCTAN (SINPNT,COSPNT,1)
      CALL VCROSS (TEMP1,XP,TEMP5)
      CALL VCROSS (TEMP2,TEMP5,TEMP1)
      SINPNP=VDOT (TEMP2,XP)/(VMAG(TEMP2)*VMAG(XP))
      COSPNP=VDOT (TEMP5,XP)/(VMAG(TEMP5)*VMAG(XP))
      PHINP=ARCTAN (SINPNP,COSPNP,1)
      TEMP1(1)=COS(PHIP)
      TEMP1(2)=SIN(PHIP)*SIN(AZ)
      TEMP1(3)=SIN(PHIP)*COS(AZ)
      CALL VCROSS (TEMP2,XT,XDT)
      CALL VCROSS (TEMP3,TEMP2,XOMEGA)
      THNT=ARCOS (VDOT(TEMP1,TEMP3)/(VMAG(TEMP1)*VMAG(TEMP3)))
CALL VCROSS (TEMP2, XP, XDP)
CALL VCROSS (TEMP3, TEMP2, XOMEGA)
THNP = ARCSIN(VDOT(TEMP3)/VMAG(TEMP1)*VMAG(TEMP3))
DTHET = THIN + THNP
DTHET = DTHET + CNV
PRINT 2060, DTHET
IF (WATP - WATOL) 1320, 1210, 1210
IF (PHINT - PI) 1220, 1220, 1270
IF (PHINP - PI) 1240, 1240, 1230
DELPH = PHINT - PHINP
GO TO 1420
DELPH = PHINT - PHINP
IF (ABS(DELPH) - PI) 1260, 1260, 1250
PHINP = PHINP + PI
DELPH = PHINT - PHINP
GO TO 1420
DELPH = PHINT - PHINP
GO TO 1420
IF (PHINT - PI) 1290, 1290, 1280
DELPH = PHINT - PHINP
GO TO 1420
DELPH = PHINT - PHINP
IF (ABS(DELPH) - PI) 1300, 1300, 1310
DELPH = PHINT - PHINP
GO TO 1420
PHINT = PHINT + PI
DELPH = PHINT - PHINP
GO TO 1420
IF (PHIT - PI) 1330, 1330, 1370
DELPH = PHIT - PHIP
IF (PHIP - PI) 1420, 1420, 1430
IF (ABS(DELPH) - PI) 1350, 1360, 1360
DELPH = PHIT - PHIP
GO TO 1420
PHIT = PHIT + PI
DELPH = PHIT - PHIP
GO TO 1420
IF (PHIP - PI) 1380, 1380, 1410
DELPH = PHIT - PHIP
IF (ABS(DELPH) - PI) 1390, 1400, 1400
DELPH = PHIT - PHIP
GO TO 1420
PHIP = PHIP + PI
DELPH = PHIT - PHIP
GO TO 1420
DELPH = PHIT - PHIP
DELPH = DELPH + CNV
WATP = WATP * CNV
PHIP = PHIP + CNV
PHITO = PHIT + CNV
PRINT 2060, DTHET
E-18
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-l) 1460,1440.1460
1440 JLIGHT=1
GO TO 550
1450 BSVPAD=BSVPT*CNV
PRINT 1960, BSVPAD
GO TO 1650
1460 CONTINUE
PRINT 2080, ICOR
IF (ICOR-2) 1470,1530,160
1470 IF (ABS(DTIIHE)-.02/CNV) 1530,1480,1480
1480 DLTLO=DTIIHE/OMEGA
TULO=TULO+DLTLO
T=TSTI
PRINT 1980, DLTLO
TUTP=TUTP+DLTLO
DO 1490 I=1,3
XTR1(I)=XTS(I)
XT(I)=XTS(I)
1490 XDT(I)=XDS(I)
DPEHE=DELPH-DPHR
TDLLO=T+DLTLO
CALL RKG (PHIO,AZO,XT,XDT,TSTI,TDLLO)
PRINT 2320
CALL PRINT (TDLLO,XT,XT,AZ,PHI,TULO)
DO 1500 I=1,3
1500 XTR2(I)=XT(I)
DLPLOC=ARCS,TVDOT(XTR1,XTR2)/VMAG(XTR1)*VMAG(XTR2))
DLPLOC=(DLTLO/ABS(DLIILO))*DLPLOC
DLTT1=(DLPLOC-(DLPLOC*DPDCU)/DLPD2)-DLTLO*DPDCU)/DLPD2
DLTT2=DPHEE/(DLPD2-2DPDCU)
DLTTT2=DLTT1+DLTT2
TEST2=TEST2+DLTTT2
1510 CALL RANGA (XT,XDT,XOMEGA,PHITT)
CALL VCRROSS (TEMP1,XT,XDT)
CALL VCRROSS (TEMP2,TEMP1,XOMEGA)
CALL VUNIT (TEMP4,TEMP1)
DUM=VDOT(XOMEGA,TEMP4)
DUM=DUM1+DUM1
XINT=ARTAN(SQRT(ONE-DUM),DUM1)
TEMP1(1)=COS(PHI)
TEMP1(2)=SIN(PHI)*SIN(AZ)
TEMP1(3)=SIN(PHI)*COS(AZ)
THIS=THNT+THNT-DTIIHE
CALL MAROT (AAA,AZ-P1/2,1,1)
PROGRAM TARG

