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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by

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Under Contract NAS8-21810

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NORTHRROP SERVICES, INC.
HUNTSVILLE, ALABAMA
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ABSTRACT

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

Orbiter - chaser or pursuit vehicle
Space Station - any target vehicle, satellite
Shuttle Launch Vehicle - booster plus orbiter configuration
Intermediate Orbit - a phasing orbit for the orbiter on-orbit used to alleviate large phasing differences between vehicles. (= 100 n mi Parking orbit for this analysis)
Constant Delta Height (CDH) - a height differential existing between the orbiter and the space station (an orbit approximately 10 n mi below or above the space station). Same as coelliptic orbit.
Transfer Phase Initiation (TPI) - A point on the CDH orbit when gross rendezvous conditions have been met in order to make the final transfer to the rendezvous point.
On-Orbit - the pursuit vehicle after insertion and before rendezvous during all of its intermediate phasing orbits.
### SYMBOLS

<table>
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<th>Explanation</th>
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<tr>
<td>Δi</td>
<td>Wedge angle between planes at TPI</td>
</tr>
<tr>
<td>Δφ</td>
<td>Range angle difference at TPI after isolation</td>
</tr>
<tr>
<td>Δθ₈</td>
<td>Nodal difference at TPI</td>
</tr>
<tr>
<td>ΔT₅φ</td>
<td>Lift-off time correction to compensate for nodal regression</td>
</tr>
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<td>Δφ₈TB</td>
<td>First pass Range angle difference using first guess two-body targeting</td>
</tr>
<tr>
<td>Xₛ, Yₛ, Zₛ</td>
<td>Space fixed launch coordinate system</td>
</tr>
<tr>
<td>Aₛ</td>
<td>Launch aximuth</td>
</tr>
<tr>
<td>φₗ</td>
<td>Geodetic latitude of launch site (28.608°)</td>
</tr>
<tr>
<td>φₛSV</td>
<td>Sun vector right ascension</td>
</tr>
<tr>
<td>αₛSV</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>λₗ</td>
<td>longitude of launch site</td>
</tr>
<tr>
<td>Δφ</td>
<td>difference in range angles of orbiter and space station at time of orbiter insertion</td>
</tr>
<tr>
<td>ψ</td>
<td>insertion latitude, a function of inclination of the space station</td>
</tr>
<tr>
<td>I₀D</td>
<td>desired inclination for targeting purposes</td>
</tr>
<tr>
<td>Pₛ</td>
<td>Semi-latus rectum of CDH orbit</td>
</tr>
<tr>
<td>eₛ</td>
<td>eccentricity of CDH orbit</td>
</tr>
<tr>
<td>(\bar{\omega},</td>
<td>\omega</td>
</tr>
<tr>
<td>PₛP</td>
<td>Semi-latus rectum of orbiter on-orbit during Hohmann transfer</td>
</tr>
<tr>
<td>eₛP</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>φₕ</td>
<td>Range angle</td>
</tr>
<tr>
<td>φₕ</td>
<td>true anomaly</td>
</tr>
<tr>
<td>αₚL</td>
<td>argument of perigee</td>
</tr>
</tbody>
</table>
SYMBOLES (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
\(\dot{x}_{P}, \dot{\bar{x}}_{P}\)  State vector position and velocity of orbiter
\(\dot{x}_{T}, \dot{\bar{x}}_{T}\)  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)

- WATP: Wedge angle between the space station and the orbiters plane
- WATOL: Tolerance to select which $\Delta \phi$ to use (for example, WATOL < 0.1 :: $\Delta \phi = \phi_T - \phi_P$ or $\Delta \phi = \phi_{NT} - \phi_{NT}$)
- TSTI: Time of Circularization
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 (≥ 100 x 265 n mi)
- Coelliptic impulse (≥ 260 n mi)

The launch azimuth (Az), inclination (i) and node (θN) 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.

1-1
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.
Section II
DISCUSSION

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

Other advantages of this targeting technique include:

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

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

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

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

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

The ascent trajectory was programmed as a functional representation of an ascent profile. This is presently a sixth order curve fit polynomial as shown in the flowchart on page D-6. Future work in this area includes curve fit techniques using exponential curves and other types of fits which will improve curve-fit accuracy and reduce ephemerical curve-fit coefficients.
Section III
RENEZVOUS 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\textsubscript{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 SFN01). A value of SFN01=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 (SFN02) and the coelliptic phasing, 10 n mi below or above target, (SFN03) will insure extra stay time in all phasing orbits until rendezvous is accomplished. This extra stay time will enforce adequate time for crew and orbiter check-out, orbit evaluation and system checkout, propulsion checkout, tracking acquisition, and navigation up-date. Any realistic targeting technique has to provide this extra controlled stay time for real time targeting.

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

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

\[
x_N = [\phi_L]_3 [A_z - \frac{\pi}{2}]_1 \tilde{x}_S
\]

\[
\tilde{x}_{SV} = [-\alpha_{SV}]_3 [-\phi_{SV}]_2 \tilde{x}_N
\]
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 a earlier publication (ref. 1), but in a different manner.

A pictorial illustration of the position of the orbiter and space station at insertion \((T_N + T_1)\) and at lift-off \((T_N)\) for the tracking network is given in Figure 3-7. The \(\Delta\phi\) 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 \( I_D \) and launch azimuth \( A_Z \) at lift-off can be determined to achieve rendezvous with near-circular target satellites at various inclinations and various altitudes. Also, the time of launch (Universal Time, U.T.) and the timeline bases from lift-off have been determined for the orbital maneuver to accomplish rendezvous.

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

Several cases were run for a northerly launch, without a lighting constraint. The phase relation of the orbiter at TPI is below and behind the space station by a 10 n mi height differential (the orbiter lags the space station by a desired \( \Delta \phi = -0.29 \) degree). Isolated phase angles at TPI of 0.29, 0.32, 0.28, and 0.24 degree were obtained (as shown in Table 4-1), which are all within the desired tolerance of 0.05 degree. Also, the inplane conditions at TPI are within acceptable limits as can be observed from the values of \( A_i \) and \( \Delta \phi_N \). 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 \( \Delta T_{LO} \), with the negative values representing launch before the spherical in-plane point.

Similar results for a southerly launch with a lighting constraint are presented in Table 4-2. The desired sun angle input was 110.0 degrees.
Figure 4-1. INCLINATION SYNCHRONIZATION DURING COELLIPTIC COAST-ON-ORBIT DECK-

\[ \Delta \Phi = \Phi_T - \Phi_P \]

\[ 3.3^\circ < \Delta \Phi < 4.8^\circ \]

**APSIDAL ROTATION**

INCLINATION (deg)

TIME FROM APSIDAL ROTATION (time/sec)

ORBITER

SPACE STATION
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 AND RANGE ANGLE</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>( \Delta \theta ) (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>( \Delta \psi ) (deg)</td>
<td>0.29</td>
<td>0.32</td>
<td>0.28</td>
<td>0.24</td>
</tr>
<tr>
<td>( \Delta \theta_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>( \Delta T_{LO} ) (sec)</td>
<td>-284.7</td>
<td>-226.4</td>
<td>-199.06</td>
<td>-143.6</td>
</tr>
<tr>
<td>( \Delta \phi_T ) (deg)</td>
<td>-0.81</td>
<td>-2.21</td>
<td>-4.43</td>
<td>5.94</td>
</tr>
<tr>
<td>SFNO3 (unitless)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Table 4-2. LIFT-OFF TIME CORRECTION FOR NEAR-CIRCULAR TARGET ORBITS
FOR SOUTHERLY LAUNCH WITH LIGHTING CONSTRAINT

<table>
<thead>
<tr>
<th>TRUE ANOMALY</th>
<th>45°</th>
<th>135°</th>
<th>225°</th>
<th>315°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RANGE ANGLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABOVE AND AHEAD</td>
<td>255°</td>
<td>345°</td>
<td>75°</td>
<td>165°</td>
</tr>
<tr>
<td>Insertion</td>
<td>0 hr. 6 m. 11 s.</td>
<td>0 hr. 6 m. 1111 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. 50 m. 48 s.</td>
<td>0 hr. 60 m. 4 48 s.</td>
<td>0 hr. 50 m. 48 s.</td>
<td>0 hr. 50 m. 48 s.</td>
</tr>
<tr>
<td>Perigee</td>
<td>18 hr. 27 m. 36 s.</td>
<td>2 hr. 39 m. 29 s.</td>
<td>7 hr. 51 m. 52 s.</td>
<td>13 hr. 30 m. 17 s.</td>
</tr>
<tr>
<td>Constant Delta Height</td>
<td>19 hr. 16 m. 59 s.</td>
<td>3 hr. 30 m. 3 s.</td>
<td>8 hr. 42 m. 23 s.</td>
<td>14 hr. 19 m. 59 s.</td>
</tr>
<tr>
<td>Transfer Phase Initiation</td>
<td>26 hr. 22 m. 50 s.</td>
<td>8 hr. 37 m. 27 s.</td>
<td>14 hr. 33 m. 22 s.</td>
<td>18 hr. 50 m. 34 s.</td>
</tr>
<tr>
<td>Sun Angle (deg)</td>
<td>109.91</td>
<td>109.88</td>
<td>109.92</td>
<td>109.84</td>
</tr>
<tr>
<td>Δi (deg)</td>
<td>$8.17 \times 10^{-4}$</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>ΔΘN (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>ΔTLO (sec)</td>
<td>319.65</td>
<td>190.1</td>
<td>235.9</td>
<td>275.42</td>
</tr>
<tr>
<td>ΔΦTB (deg)</td>
<td>35.5</td>
<td>13.36</td>
<td>22.7</td>
<td>16.11</td>
</tr>
<tr>
<td>SFN03 (unitless)</td>
<td>4.0</td>
<td>3.0</td>
<td>3.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
The results presented in Tables 4-1 and 4-2 are for effecting rendezvous with the baseline target in a 270 n mi orbit with an approximate 55 degree inclination. Rendezvous targeting was accomplished in all cases considered, with a time constraint of approximately 24 hours to the TPI point.