CALL MAROT (BBB, PHI, 3, 1)  A 901
CALL MAMUL (CCC, BBB, AAA)  A 902
CALL MAROT (AAA, HTNE, 2, -1)  A 903
CALL MAROT (BBB, XINT, 1, -1)  A 904
CALL MAMUL (DDD, BBB, AAA)  A 905
CALL MAMUL (AAA, DDD, CCC)  A 906
CALL MAROT (BBB, PHIT, 2, -1)  A 907
CALL MAMUL (CCC, BBB, AAA)  A 908
CALL FATT (DDD, CCC)  A 909
RRT=VMAG(XT)  A 910
VVT=VMAG(XDT)  A 911
GAMMA=ARSin(VDOTTXT,XDT/(RRT*VVT))  A 912
TEMP1(1)=RRT  A 913
TEMP1(2)=ZERO  A 914
TEMP1(3)=ZERO  A 915
CALL FATMU (XT, DDD, TEMP1)  A 916
TEMP1(1)=VVT*Sin(GAMMA)  A 917
TEMP1(2)=ZERO  A 918
TEMP1(3)=VVT*COS(GAMMA)  A 919
CALL FATMU (XT, DDD, TEMP1)  A 920
T=TSTI  A 921
DO 1520 I=1, 3
XP(I)=XPS(I)  A 922
XP(I)=XPS(I)  A 923
T=T=TUL0  A 924
IF (ABS(DPHEE)>.05/CNV) 1580, 1580, 1540  A 925
1530 DPHEE=DELPH-DPHR  A 926
1540 DT=DPHEE/(DLPD2-DPDCU)  A 927
1550 XDP(I)=XDP(I)  A 928
1560 XDP(I)=XDP(I)  A 929
1570 X=(XDT(I)-XTS(I))  A 930
1580 X=(XDT(I)-XTS(I))  A 931
1590 X=DTS(I)+XDT(I)  A 932
1600 XP(I)=XP(I)  A 933
1610 XP(I)=XP(I)  A 934
1620 XP(I)=XP(I)  A 935
1630 XP(I)=XP(I)  A 936
1640 XP(I)=XP(I)  A 937
1650 XP(I)=XP(I)  A 938
1660 XP(I)=XP(I)  A 939
1670 XP(I)=XP(I)  A 940
1680 XP(I)=XP(I)  A 941
1690 XP(I)=XP(I)  A 942
1700 XP(I)=XP(I)  A 943
1710 XP(I)=XP(I)  A 944
1720 XP(I)=XP(I)  A 945
1730 XP(I)=XP(I)  A 946
1740 XP(I)=XP(I)  A 947
1750 XP(I)=XP(I)  A 948
1760 XP(I)=XP(I)  A 949
1770 XP(I)=XP(I)  A 950

PROGRAM TARG

XP(I)=XPS(I)
XDP(I)=XDPS(I)
XT(I)=XTS(I)
1600 XDT(I)=XDTS(I)
       GO TO 740
1610 DLTLO=DTH/EOMEGA
       DO 1620 I=1,3
       XTR(I)=XTS(I)
       XT(I)=XTS(I)
1620 XDT(I)=XDTS(I)
       TULO=TULO+DLTLO
       T=TST
       PRINT 1980, DLTLO
       TUTP=TUTP-MLTLO
       Do 1630 I=1,3
       XTR(I)=XTS(I)
       XT(I)=XTS(I)
1630 XDT(I)=XDTS(I)
       TF=TST+DLTLO
       CALL RKG (PHIO,AZO,XT,XT,XTS,TF)
       CALL PRINT (TF,XT,XDT,AZ,PHI,TULO)
       DO 1640 I=1,3
1640 XTR2(I)=XT(I)
       DLPLOC=ARCSV(VDOT(XTR1,XTR2)/VMAG(XTR1)*VMAG(XTR2))
       DLPLOA=(DLTLO/ABS(DLTLO)) * DLPLOC
       DLT1=(DLPLOC-DLPD)/DLPD2
       TTEST2=TTEST1+DLT1
       GO TO 1510

C

C

1650 TIMLAU=TULOS+DTULOT
       TIMIN=TULOS+DTULOT+TI
       CALL RKG (PHIO,AZO,XT,XT,XTLO,TULOS,TIMLAU)
       Do 1660 I=1,3
       XT(I)=XTLO(I)
1660 XDT(I)=XDTL0(I)
       JINS=1
       KINS=0
       DTH=EOMEGA+DTULOT
       GO TO 1510
1670 IF (KINS) 1680,1670,1680
1680 PRINT 320
       PUNCH 2350, XT,XDT
       PUNCH 2350, XT,XDT
       PUNCH 2100, XT,XDT
       CALL PRINT (TI,XT,XDT,AZ,PHI,TULOS,DTULOT)
       GO TO 1710
1690 CALL RKG (PHIO,AZO,XTS1,XDTS1,TULOS,TI,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) = XTS1(I)
1700 XDT(I) = XDT1(I)
GO TO 1510

1710 PRINT 2380, TIMLAU

1720 FORMAT (1E16.8//)
1730 FORMAT (32H CIRCULARIZE W/O C D H EQUATIONS//)
1740 FORMAT (1E16.8//)
1750 FORMAT (212)
1760 FORMAT (5E15.8/2E15.8)//
1770 FORMAT (17H NORTHERLY LAUNCH//)
1780 FORMAT (17H SOUTHERLY LAUNCH//)
1790 FORMAT (17H TIME15.8,7H ATE15.8,7H ET15.8,7H XE15.8,7H XE15.8,7H X15.8,7H)
1870 FORMAT (17H TIME15.8,7H ATE15.8,7H ET15.8,7H XE15.8,7H)
1900 FORMAT (49H ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT/)
1910 FORMAT (35H FIRST GUESS ON THE LAUNCH AZIMUTH=E15.8//)
1920 FORMAT (38H INSTANTANEOUS LATITUDE OF INSERTION=E15.8//)
1930 FORMAT (32H DESIRED LATITUDE FOR INSERTION=E15.8//)
1940 FORMAT (21H THIS IS THE SOLUTION)
1950 FORMAT (52H DESIRED VALUE OF INCLINATION FOR TARGETING PURPOSE=E15.8//)
1960 FORMAT (61H INSERTION CONDITIONS DETERMINED FROM STEADY STATE TRAJ)
1970 FORMAT (46H ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION=E15.8//)
1980 FORMAT (40H STATE VARIABLES OF ORBITER AT INSERTION/7H XPE15.8)
1990 FORMAT (2ZPPE15.8//)
2000 FORMAT (59H STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSER)
2010 FORMAT (7H XTE15.8,7H YTE15.8,7H ZTE15.8,7H XDTE15.8,7H)
2020 FORMAT (17H YDTE15.8,7H ZDTE15.8//)
2030 FORMAT (39H INTERSECTION ASSUMING CIRCULAR ORBIT=E15.8//)
2040 FORMAT (16H PHASE ANGLE DPA1=E15.8//)
2050 FORMAT (3E16.8//)
2060 FORMAT (35H BEFORE PERIGEE BURN AT TIME TTEST2//)
2070 FORMAT (35H AFTER PERIGEE BURN AT TIME TTEST2//)
2080 FORMAT (72HISFN03 HAS BEEN BUMPED BY .5 BECAUSE THE TIME OF TPI OC)
2090 FORMAT (1CURRED BEFORE CDH//)
2100 FORMAT (33H THE SOLAR VECTOR ANGLE ACHIEVED=E15.8//)
2110 FORMAT (7H WATPOE15.8,7H PHIPOE15.8,7H PHITOPOE15.8,7H PHINTPOE15.8//)
2120 FORMAT (187H PHINPE15.8//)
2130 FORMAT (50H THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO=E15.8)
2140 FORMAT (62H1 TARGETING VALUES FOR THE C O V 100 NM CIRCULARIZATION AT)
2150 FORMAT (1APOGEE//)
2160 FORMAT (29H POSITIONS VECTOR FOR IGNITION//)
2170 FORMAT (37H TARGETING VALUES FOR DESIRED ELLIPSE/24H ANGULAR MOMEN
PROGRAM TARG