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

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

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

PROGRAM INPUTS AND OUTPUTS

5.1 INPUT

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

Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISURF</td>
<td>ISURF</td>
<td>=1, Boost cut-off surface =0, Steady state trajectory comp. (see page D-6 of flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>ILIG</td>
<td>ILIG</td>
<td>=1, Lighting constraint considered =0, No lighting considered (see page D-10 of flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>A&lt;sub&gt;0&lt;/sub&gt; to A&lt;sub&gt;6&lt;/sub&gt;</td>
<td>A(7)</td>
<td>Polynomial coefficients as a function of inclination to determine latitude of insertion for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>B&lt;sub&gt;0&lt;/sub&gt; to B&lt;sub&gt;6&lt;/sub&gt;</td>
<td>B(7)</td>
<td>(Same as above for southerly launch).</td>
<td>Deg</td>
</tr>
<tr>
<td>C&lt;sub&gt;0&lt;/sub&gt; to C&lt;sub&gt;6&lt;/sub&gt;</td>
<td>C(7)</td>
<td>Polynomial coefficients as a function of inclination to determine azimuth of insertion for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>D&lt;sub&gt;0&lt;/sub&gt; to D&lt;sub&gt;6&lt;/sub&gt;</td>
<td>D(7)</td>
<td>(Same as above for northerly node).</td>
<td>Deg</td>
</tr>
<tr>
<td>E&lt;sub&gt;0&lt;/sub&gt; to E&lt;sub&gt;6&lt;/sub&gt;</td>
<td>E(7)</td>
<td>(Same as above for northerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>F&lt;sub&gt;0&lt;/sub&gt; to F&lt;sub&gt;6&lt;/sub&gt;</td>
<td>F(7)</td>
<td>Polynomial coefficients as a function of inclination to determine azimuth of insertion for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>G&lt;sub&gt;0&lt;/sub&gt; to G&lt;sub&gt;6&lt;/sub&gt;</td>
<td>G(7)</td>
<td>(Same as above for southerly node)</td>
<td>Deg</td>
</tr>
<tr>
<td>H&lt;sub&gt;0&lt;/sub&gt; to H&lt;sub&gt;6&lt;/sub&gt;</td>
<td>H(7)</td>
<td>(Same as above for southerly time-of-insertion).</td>
<td>Deg</td>
</tr>
<tr>
<td>Q&lt;sub&gt;0&lt;/sub&gt; to Q&lt;sub&gt;6&lt;/sub&gt;</td>
<td>Q(7)</td>
<td>Range angle of insertion (northerly).</td>
<td>Deg</td>
</tr>
<tr>
<td>S&lt;sub&gt;0&lt;/sub&gt; to S&lt;sub&gt;6&lt;/sub&gt;</td>
<td>S(7)</td>
<td>Range angle of insertion (southerly).</td>
<td>Deg</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>The universal time ephemeris data received from tracking station.</td>
<td>Sec</td>
</tr>
</tbody>
</table>
Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS (Continued)

<table>
<thead>
<tr>
<th>MATH SYMBOL</th>
<th>FORTRAN ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_N )</td>
<td>TN</td>
<td>The universal time of the in-plane opportunity for northerly launch.</td>
<td>Sec</td>
</tr>
<tr>
<td>( T_S )</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>HPER</td>
<td>HPER</td>
<td>Altitude of perigee of orbiter insertion.</td>
<td>N MI</td>
</tr>
<tr>
<td>( A_N )</td>
<td>AN</td>
<td>Semi-major axis of space station received from tracking network for northerly opportunity ((T_N)).</td>
<td>M</td>
</tr>
<tr>
<td>( e_N )</td>
<td>EN</td>
<td>Eccentricity of space station received from tracking network for northerly opportunity ((T_N)).</td>
<td>Unitless</td>
</tr>
<tr>
<td>( i_N )</td>
<td>( \chi_{ENCN} )</td>
<td>Inclination of space station received from tracking network for northerly opportunity ((T_N)).</td>
<td>Deg</td>
</tr>
<tr>
<td>( \theta_{NN} )</td>
<td>TNNN</td>
<td>Descending node for northerly launch ((T_N)).</td>
<td>Deg</td>
</tr>
<tr>
<td>( \alpha_{PLN} )</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>( \phi_N )</td>
<td>PNIN</td>
<td>True anomaly of space station for northerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>( A_S )</td>
<td>AS</td>
<td>Semi-major axis for southerly launch.</td>
<td>M</td>
</tr>
<tr>
<td>( e_S )</td>
<td>ES</td>
<td>Eccentricity for southerly launch.</td>
<td>Unitless</td>
</tr>
<tr>
<td>( i_S )</td>
<td>XENCS</td>
<td>Inclination for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>( \theta_{NS} )</td>
<td>THNS</td>
<td>Node for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>( \alpha_{PLS} )</td>
<td>ALFAS</td>
<td>Argument of perigee for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>( \phi_S )</td>
<td>PHIS</td>
<td>True anomaly for southerly launch.</td>
<td>Deg</td>
</tr>
<tr>
<td>( \phi_L )</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 ALFA-NUMERIC NAME</th>
<th>DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_L$</td>
<td>XLAMAL</td>
<td>Longitude of launch site measured negative west of prime meridian.</td>
<td>Deg</td>
</tr>
<tr>
<td>$b_{SVD}$</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>$a_1, b_1, c_1$</td>
<td>Coefficients for calculation of the declination angle of the sun W.R.T. in the equatorial plane. (see page D-10 of the flowchart)</td>
<td>Unitless</td>
</tr>
<tr>
<td>$e_{TOL}$</td>
<td>TOLE</td>
<td>When the space station gets within this tolerance, a simplified logic for the space station in a circular orbit will be inacted (eccentricity tolerance).</td>
<td>Unitless</td>
</tr>
<tr>
<td>$T_Y$</td>
<td>TY</td>
<td>Number of days past January 1 of launch year.</td>
<td>Days</td>
</tr>
<tr>
<td>$\Delta H_D$</td>
<td>DLHD</td>
<td>The desired differential height for the orbiter: $&gt; 0$ :: CHD below target; $&lt;0$ :: CDH above target.</td>
<td>N MI</td>
</tr>
<tr>
<td>$\Delta H_B$</td>
<td>DLHB</td>
<td>A bias used to insure that the transfer orbit will intersect the C.D.H. orbit.</td>
<td>N MI</td>
</tr>
<tr>
<td>SFN01</td>
<td>SFN01</td>
<td>Scale factor for the initial orbiter insertion orbit. (Generally $= .5$)</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFN02</td>
<td>SFN02</td>
<td>Transfer orbit scale factor for intermediate phasing orbit ($SFN02 = .5$ for second orbital intersection).</td>
<td>Unitless</td>
</tr>
<tr>
<td>SFN03</td>
<td>SFN03</td>
<td>Scale factor for phasing time in the coelliptic C.D.H orbit (normally $= 1.5$).</td>
<td>Unitless</td>
</tr>
<tr>
<td>SLM</td>
<td>SLM</td>
<td>Slope of the $\Delta \phi = f(\Delta H)$ 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 $\beta_{\text{SVD}}$, $a$, $b$, $c$, $T_Y$ 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 $\beta_{\text{SVD}}$, and coefficients for calculation of the suns 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>
<thead>
<tr>
<th>CARD</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>
</tr>
<tr>
<td>2</td>
<td>27.785842</td>
<td>.15193435</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16.249967</td>
<td>.069000928</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>106.6733904</td>
<td>-1.2483319</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>113.74390</td>
<td>.81471544</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>361.2315599</td>
<td>.19373362</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>71.972429</td>
<td>1.2579258</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>69.504248</td>
<td>-.842646</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>359.43239</td>
<td>.2231473</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>250.25958</td>
<td>-.43718955</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>309.06871</td>
<td>.47380784</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1000.0</td>
<td>2000.0</td>
<td>3000.0</td>
<td>900.0</td>
</tr>
<tr>
<td>13</td>
<td>6878206.0</td>
<td>0.000001</td>
<td>55.0</td>
<td>157.3</td>
</tr>
<tr>
<td>14</td>
<td>6878206.0</td>
<td>0.000001</td>
<td>55.0</td>
<td>23.9</td>
</tr>
<tr>
<td>15</td>
<td>28.608</td>
<td>-80.0</td>
<td>110.0</td>
<td>23.444</td>
</tr>
<tr>
<td>16</td>
<td>0.000074</td>
<td>300.0</td>
<td>10.0</td>
<td>4.0</td>
</tr>
<tr>
<td>17</td>
<td>1.5</td>
<td>.029</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, h, Δv). 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, Δφ, Δi, ΔθN, 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,

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

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,

\[ e_S P_p \cos \theta_p \cos \Delta \alpha - \sin \theta_p \sin \Delta \alpha \] - \[ e_p P_S \cos \theta_p = P_S - P_p \]

Factoring out \( \cos \theta_p \):

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

Now let

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

\[ \Delta = e_S P_p \cos \Delta \alpha - e_p P_S \]

\[ P_o = P_S - P_p \]

then;

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

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

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

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

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

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

and

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

\[ A = -\beta^2 - \Delta^2 \]

\[ B = 2P_o \beta \]

\[ C = \Delta^2 - P_o^2 \]

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 (ΔH) at apogee and perigee. Thus, to insure the ΔH will be the same at apogee and perigee, the following equation was developed (see reference 1 for complete derivation):

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

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

Letting

\[ A = 1 \]
\[ B = RRP - RAT - RPT \]
\[ C = RAT \cdot RPT + \frac{RRP}{2} \cdot \cos \theta_D \cdot (RPT - RAT) - \frac{RRP}{2} \cdot (RAT + RPT) \]

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
PARAMETERS FOR 50X100 N.M. PHASING ORBIT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHP</td>
<td>6.47076602E+06</td>
<td>NAP</td>
<td>1.00000011E+02</td>
</tr>
<tr>
<td>AP</td>
<td>6.51706600E+02</td>
<td>WHP</td>
<td>6.87566714E+02</td>
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PARAMETERS FOR THE TARGET ORBIT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHT</td>
<td>6.97759324E+06</td>
<td>WVT</td>
<td>7.61364526E+06</td>
</tr>
<tr>
<td>AT</td>
<td>6.87779786E+02</td>
<td>MAT</td>
<td>2.72209976E+02</td>
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<tr>
<td>VVT</td>
<td>7.87643684E+03</td>
<td>HAT</td>
<td>2.70000000E+01</td>
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<tr>
<td>GAMATOT</td>
<td>-2.8145834E-02</td>
<td>EP</td>
<td>7.10442869E+10</td>
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<tr>
<td>ROOT</td>
<td>7.00000000E+00</td>
<td>HPP</td>
<td>4.99999992E-02</td>
</tr>
<tr>
<td>TET</td>
<td>9.3039384E+04</td>
<td>PHOOTT</td>
<td>6.34910197E+02</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>RRT</td>
<td>6.07755324E+06</td>
</tr>
<tr>
<td>AT</td>
<td>6.87300079E+03</td>
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<tr>
<td>VVT</td>
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</tr>
<tr>
<td>GAMATOT</td>
<td>-2.8567425E-02</td>
</tr>
<tr>
<td>ET</td>
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</tr>
<tr>
<td>HAT</td>
<td>2.70000000E+01</td>
</tr>
<tr>
<td>HPP</td>
<td>4.99999992E-02</td>
</tr>
<tr>
<td>PHOOTT</td>
<td>6.34910197E+02</td>
</tr>
</tbody>
</table>

SECOND HUMAN TRANSFER OUT OF 100 NM CIRCULAR TOWARDS COELLIPTIC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>ORBIT PERIOD</td>
<td>5.73450173E+03</td>
</tr>
<tr>
<td>CATCH UP RATE</td>
<td>2.33315045E+03</td>
</tr>
<tr>
<td>IMPULSE</td>
<td>3.37208778E+03</td>
</tr>
<tr>
<td>OMMR</td>
<td>6.44419645E+01</td>
</tr>
</tbody>
</table>

COELLIPTIC LIMIT PLANNING VEHICLE IN CDO ORBIT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>E43</td>
<td>2.94953454E+01</td>
</tr>
<tr>
<td>F43</td>
<td>5.32566958E+04</td>
</tr>
<tr>
<td>GAH40</td>
<td>4.67333549E+03</td>
</tr>
<tr>
<td>WAP4</td>
<td>6.85663201E+05</td>
</tr>
<tr>
<td>RAP4</td>
<td>6.50630536E+06</td>
</tr>
<tr>
<td>AP4</td>
<td>6.8602782E+06</td>
</tr>
</tbody>
</table>

THE TPI INITIATION ANGLE IS RELATIVE TO THE TARGET 2.90000000E+01
THIS SECTION DETERMINES THE CATCH UP RATE IN THE CDO ORBIT
IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE FOR THE TOTAL MISSION

TAU4 5.95349422E+03  GPA4 4.36625377E+06  DPDICO 2.56925472E+04  DLL440 3.92220941E+00  TTH4 2.35707441E+04  OMMR 3.66133559E+01  DVT4 2.11576146E+02

C-3
RANGE ANGLE OF PURSUITE 2.24221587E 02
RANGE ANGLE OF TARGET A.58508971E 00

PHASE ANGLE DPA 1.44235504E 02
9.060029064E-01 5.0600090E-01 1.50600090E 00

STATE OF SPACE STATION:

TIME FROM LIFT-OFF

HR= 0 MIN= 0 SEC= 1.18361496E 01

UNIVERSAL TIME

HR= 0 MIN= 0 SEC= 3.1836156E 01

TIME 3.71836156E 02
Y= 6.10986085E 00
AA 2.72785441E 00
EL 0.13154643E 04
PHI10 8.5039741E 00

STATE OF SPACE STATION:

TIME FROM LIFT-OFF

HR= 11 MIN= 0 SEC= 1.3210452E 01

UNIVERSAL TIME

HR= 11 MIN= 0 SEC= 3.3210452E 01

TIME 4.00204418E 04
Y= 5.99729311E 00
AA 2.72799427E 02
EL 4.44957757E 04
PHI10 7.19909143E 00

COMPUTATIONS FOR SECTION 4-A

DPH10 2.2310342E 01 DPH2 1.1943306E 02 OT2 2.58237943E 04 T8ST 4.0235201E 04
DT 1.34979219E 04 TI 3.27403615E 02 TTEST1 3.70610135E 03 TTEST2 2.86138677E 04

STATE OF SPACE STATION

C-4
STATE OF SPACE STATION

TIME FROM LIFT-OFF
HRS= 0  MIN= 48  SEC= 2.78113475E01

UNIVERSAL TIME
HRS= 1  MIN= 21  SEC= 4.78113475E01

TIME 2.00781135E 03  X 4.74050161E 00  Y=7.76372924E 05  Z=7.95491911E 06  XD 5.50868893E 03  YD 2.45599879E 32  ZD 5.25321998E 03
AA 2.75639694E 02  AP 2.64993047E 02  RA 6.56893312E 06  P 6.87886690E 16  A 6.87886676E 06
E 1.41992779E 03  C3=5.39447411E 07  ENC 5.90513949E 01  THN 1.57154975E 02  TW 1.27562463E 01  ALFAD 2.03817000E 02
PH10 1.67932946E 02

STATE OF ORBITER

TIME FROM LIFT-OFF
HRS= 0  MIN= 48  SEC= 2.78113475E01

UNIVERSAL TIME
HRS= 1  MIN= 21  SEC= 4.78113475E01

TIME 2.00781135E 03  X=8.96246900E 04  Y=7.61047675E 05  ZD 7.25775072E 02  XD=3.12669843E 32  ZD=7.72473163E 03
AA 1.00480441E 02  AP 5.03904960E 01  RA 6.56425875E 06  P 5.61895980E 16  A 6.51849256E 06
E 7.03643014E 03  C3=6.11562536E 07  ENC 5.49871015E 01  THN 1.58363434E 02  TW 1.79888744E 02  ALFAD 1.39231907E 02
PH10 4.06967772E 01
TARGETING VALUES FOR THE COV 100 NM CIRCULARIZATION AT APOGEE