1) Targeting Values for the COV Perigee Burn

2) Targeting Values for the Target Orbit

3) Catch Up Rate and Angle for the Half Orbit of the 50x100 NM Phasing Orbit

4) Coelliptic Orbit Placing Vehicle in CDH Orbit

5) Computations for Section 4-8

6) Computations for Lighting Conditions Section 4-10

TIDY
PROGRAM TARG

18/7H LAMDAOE15,8,7H PHSVOE15,8,7H ALSVOE15,8,7H BSVPTOE15,8,7H
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.
2370 FORMAT (18,7H YDTE15,8,7H ZDTE15,8,7H//)
2380 FORMAT (35H STATE VECTOR OF TARGET AT LIFT OFF//)
2390 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=TO
DT=TF-TO
M=0
DO 10 I=1, N
  X(I)=XI(I)
10 CALL DEQ (X, T, TE, AB, TI)
DO 30 I=1, N
  F(I, I)=TE(I)
30 DO 70 K=2, 13
    DO 40 I=1, N
      XDUM(I)=X(I)
40 NN:=K-1
    DO 50 I=1, N
      DO 50 J=1, NN
45 XDUM(I)=XDUM(I)+DT*BETA(K, J)*F(J, I)
50 TDUM=T+ALPH(K)*DT
    CALL DEQ (XDUM, TDUM, TE, AB, TI)
55 DO 60 I=1, N
    F(K, I)=TE(I)
60 CONTINUE
DO 80 I=1, N
  XDUM(I)=X(I)
80 DO 90 I=1, N
    DO 90 L=1, I
90 X(I)=X(I)+DT*CH(L)*F(L, I)
EPS=1.
DO 120 I=1, N
  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))-FPS) 100, 110, 110
100 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
   ER = ABS(TE(I))
   DO 140 I = 2, N
   IF (ABS(TE(I)) - ER) 140, 140, 130
   ER = ABS(TE(I))
140 CONTINUE
   DT1 = DT
   M = M + 1
   AK = 8
   DT = AK * DT1 * (TOL / ER)**.125
   IF (ER - TOL) 150, 150, 180
150 T = T + DT1
   IF (ABS(DT) - AHS(TF - T)) 170, 170, 160
160 DT = TF - T
170 CONTINUE
   GO TO 240
190 DO 190 I = 1, N
190 X(I) = XDUM(I)
200 IF (M - KT) 210, 220, 220
210 IF (T - TF) 20, 230, 20
220 TF = T
230 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)
  DX(I) = DXI(I)
10 X(1+3) = DXI(I)

GM = 3.986039E14
RCONV = 1.7539252E-01
RPHIL = PHIL * RCONV
HAZ = AZ * RCONV
AC3 = COS(RPHIL)
AB(1) = SIN(RPHIL)
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(1) = 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) = 23H3./4100.
  BETA(12,1) = 3./205.
  BETA(13,1) = -1777./4100.
  BETA(3,2) = 1./12.
SURROUNTE 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 NEQ (X, TI, DX, AB, TI)
TOL = 5E-06
TI = TI
CALL RK713 (T0, TF, TOL, X, 6, 2000, M, BETA, ALPH, CH, TI, AB)
CALL NEQ (X, TF, DX, AB, TI)
UN 40 I = 1
XI(1) = X(I)
40 DXI(I) = X(I + 3)
SURROUTINE RKG (PHIL, AZ, XI, DXI, TI, TF)
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)
CALL VCROSS (PU, THNU, HU)
GM = 3.986031979E+14
RM = SQRT(VDOT(R, R))
P = VDOT(H, H) / GM
RD = VDOT(V, RU)
A = GM * RM / (2 * GM - RM * VDOT(V, V))
TEST = (LO - P / A)
IF (TEST .LT. 20) GO TO 20
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(THNU, T), 1)
CALL VCROSS (R, W, THNU)
ENC = ARTAN(VDOT(HU, B), VDOT(HU, W), 1)
RE = 6378166.
CNV = 1852.
C3 = - GM / A
RA = A * (1, + E)
RP = A * (1, - 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

E-32
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 2·PI
IF ISW = -1 the angle is put between -PI and +PI

\[ \pi = 3.14159265 \]

IF (SANG) 1, 7, 10
1 IF (CANG) 2, 3, 4
2 ARTAN = -\pi + \text{ATAN}(\text{SANG}/\text{CANG})
   GO TO 5
3 ARTAN = -\pi/2,
   GO TO 5
4 ARTAN = \text{ATAN}(\text{SANG}/\text{CANG})
5 IF (ISW) 14, 14, 6
6 ARTAN = 2·\pi·\text{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 + \text{ATAN}(\text{SANG}/\text{CANG})
   GO TO 14
12 ARTAN = \pi/2,
   GO TO 14
13 ARTAN = \text{ATAN}(\text{SANG}/\text{CANG})
14 RETURN