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

TIME FROM LIFT-OFF

MARS* 0  MIN=48  SEC= 2.78113475E 01

UNIVERSAL TIME

MARS* 1  MIN=21  SEC= 4.78113475E 01

| TIME | 2.90781135E 03 | X | 0.55195358E 06 | Y | 8.96246001E 04 | Z | 7.13475475E 05 | XH | 7.25775872E 02 | YH | 3.12465043E 02 | ZH | 7.12473853E 03 |
|------|----------------|---|----------------|---|----------------|---|----------------|----|----------------|----|----------------|---|
| AA   | 1.00482044E 02 | AP| 5.00584900E 01 | RA| 6.36425975E 06 | RP| 6.47252832E 06 | THN| 1.58533434E 02 | TM| 1.79887444E 02 | ALFA| 1.39231967E 02 |
| E    | 7.03643014E 03 | C3| 8.11505361E 07 | ENC| 9.45671915E 01 | TTH| 1.78533724E 02 |
| PH10 | 0.06567772E 01 | N  | 4.15679972E 01 | N  | 5.15679972E 01 | N  | 6.15679972E 01 |

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR

AM(1)| 9.19258438E 08 | AM(2)| 9.11581786E 10 | AM(3)| 2.11581786E 09 |

ECCENTRICITY VECTOR

EV(1)| 5.82076059E-11 | EV(2)| 9.09494702E-13 | EV(3)| 1.81499400E-12 |

VELOCITY TO BE GAINED VECTOR

VG(1)| 1.07534396E 03 | VG(2)| 1.10439716E 02 | VG(3)| 2.73133456E 01 |

STATE OF ORBITER

TIME FROM LIFT-OFF

MARS* 8  MIN=42  SEC= 5.38091555E 01

UNIVERSAL TIME

MARS* 9  MIN=16  SEC= 5.38091555E 01

| TIME | 3.13430920E 04 | X | 5.16295575E 06 | Y | 2.89778792E 05 | Z | 2.04947975E 06 | XH | 8.12460419E 03 | YH | 2.90764934E 02 | ZH | 6.12460492E 03 |
|------|----------------|---|----------------|---|----------------|---|----------------|----|----------------|----|----------------|---|
| AA   | 1.00530345E 02 | AP| 1.00816352E 02 | RA| 6.57908900E 06 | RP| 6.56487881E 06 | THN| 1.58653152E 02 | TM| 3.36645869E 02 | ALFA| 1.58926709E 02 |
| E    | 5.71948199E 04 | C3| 6.26783425E 07 | ENC| 5.50045691E 01 | TTH| 1.58653152E 02 |
| PH10 | 0.71343160E 02 | N  | 4.15679972E 01 | N  | 5.15679972E 01 | N  | 6.15679972E 01 |

STATE OF SPACE STATION

TIME FROM LIFT-OFF

MARS* 8  MIN=42  SEC= 5.38091555E 01
THIS IS THE SOLUTION

THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TUL0=2.29565903E 02
STATE OF ORBIT:

TIME FROM LIFTOFF

HRS= 7 MIN= 4
SEC= 8,6478750E 03

UNIVERSAL TIME

HRS= 7 MIN= 37
SEC= 7,7008992F 01

TIME 2.4806754E 04
x 2.7699172E 06
AP 1.0520970E 03
E 1.8057403E 02
PM10 1.5159413E 02

NORTHROP SERVICES, INC.

STATE OF SPACE STATION

TIME FROM LIFTOFF

HRS= 7 MIN= 6
SEC= 8,5747085E 00

UNIVERSAL TIME

HRS= 7 MIN= 37
SEC= 3.7008992F 01

TIME 2.50685741E 04
x 4.24805471E 06
AP 2.74420741E 02
E 1.8290392E 02
PM10 1.6219202E 02

STATE OF PLATFORM:

TIME FROM LIFTOFF

HRS= 7 MIN= 4
SEC= 8,5747085E 00

UNIVERSAL TIME

HRS= 7 MIN= 37
SEC= 3.7008992F 01

TIME 2.60685711E 04
x 2.7699172E 06
AP 1.0521214E 03
E 1.8057411E 02
PM10 1.51594132E 02
TARGETING VALUES FOR THE CON PERIGEE BURN

POSITION VERTEX FOR IGNITION

STATE OF ORBITER

TIME FROM LIFT-OFF
HRS= 7  MINS= 2  SEC= 4.87478295E 00

UNIVERSAL TIME
HRS= 7  MINS= 37  SEC= 3.7088792E 01

TIME 2.9606974E 04  x= 7.33766996E 05  y= 3.94341787E 06  z= 7.14524177E 03  VD 1.27596759E 32  2D 3.22849464E 03
E 1.81979137E 04  C3= 5.49049508E 01  ENC 5.49049508E 01  THN 1.56973787E 02  TM 1.01491153E 31  ALFAD 2.27099611E 02

TARGETING VALUES FOR DESIRED ELLIPSE

ANGULAR MOMENTUM VECTOR
AM(1)= 2.41796710E 08  AM(2)= 9.16709570E 10  AM(3)= 2.74236786E 09

ECCENTRICITY VECTOR
EV1(1)= 4.21737392E 01  EV1(2)= 5.08351639E 02  EV1(3)= 9.92261466E 01

VELOCITY TO BE GAINED VECTOR
VG1(1)= 5.27312451E 01  VG1(2)= 1.47648403E 01  VG1(3)= 3.78273233E 01

AFTER PERIGEE BURN AT TIME TTEST2

STATE OF ORBITER

TIME FROM LIFT-OFF
HRS= 7  MINS= 7  SEC= 6.7477285E 00

UNIVERSAL TIME
HRS= 7  MINS= 37  SEC= 3.7088792E 01

TIME 2.9606974E 04  x= 7.33766996E 05  y= 3.94341787E 06  z= 7.14524177E 03  VD 1.29071933E 32  2D 3.22977373E 03
AA 2.66274154E 12  RA 6.56561092E 06  p 6.71726993E 06  A 6.72685096E 06
E 2.31975417E 04  C3= 5.93084238E 01  ENC 5.49049508E 01  THN 1.56973787E 02  TM 0  ALFAD 2.08945876E 02

STATE OF SPACE STATION

Reproduced from best available copy.
### Targeting Values for the Pod Maneuver for COV

**Position Vector for Ignition**

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<th>Time from Lift-off</th>
</tr>
</thead>
<tbody>
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<td>Time: 7 min 50 sec</td>
</tr>
<tr>
<td>Universal Time</td>
<td>Universal Time</td>
</tr>
<tr>
<td>Time: 2,977,000,320</td>
<td>Time: 2,977,000,320</td>
</tr>
<tr>
<td>+4.9362,0779E-06</td>
<td>+4.9362,0779E-06</td>
</tr>
<tr>
<td>1.3667,5536E-02</td>
<td>1.3667,5536E-02</td>
</tr>
<tr>
<td>6.9706,892E-02</td>
<td>6.9706,892E-02</td>
</tr>
<tr>
<td>1.5662,23E-02</td>
<td>1.5662,23E-02</td>
</tr>
<tr>
<td>Time: 2,977,000,320</td>
<td>Time: 2,977,000,320</td>
</tr>
<tr>
<td>Universal Time</td>
<td>Universal Time</td>
</tr>
<tr>
<td>Time: 2,977,000,320</td>
<td>Time: 2,977,000,320</td>
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<tr>
<td>+4.9362,0779E-06</td>
<td>+4.9362,0779E-06</td>
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<tr>
<td>1.3667,5536E-02</td>
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<tr>
<td>1.5662,23E-02</td>
<td>1.5662,23E-02</td>
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</tbody>
</table>

### Targeting Values for Desired Ellipse

**Angular Momentum Vector**
- AM(1): 1.420492E+02
- AM(2): 2.221952E+02
- AM(3): 2.833203E+00

**Eccentricity Vector**
- Ev(1): 0.699528E+00
- Ev(2): 1.249578E+00
- Ev(3): 1.015190E+00
STATE OF SPACEx STATION

TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME 2.97720325 ± 0.4
X = 5.79976644E-06
AA 2.71755633E-12
B 2.92764299E-14
P/110 3.97928171E-12

STATE OF ON-BOARD

TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME 2.97720325 ± 0.4
X = 4.94627779E-06
AA 2.14747172E-12
B 2.90836684E-14
P/110 3.52647712E-12

COM HAS BEEN ACCOMPLISHED
UNIVERSAL TIME FOR TPI

STATE OF SPACE STATION:

TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME 4.66739033 4
x = 0.4032204E 0
y = -0.58579497E 0
z = 0.44515532E 0
THH 5.62266217E 03
TD = 0.63984289E 03
ZO = 0.52935449E 03

STATE OF PHOEBE:

TIME FROM LIFT-OFF

UNIVERSAL TIME

TIME 4.49739973 4
x = 0.4792258E 0
y = -0.5967325E 0
z = 0.41229898E 0
THH 5.59423220E 03
TD = 0.5557516E 03
ZO = 0.58813479E 03

DTWOU = 0.87449294E 04

WATRO = 0.91165548E 04
PHIPO = 0.37730949E 01
PHINTO = 0.40599938E 01
PHINP = 0.91869971E 01

DELPHI = 3.98749911E 01

THE SOLAR VECTOR ACHIEVED = 0.09900419E 02

STATE VECTOR OF TARGET AT LIFT-OFF

XT = 0.91354177 06
YT = 0.36983100E 05
ZT = 0.22497319E 06
THH = 0.89484216E 03
TD = 0.93095961E 03
ZO = 0.31691929E 03
TIME FROM LIFT-OFF
HRS: 0     MINS: 0     SEC: 0

UNIVERSAL TIME
HRS: 0     MINS: 69     SEC: 3.47447959E-01

TIME
x: 2.9153157E-06
y: 7.3893106E-06
z: 6.22497319E-06
x: 6.49464216E-03
y: 1.93938596E-02
z: 3.21997129E-03

STATE VECTOR OF TARGET AT INSERTION

TIME FROM LIFT-OFF
HRS: 0     MINS: 0     SEC: 1.14494496E-01

UNIVERSAL TIME
HRS: 0     MINS: 35     SEC: 4.73177114E-01

TIME
x: 5.16408959E-06
y: 1.49172695E-06
z: 4.54081138E-06
x: 5.02722046E-03
y: 2.82498863E-03
z: 5.71013338E-03

THE UPDATED TIME OF LAUNCH: 1.77043419E-03
## Appendix D

### PROGRAM MODULES AND DETAILED FLOWCHART

#### D.1 PROGRAM MODULES

<table>
<thead>
<tr>
<th>Name</th>
<th>Function or Subroutine</th>
</tr>
</thead>
<tbody>
<tr>
<td>RK713</td>
<td>This is a seventh order Runge-Kutta integration routine which can integrate backward or forward</td>
</tr>
<tr>
<td>RKG</td>
<td>The main routine of the integration package. Integration is variable step-size with an accuracy tolerance of 0.0000005 for the state</td>
</tr>
<tr>
<td>CONIC</td>
<td>Computes orbital parameters given the state. (Only for elliptical orbits.)</td>
</tr>
</tbody>
</table>
| GMAT   | Matrix transformation from space fixed inertial launch coordinate system ($\bar{X}_S$) to the in-plane $\bar{X}''''$ system  
\[
\bar{X}'''' = [-i]_1 [-\theta_N]_2 [\phi_L]_3 [A_Z - \frac{\pi}{2}]_1 \bar{X}_S 
\]  |
| MAROT  | Sets up elements of transformation matrix for an angle of rotation about the X, Y, and Z axis |
| ARTAN  | Arctangent from 0 to $2\pi$ or $-\pi$ to $\pi$ according to flag |
| POLY   | Evaluates an $n^{th}$ order polynomial given its coefficients |
| ECCV   | Computes eccentricity vector $\bar{e}$  
\[
\bar{e} = \bar{v} \times \frac{\bar{\mu}}{\bar{r}^3} - \frac{\bar{r}}{\bar{r}} 
\]  |
| DEG    | Earth's gravitational potential function. Evaluates the acceleration due to gravity for all three components |
| FATT   | Matrix transpose (3x3) |
| FATMU  | Matrix multiplication (3x3 times 1x3) |
| PRINT  | Calculates the U.T. in hours, min., sec, adds the U.T. to the mission Time "T", and prints out state and orbital parameters of each vehicle in flight.  
(Nota: the program integrates in mission time, thus U.T. of launch is added to mission time from lift-off to obtain instantaneous U.T. time in flight) |
| FATMUL | Matrix multiplication (3x3 times 3x3) |
| TIME   | Determines Keplerian time of flight between two positions on an elliptical orbit |
| RANGA  | Computes range to and from descending node w.r.t. equator to the instantaneous radius vector |
| TRUE   | Computes true anomaly from perigee to the instantaneous radius vector |
D.2 FLOWCHART

EPHEMERIS DATA OF SPACE STATION

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

JPASS = 0, KPASS = 0

YES \( T_{N-T_S} < 0 \) NO

YES \( T_{N-T} \geq TTOL \) NO YES \( T_{S-T} \geq TTOL \) NO

TULO = \( T_N \)
NORTH = 1

TULO = \( T_S \)
NORTH = 0

TULO = \( T_N \)
NORTH = 1

2-0
FROM PG. D-7

YES NORTH = 1 NO

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

\( T = T_S \)
\( e = e_S \)
\( a = a_S \)
\( i = i_S \)
\( \theta_N = \theta_{NN} \)
\( \alpha_{PL} = \alpha_{PLN} \)
\( \phi = \phi_N \)

JPASS = 0

YES \( \theta_N - 90 < 0 \) NO

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

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

2-1
TO PG. D-3
\[ \phi_T = \phi - \alpha_{PL} \]

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

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

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

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

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

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

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

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

\[\gamma_0 = \tan^{-1} \left( \frac{e \sin \phi}{1+e \cos \phi} \right)\]
\[
\begin{align*}
\begin{bmatrix}
\dot{x}_T \\
\dot{y}_T \\
\dot{z}_T
\end{bmatrix} &= [K]^{-1} 
\begin{bmatrix}
R_0 \\
0 \\
0
\end{bmatrix} ;
\begin{bmatrix}
\dot{x}_T \\
\dot{y}_T \\
\dot{z}_T
\end{bmatrix} &= [K]^{-1} 
\begin{bmatrix}
V_0 \sin \gamma_0 \\
0 \\
V_0 \cos \gamma_0
\end{bmatrix}
\end{align*}
\]

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

FROM PAGE D-5

\[J\text{PASS} = 0\] NO \quad \text{YES}

\[K\text{PASS} = 0\] NO \quad \text{YES}

FROM PG. D-5

\[2-4\]

RANGA

\[\hat{A}_{MT} = \frac{\ddot{x}}{\dot{x}} \times \frac{|\ddot{x}|}{|\dot{x}|} \hat{x}_T \times \hat{\dot{x}}_T \]

\[\hat{D}_{NT} = \hat{A}_{MT} \times \hat{\Omega} \]

\[\hat{E}_{RA} = \cos \phi_{\lambda} \hat{i} + \sin \phi_{\lambda} \sin \alpha_{\lambda} \hat{j} - \sin \phi_{\lambda} \cos \alpha_{\lambda} \hat{k} \]

\[\psi = \sin^{-1}(\frac{\dot{x}_T}{|\dot{x}_T|}) \]

\[\theta_{NT} = \cos^{-1}(\frac{\hat{E}_{RA} \cdot \hat{D}_{NT}}{|\hat{D}_{NT}|}) \]

\[I_{NT} = \tan^{-1}\left(\frac{1 - (\hat{\Omega} \cdot \hat{A}_{MT})^2}{(\hat{\Omega} \cdot \hat{A}_{MT})^2}ight)^{1/2} \]

\[A_T = \frac{\dot{x}_T}{\mu/(2\mu - \dot{x}_T^2)} \frac{|\dot{x}_T|}{|\dot{x}_T|} \]

TO PAGE D-5
$\psi_{DN} = \sum_{M=0}^{6} A_M I_{NT}^M$

$A = (1 - \cos^2 I_{NT}/\cos^2 \psi_{DS})^{1/2}$

$\phi_{LS} = \tan^{-1} \left( \frac{\tan \psi_{DN}}{A} \right)$

$\phi_{LS} = \pi + \phi_{LS}$

$\Delta\phi_R = \phi_{LS} - \phi_T$

$\psi_{DS} = \sum_{M=0}^{6} B_M I_{NT}^M$

$A = (1 - \cos^2 I_{NT}/\cos^2 \psi_{DS})^{1/2}$

$\phi_{LS} = \tan^{-1} \left( \frac{\tan \psi_{DS}}{A} \right)$

$\phi_{LS} = 2\pi - \phi_{LS}$

$\Delta\phi_R = \phi_{LS} - \phi_T$

$\phi_T > \pi$

$\Delta\phi_R > 0$

$\Delta T = TGR$

$\Delta T > 10$

$\Delta T > 100$

$\phi = \sqrt{\mu/AT^3}$

$TGR = \Delta\phi_R/\phi$
FROM PAGE D-5

ISURF = 1

STEADY STATE TRAJ. COMP.