END
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, TI)

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
  20 DX(I)=X(I+3)

R2=X(1)*X(1)+X(2)*X(2)+X(3)*X(3)
RI=1./R2
R21=1./R2

B=AA*AA*R21
BB=AA*RI
A=(AB(1)*X(1)+AB(2)*X(2)+AB(3)*X(3))*RI

A2=AA
A4=AA*

GR=B*(FJ*(1.-5.*A2)*3.*FD*(1./7,-2.*A2+3.*A4)*B+FH*BB*A*(3.-7.*A2)

GP=B*(2.*FJ*A+4.*FD*A*(3./7,A2)*B+3.*FH*BB*(A2-1./5.))

DO 30 I=1,3
  30 DX(I+3)=-GM*R21*((1.+GR)*X(I)*RI+GP*AB(I))
RETURN
END
SUBROUTINE FATT (BBB, AAA)

DIMENSION BH8(3,3), AAA(3,3)

DO 10 L=1,3
DO 10 M=1,3
10 BH8(L,M) = 0,

DO 20 J=1,3
DO 20 I=1,3
20 BBB(J,1) = AAA(I,J)
RETURN
END
SUBROUTINE FATMU (EEE, AAA, DDD)

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

DO 10 L=1,3

EEE(L)=.K

DO 20 I=1,3

DO 20 J=1,3

EEE(I)=EEE(I)+AAA(I,J)*DDD(J)

RETURN

END

E-38
SUBROUTINE PRINT (T,RI,VI,AZ,PH,TULO)

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

TT=T
ICOR=0

10 HR=TT/3600.
   IHR=HR
   XMIN=(TT-IHR*3600.)/60.
   MIN=XMIN
   SEC=TT-IHR*3600.-MIN*60.
   IF (ICOR-1) 20,30,30

20 PRINT 40, IHR, MIN, SEC
   TT=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,PHII)
   ENC1=ENC*CNV
   THN1=THN*CNV
   TH1=TH*CNV
   ALF1=ALF*CNV
   PHII1=PHII*CNV
   PRINT 60, T,RI,VI,AA,AP,RA,RP,P,A,E,C3,ENC1,THN1,TH1,ALF1,PHII1
   RETURN

40 FORMAT (2X,10H 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,2HXD,E15.8,5X,2HYD,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,2HP,E15.8,2X,5H A,E15.8,3/5X,2HE,E15.8,4X,3H C3,E15.8,4X,3H ENC,E15.8,4X,3HTHN,E15.8,5X,2HT4H,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)

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

THIS SUBROUTINE DETERMINES THE KEPLERIAN TIME OF FLIGHT BETWEEN TWO POSITIONS ON AN ELLIPTICAL ORBIT

DIMENSION TH(2), SINE(2), COSE(2), ECA(2), XM(2)
TH(1)=THA
TH(2)=THB
DO 10 I=1,2
SINE(I)=SORT(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),1)
10 XM(I)=ECA(I)-E*SIN(ECA(I))
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=TF-A-TFA
RETURN
END
SUBROUTINE HANGA(XT, XDT, XOMEGA, PHIT)
DIMENSION TEMP1(3), TEMP2(3), TEMP3(3), XOMEGA(3), XT(3), XDT(3)
CALL VCROSS (TEMP1, XT, XDT)
CALL VCROSS (TEMP2, TEMP1, XOMEGA)
CALL VCROSS (TEMP3, TEMP1, TEMP2)
RRT = VMAG (XT)
SINPHIT = VDOT (TEMP3, XT) / (VMAG (TEMP3) * RRT)
COSPHT = VDOT (TEMP2, XT) / (VMAG (TEMP2) * RRT)
PHIT = ARTAN (SINPHIT, COSPHIT, 1)
RETURN
END
SUBROUTINE TRUE(XP,XDP,TEMP1,PTA)
DIMENSION XP(3),XDP(3),TEMPI(3),TEMP2(3),TEMP3(3)

EP=VMAG(TEMPI)
RMP=VMAG(XP)
CALL VCROSS (TEMP2,XDP,XP)  \ A 549
CALL VCROSS (TEMP3,TEMPI,TEMP2)  \ A 550
COSPTA=VDOT (TEMPI,XP)/(EP*RMP)  \ A 551
SINPTA=VDOT (TEMP3,XP)/(VMAG(TEMP3)*RMP)  \ A 552
PTA=ARCTAN(SINPTA,COSPTA,1)  \ A 553
RETURN
END

FORTRAN DIAGNOSTIC RESULTS FOR TRUE