TO PAGE D-7

INSERTION CONDITIONS FOR NORTHERNLY LAUNCH

YES

NO

NORTH = 1

INSERTION CONDITIONS SOUTHERNLY FOR LAUNCH

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

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

YES

NORTH = 1

NO

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

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

3-2 TO PAGE D-7
$K_{PASS} = 1, J_{PASS} = 1$

$R_O = \text{HPER} \ast CF + R^\Theta$

$R_A = \text{HAP} \ast CF + R^\Theta$

$e = (R_A - R,O)/(R_A + R,O)$

$V_O = \sqrt{\mu(1 + e)/R_O}$

$a = (R_A - R,O)/2$

$\gamma_O = 0.0$

---

$\bar{x}_P = \bar{x}_T$

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

$K_{PASS}=0$

$J_{PASS}=1$

---

$\bar{x}_{LO} = \bar{x}_T$

$\dot{\bar{x}}_{LO} = \dot{\bar{x}}_T$

$\bar{x}_T = \int_{T+T_1}^{T} \dot{\bar{x}}_T dt$

$\dot{\bar{x}}_T = \int_{T}^{T+T_1} \ddot{\bar{x}}_T dt$

---

$\text{FROM PG. D-4}$

$3-3$

$3-5$

$\text{FROM PAGE D-6}$

$2-0$

$\text{TO PAGE D-2}$

$3-4$

$\text{TO PAGE D-8}$

$4-0$
\[ \tau_{p4} = 2\pi \left( \frac{A_{p4}}{\mu} \right)^{1/2} \]
\[ \delta_{AP4} = \left( \frac{\mu}{A_{p4}} \right)^{1/2} \]
\[ \Delta\phi_R = SLM \cdot \Delta H \]
\[ \Lambda\phi_{MR4} = \Lambda\phi_{CU} \left( \tau_{p4} \right) \left( SFN03 + X_N \right) + \Delta\phi_R \]
\[ TTP1 = T_4 + \tau_{p4} \left( SFN03 + X_N \right) \]
\[ \Lambda\phi_{MRT1} = \Lambda\phi_{MR1} + \Lambda\phi_{MR2} + \Lambda\phi_{MR3} + \Lambda\phi_{MR4} \]
\[ \Lambda V_{IT} = \Lambda V_2 + \Lambda V_3 + \Lambda V_4 + \lambda V_R \]

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

- If \( \phi_{T1} - \phi_{P1} \geq 0 \) (NO):
  - \( \Delta\phi_{A1} = \Delta\phi_{A1} \)
- If \( \phi_{T1} - \phi_{P1} < 0 \) (YES):
  - \( \Delta\phi_{A1} = \phi_{T1} - \phi_{P1} \)

- If \( \Delta\phi_{A1} - \Delta\phi_{MRT1} \geq 0 \) (NO):
  - \( \Delta\phi_{A1} = \Delta\phi_{A1} + 2\pi \)
- If \( \Delta\phi_{A1} - \Delta\phi_{MRT1} < 0 \) (YES):
  - \( \Delta\phi_{A1} = \Delta\phi_{A1} \)

\[ \Delta T_1 = SFN03 \cdot \tau_{p4} + \tau_{p1}/2 + \tau_{p3} (SFNO2) \]
\[ \Delta\phi_1 = \Delta\phi_{MR1} + \Delta\phi_{MR3} + \Delta\phi_{CU} \tau_{p4} (SFN03) \]
\[ \Delta\phi_2 = \Delta\phi_{A1} - \Delta\phi_1 - \Delta\phi_R, \Delta T_2 = \Delta\phi_2/\Delta \phi_2 \]
\[ TSBST = T_1 + \Delta T_1 + \Delta T_2, TEST1 = T_1 + \tau_{p1}/2 - 200 \]
\[ TTEST2 = T_1 + \tau_{p1}/2 + \Delta T_2 \]
4-2 FROM PG. D-9

ORBIT INTEGRATION OF ORBITER AND SPACE STATION FROM T1 TO TSBST

4-13 FROM PG. D-17

B

YES

ILIG = 1

NO

TUP = TSBST

4-3 TO PG. D-11

JFLAG = 1

YES

JFLAG = 0

COS(BSVPT) = 1

NO

BVP = T - TSBST

JLIGHT = YES

(CPRINT LIGHTING ANGLE)

3V = SV1i + SV2j + SV3k, \( \hat{x}_T = x_T^i + y_T^j + z_T^k), \( \hat{r}_{MT} = \hat{x}_T \times \hat{x}_T \)

\( \hat{p}_V = \hat{r}_{MT} \times 3V, \hat{v}_V = \hat{r}_V \times \hat{r}_{MT}, \sin(BSVPT) = \hat{x}_T \cdot \hat{v}_V/|\hat{x}_T||\hat{v}_V|\)

\( \cos(BSVPT) = \hat{x}_T \cdot \hat{v}_V/|\hat{x}_T||\hat{v}_V|, \ BSD = |\hat{x}_T \times \hat{x}_T|/(\hat{x}_T \cdot \hat{x}_T) \)

BSVP = TAN\(^{-1}\) \(\sin(BSVPT)/\cos(BSVPT)\)

4-21 TO PAGE D-20

M-1082

D-10
4-3 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 T1 TO TTEST1

ECCV

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

TRUE

PTA

TIME

TGP2

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

\[
\text{NO} \quad \text{TGP2} < 2 \quad \text{YES}
\]

\[
\begin{align*}
R_{AP} &= R_{RP} = |\dot{x}_p|, \quad V_C = (n/R_{AP})^{1/2}, \quad \tilde{N}_{CPP} = \dot{x}_p \times \dot{x}_p \\
\tilde{V}_{CP} &= \dot{x}_p \times \tilde{N}_{CPP}/(|\dot{x}_p \times \tilde{N}_{CPP}|), \quad \tilde{V}_{CP} = V_C \tilde{V}_{CP} \\
\tilde{v} &= \tilde{v}_{CP} - \dot{x}_p, \quad V_{g1} = |\tilde{v}_{g1}|, \quad \dot{x}_p = \tilde{V}_{CP}. \quad \text{TST1} = T \\
\dot{x}_{PS} &= \dot{x}_p, \quad \dot{x}_{PS} = \dot{x}_p, \quad \dot{x}_{TS} = \ddot{x}_T, \quad \ddot{x}_{TS} = \ddot{x}_T
\end{align*}
\]

{MAJOR ISOLATION LOOP 4-15 FROM PAGE D-19}

ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TTEST2

4-4 TO PG. D-12
\[ A_T = \mu |\dot{x}_T|/(2\mu - |\ddot{x}_T|^2|\dot{x}_T|) \]
\[ R_{ATD} = A_T(1 + E_T) - \Delta H_D \]
\[ R_{PTD} = A_T(1 - E_T) - \Delta H_D, A_TD = (R_{ATD} + R_{PTD})/2 \]
\[ E_{TD} = (R_{ATD} - R_{PTD})/(R_{ATD} + R_{PTD}), P_{TD} = A_TD(1 - E_{TD})^2 \]
\[ \text{COSTTAPA} = \varepsilon_{EE} \cdot (-\varepsilon_{EP})/(E_{TE}E_{TP}) \]
\[ R_{TD} = P_{TD}/(1 + E_{TD} \text{COSTTAPA}) \]
\[ \text{DRTEST} = R_{AP} - R_{TD} - 100.0, \text{IPASSI} = 0 \]

\[ \alpha_T = \tan^{-1}(\sin\alpha_T/\cos\alpha_T) \]
\[ \sin\alpha_T = \varepsilon_{ET} \cdot D_{NAMT}/[E_T \cdot D_{NAMT}], \cos\alpha_T = \varepsilon_{ET} \cdot D_{NT}/[E_T \cdot D_{NT}] \]
\[ \alpha_T = \tan^{-1}(\sin\alpha_T/\cos\alpha_T) \]
\[ \sin\alpha_P = \varepsilon_{EP} \cdot D_{NAMP}/[E_P \cdot D_{NAMP}], \cos\alpha_P = \varepsilon_{EP} \cdot D_{NP}/[E_P \cdot D_{NP}] \]
\[ \sin\alpha_P = \varepsilon_{EP} \cdot D_{NAMP}/[E_P \cdot D_{NAMP}], \cos\alpha_P = \varepsilon_{EP} \cdot D_{NP}/[E_P \cdot D_{NP}] \]
\[ \alpha_P = \tan^{-1}(\sin\alpha_P/\cos\alpha_P) \]
\[ \Delta \alpha = \alpha_T - \alpha_P, D = E_{TD}(PP), \cos(\Delta \alpha) = P_{TD}(EP), E = -E_{TD} \cdot (PP)\sin(\Delta \alpha), F = P_{TD} - PP, \]
\[ A = -(E^2 + D^2), B = 2FE, C = D^2 - F^2 \]
\[ \text{RAD} = B^2 - 4AC, \text{STI} = (-B - \sqrt{\text{RAD}})/2A \]
\[ \text{STII} = (-B + \sqrt{\text{RAD}})/2A \]
LIFT-OFF TIME CORRECTION

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

\[ \Delta R_1 > 0 \]

- YES

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

\[ \Delta H_D' = \Delta H_1 \]

- YES

\[ \text{DRT1} < \text{DRT2} \]

\[ \Delta H_D' = \Delta H_2 \]

\[ \Delta R_1 > 0 \]

- YES

\[ \Delta H_D' = -\Delta H_D' \]

\[ R_{PP} = R_{PT} - \Delta H_D', R_{AP} = R_{AT} - \Delta H_D', E_P = (R_{AP} - R_{PP}) / (R_{AP} + R_{PP}) \]
\[ A_p = (R_{pp} + R_{AP}) / 2, P_p = A_p (1 - E_p^2), V_p = [(\mu / P_p) (1 + E_p^2 + 2E_p \text{COSTTAPP})]^{1/2} \]
\[ Y_p = \tan^{-1} [(\mu \text{SINTTAPP}) / (1 + E_p \text{COSTTAPP})], N_{CPP} = \ddot{x}_p \times \dddot{x}_p \]
\[ \nu_{pp} = \dddot{x}_p \times \tilde{N}_{cpp}[|\dddot{x}_p| \tilde{N}_{cpp}], \dddot{x}_p = \dddot{x}_p / |\dddot{x}_p|, \nu_p = V_p \cos \nu_{pp} \]
\[ + V_p \sin \nu_{pp} \dddot{x}_p, \nu_3 = \nu_p - \dddot{x}_p, V_3 = |\nu_3|, \dddot{x}_p = \nu_p \]
\[ \text{ICOR} = \text{ICOR} + 1 \]
LIFT-OFF TIME CORRECTION

FROM PG. D-14

TCDH-TUTP

*TP4-1000.

>0

NO

YES

\[ \bar{A}_{MP} = \bar{x}_P \times \bar{x}_P, \bar{A}_{MT} = \bar{x}_T \times \bar{x}_T \]

\[ \bar{N}_{TP} = \bar{A}_{MP} \times \bar{A}_{MT} \]

\[ W_{ATP} = \text{COS}^{-1} \left[ \frac{\bar{A}_{MP} \cdot \bar{A}_{MT}}{|\bar{A}_{MP}| \cdot |\bar{A}_{MT}|} \right] \]

- RANGA

\( \phi_p \)

- RANGA

\( \phi_T \)

\[ \bar{N}_{CXT} = \bar{x}_T \times \bar{N}_{TP}, \bar{N}_{CTCT} = \bar{N}_{TP} \times \bar{N}_{CXT} \]

\[ \text{SIN} \ \phi_{NT} = [\bar{N}_{CTCT} \cdot \bar{x}_T / (|\bar{N}_{CTCT}| \cdot |\bar{x}_T|)] \]

\[ \text{COS} \ \phi_{NT} = [\bar{N}_{PT} \cdot \bar{x}_T / (|\bar{N}_{TP}| \cdot |\bar{x}_T|)] \]

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

\[ \bar{N}_{CXP} = \bar{x}_P \times \bar{N}_{TP}, \bar{N}_{CP CP} = \bar{N}_{TP} \times N_{CXP}, \text{SIN} \ \phi_{NP} = \]

\[ \bar{N}_{CP CP} \cdot \bar{x}_P / (|\bar{N}_{CP CP}| \cdot |\bar{x}_P|), \text{COS} \ \phi_{NP} = \bar{N}_{TP} \cdot \bar{x}_P \]

\[ /(|\bar{N}_{TP}| \cdot |\bar{x}_P|) \], \phi_{NP} = \text{TAN}^{-1} (\text{SIN} \ \phi_{P} / \text{COS} \ \phi_{P}) \]

\[ \hat{E}_{RA} = \text{COS} \ \phi_L \hat{i} + \text{SIN} \ \phi_L \text{SIN} \ A_Z \hat{j} - \text{SIN} \ \phi_L \text{COS} \ A_Z \hat{k} \]

\[ \theta_{NT} = \text{COS}^{-1} (\hat{E}_{RA} \cdot \bar{b}_{NT} / |\bar{b}_{NT}|), \theta_{NP} = \text{COS}^{-1} (\hat{E}_{RA} \cdot \bar{b}_{NP} / |\bar{b}_{NP}|) \]

\[ \Delta \theta_E = \theta_{NT} - \theta_{NP} \]

TO PG. D-8

4-10

TO PG. D-16

4-12
\[ \Delta \phi_E = \Delta \phi - \Delta \phi_R \]

**LAST PASS NODE CORRECTION**

- \( \Delta T_{LO} = \Delta \phi_E / \phi_0 \)
- \( \dot{x}_{TR1} = \dot{x}_{TS} \)
- \( T = T_{STI} \)
- \( \dot{x}_T = \dot{x}_{TS} \)
- \( \Delta T_{LO} = T_{ULO} + \Delta T_{LO} \)
- \( \Delta T_{LOT} = T_{ULO} - T_{LO} \)
- \( T_{USS} = T_{ULO} \)
- \( T_{UL} = T_{ULO} + \Delta T_{LO} \)
- \( T_{ULOS} = T_{ULO} - \Delta T_{LO} \)

**SPACE STATION ORBIT INTEGRATION (ONLY)**

- (If \( \Delta T_{LO} < 0 \) integrate backwards)
- \( x_{TR2} = x_T + \Delta T_{LO} \)

**ACCUMULATED VALUE**

- \( \dot{x}_T = \dot{x}_{TS} \)
- \( \dot{x}_P = \dot{x}_{PS} \)
- \( T = T_{STI} \)

**ISOLAS**

- \( \text{NO} \)
- \( \text{YES} \)

**MAJOR ISOLATION LOOP**

- 4-1 FROM PG. 0-18
- 4-16 FROM PG. 0-18
- 4-19 TO PAGE D-18
- 4-15 TO PG. D-11
- 4-21 TO PAGE D-20
\[
\begin{align*}
\ddot{x}_T &= \ddot{x}_{TLO}, \quad \dot{x}_T = \dot{x}_{TLO} \\
\text{SPACE STATION INTEGRATION FROM} \\
T &= TULO \text{ TO } T = TULO + \Delta T_{LO} \\
\Delta \theta_E &= \omega \cdot \Delta T_{LO} \\
\text{KINS} &= 0 \\
\text{JINS} &= 1
\end{align*}
\]

\[
\begin{align*}
\ddot{x}_T &= \ddot{x}_{TSL}, \quad \dot{x}_T = \dot{x}_{TSL} \\
\text{SPACE STATION ORBIT INTEGRATION FROM} \\
T &= TULOS \text{ TO } T = TULOS + \Delta T_{LO} \\
\text{KINS} &= 1
\end{align*}
\]
D.3 SUBROUTINES

\[ \bar{A}_M = \bar{X} \times \bar{X} \]

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

RETURN
TRUE

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

RETURN

RANGA

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

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 CCCC(3,3), DDDD(3,3), XPS(3), XDPS(3), XTS(3), XDTS(3), EV(3)
DIMENSION AM(3), XTS1(3), XDTS1(3), XDPS1(3), XPS1(3)
DIMENSION A(7), B(7), C(7), D(7), E(7), F(7), G(7), H(7), Q(7), S(7)
DIMENSION XTLO(3), XDLO(3)

CF=1052,
GH=3960532E15
RE=6378166,
GH20,7972064E15
OMEGA=729211585E-04
PI=2,2631852
PI=3.1415926
ZERO=0,0
ONE=1,
TWO=2,0
CNV=5.72957951
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, XENC, THNS, ALFAS, PHIS
READ 2100, PHI, XLMAL, BSVD, A1, B1, C1, TOLE, TY, DLHD, DLWB, SFNO1, SFNO2,
SFNO3, SLH
JINS=0
DT1=0.5,0
DT2=200,
DT12=20,0
SSFNO3=SFNO3
JLIGHT=0
DT=SDT
PHIDPHI
AZ0=AZ
DELTH=DLHD
DLHD=DLHD*CF
DLHB=DLHB*CF
PHI=PHI/CNV
AZ=AZ/CNV
XLAMAL=XLAMAL/CNV
BSVD=BSVD/CNV
A1=A1/CNV
B1=B1/CNV
C1=C1/CNV
XENCN=XENCN/CNV
THNN=THNN/CNV
THNN=THNN/CNV
PROGRAM TARG

ALFAN=ALFAN/CNV
PHIN=PHIN/CNV
XENC=XENC/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
XENC=XENCN
THNT=THNS
ALFAT=ALFAN
PHI=PHIN
GO TO 90
80 T=TS
AT=AS
ET=ES
XENC=XENCN
THNT=THNS
ALFAT=ALFAS
PHI=PHIS
GO TO 90
90 IF (JPASS=1) 100,140,140
100 IF (THNT=PI/2) 110,110,120
110 AZL=PI-ARSIN(COS(XENC)/COS(PHI))
AZO=AZL=CNV
AZ=AZL
GO TO 130
120 AZL=ARSIN(COS(XENC)/COS(PHI))
AZ=AZL
AZO=AZL=CNV
130 PRINT 1800
PHII=PHII=CNV
ALFAT=ALFAT=CNV
XENC=XENC=CNV
THNT=THNT=CNV
PRINT 1790, T,AT,ET,XENC,T,THNT,ALFAT,PHII
PRINT 1810, AZO
140 PHIT=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, XENC, 1.-1)  
CALL MAMUL (DDD, BBB, AAA)  
CALL MAMUL (AAA, DDD, CCC)  
CALL MAROT (AAA, THNT, 2.*1)  
CALL MAROT (BBB, XENC, 1.*-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 = ARTAN(ET*SIN(PHI), ONE+ET*COS(PHI), 1)  
160 CONTINUE  
TEMP1(1) = RO  
TEMP1(2) = ZERO  
TEMP1(3) = ZERO  
TEMP2(1) = VO*SIN(GAMMO)  
TEMP2(2) = ZERO  
TEMP2(3) = VO*COS(GAMMO)  
CALL FATMU (XT, DDD, TEMP1)  
CALL FATMU (XDT, DDT, TEMP2)  
DTY3 = 100, 0  
MPASS = 0  
170 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(VDQT(XT, XOMEGA)/RRT)  
PS10 = PSI*CNY  
TEMPS(1) = COS(PHI)  
TEMPS(2) = SIN(PHI)*SIN(AZ)  
TEMPS(3) = SIN(PHI)*COS(AZ)  
THNT = ARCOS(VDQT(TEMPS, TEMP2)/VMAG(TEMP2))  
CALL UNIT (TEMP4, TEMP1)  
DUM1 = VDQT(XOMEGA, TEMP4)  
DUM = DUM1*DUM1  
XENC = ARTAN(SQRT(ONE-DUM), DUM1, 1)  
AT = RRT/GH*(TWO*GH*VDQT(XDT, XDT)*RRT)  
XENC = XENC*CNV  
PHIT = PHIT*CNV  
THNT = THNT*CNV  
PRINT 1700, PSIO  
IF (MPASS =-1) 180, 300, 180  
180 IF (THNT = PI/TWO) 200, 190, 190
190 NORTH=1
   GO TO 210
200 NORTH=0
   SOUTHERNLY LAUNCH COEFFICIENTS
210 IF (NORTH) = 1 THEN 220, 230, 240
220 PSD0=POLY(B,XENCO,6)
   PSID=PSIDO/CNV
   DUM=COS(XENC)/COS(PSID)
   AA=SQRT(ONE-DUM*DUM)
   PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
   PHILS=PI2-PHILS
   DPHRR=PHILS-PHIT
   GO TO 240
   NORTHERNLY LAUNCH COEFFICIENTS
230 PSD0=POLY(A,XENCO,6)
   PSID=PSIDO/CNV
   DUM=COS(XENC)/COS(PSID)
   AA=SQRT(ONE-DUM*DUM)
   PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
   PHILS=PI+PHILS
   DPHRR=PHILS-PHIT
240 CONTINUE
   DPHRR=DPHRR/CNV
   PRINT 1710, PSIDO
   IF (PHIT=PI) THEN 290, 290, 250
250 IF (DPHRR) THEN 290, 290, 260
260 PHID=SQRT(GM/(AT*AT*AT))
   TGR=DPHRR/PHID
   IF (TGR=100.0) THEN 270, 270, 290
   IF (TGR=20.0) THEN 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, PH1, TULOD)
   GO TO 170
300 PRINT 1840
   PRINT 1820, PSIO
   PRINT 1830, PSID0
   XIDO=XENCO
   PRINT 1850, XENC0
   IF (ISURF) = 1 THEN 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
THNSP=POLY(G,XIDO,6)
T1S=POLY(H,XIDO,6)
PHIPS=POLY(S,XIDO,6)
PHII=PHIPS/CNV
ALFAT=0,0
THNT=THNSP/CNV
AZ=AZS/CNV
T1=T1S

360 XENCT=XIDO/CNV
PRINT 1870, AZO
KPASS=1
JPASS=1
RO=HPR*CF+RE
RA=WPR*CF+RE
ET=(RA-RO)/(RA*RO)
AT=(RA-RO)/TWO
V0=SQRT(GMO*(ONE+ET)/RO)
GAMMO=0,0
GO TO 140

370 IF (KPASS=1) 410,380,380
380 DO 390 I=1,3
XP(I)=XT(I)
390 XP(I)=XDT(I)
400 KPASS=0
PRINT 1880, XP,XDP
PUNCH 2350, XP,XDP
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)
program targ

call print (tf, xt, xdt, az, phi, tulod)
print 1840
print 1890, xt, xdt

TULOS = TULO
DO 430 I = 1, 3
XTS(I) = XT(I)
XDTS(I) = XDT(I)
XP1(I) = XP(I)
430 XDPS(I) = XDP(I)

440 RRP = sqrt(vdot(xp, xp))
VVP = sqrt(vdot(xdp, xdp))
AP = GM * RRP / (GM2 - VVP * VVP * RRP)
RRT = sqrt(vdot(xt, xt))
VVT = sqrt(vdot(xdt, xdt))
AT = GM * RRT / (GM2 - VVT * VVT * RRT)
PDA1 = sqrt(GM / (AP * AP * AP))
PDTA1 = sqrt(GM / (AT * AT * AT))
DLPD1 = PDP1 - PDA1
DLMR1 = DLPD1 * PI * sqrt((AP * AP * AP) / GM)
GAMAP = ARSIN(vdot(xp, xdp) / (RRP * VVP))
HP = RRP * VVP * COS(GAMAP)
EP = sqrt((ONE - HP * HP) / (GM * AP))
RPP = AP * (ONE - EP)
RAP = AP * (ONE + EP)
VAP = sqrt((GM / AP) * sqrt((ONE + ONE) / (ONE + ONE)))
GAMAT = ARSIN(vdot(xt, xdt) / (RRT * VVT))
HT = RRT * VVT * COS(GAMAT)
ET = sqrt((ONE - HT * HT) / (GM * AT))
RAT = AT * (ONE + ET)
RPT = AT * (ONE - ET)
TAP1 = PI2 * sqrt((AP * AP * AP) / GM)
T2 = T1 + TAP1 / TWO

DR = RAT - RPT
GAMAP0 = GAMAP * CNV
HAT = (RAT - RE) / CF
PHDOTP = PDP1 * 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
PROGRAM TARG

RCP = RAP

VCP = SQRT (GM / RCP)

DUM = SQRT (RCP * RCP * RCP / GM)

TAUCP = PI2 * DUM

PDOTCP = ONE / DUM

DLPD2 = PDOTCP * PDTP1

DLMR2 = SFNO1 * DLPD2 * TAUCP

DELV2 = VCP * VAP

T3 = T2 * SFNO1 * TAUCP

PDOTCO = PDOTCP * CVNS * DLMR20 = DLMR2 * CVN

PRINT 2170

PRINT 2180, RCP, VCP, TAUCP, PDOTCO, DLPD2, DLMR20, DELV2, T3

IF (ILIGL = 1) 450, 460, 450

450 XN = 0

GO TO 470

460 XN = ONE

470 CONTINUE

RAP3 = RCP

AP3 = (RPP3 * RAP3) / TWO

DUM = SQRT (AP3 * AP3 / AP3 / GM)

TAUP3 = PI2 * DUM

PDPA3 = ONE / DUM

DLPD3 = PDPA3 * PDTP1

DLMR3 = SFNO2 * DLPD3 * TAUP3

T4 = T3 * SFNO2 * TAUP3

VPP3 = SQRT (GM2 * RAP3 / RPP3)

DELV3 = VPP3 * VCP

PRINT 2190

PRINT 2190, RCPP30, PDPA30, DLPD30, DELV3, T4, DLMR30

CIRCULARIZATION AT CDH ALTITUDE

RAP3 = RAT - DLHD - DLHB

AP3 = (RPP3 * RAP3) / TWO

EP3 = (RAP3 * RPP3) / (RPP3 * RAP3)

RPP4 = RAP - DLHD

RAP4 = RAT - DLHD

AP4 = (RPP4 * RAP4) / TWO

EP4 = (RAP4 * RPP4) / (RPP4 * RAP4)

P3 = AP3 * (ONE - EP3 * EP3)


TH4 = ARCOS ((P3 - P4) / (EP3 + P4 + EP4 + P3))

R4 = P4 / (ONE + EP4 * COS(TH4))

V4 = SQRT ((GM2 * AP3 / R4 - GM) / AP3)

GAM4 = ARCTAN (R4 * EP3 * SIN(TH4), P3, -1)

VT4 = SQRT ((GM2 * AP4 / R4 - GM) / AP4)

GAM4 = ARCTAN (R4 * EP4 * SIN(TH4), P4, -1)

DELV4 = SQRT (VT4 * VT4 + V4 * V4 - TWO * VT4 + V4 * COS(GAM4 - GAM4))
TH40=TH4*CNV
GAMA40=GAMA4*CNV
GAMT40=GAMT4*CNV
PRINT 2210
DUM=SORT(AP4*AP4*AP4/GM)
TAUP4=PI2*DUM
PDPA4=ONE/DUM
PDPA40=PDPA4*CNV
DPDCU=PDPA4-PTA1
DPH0=SLM*DELTH
DHR=DPH0/CNV
PRINT 2230, DPH0
DELVR=0,0
DLMR4=DPDCU*TAUP4*(SFNO3*XN)+DHR
TTP4=TAUP4*(SFNO3*XN)+DHR/DPDCU
DPDCU0=DPDCU*CNV
DVIT=DELV2+DELV3+DELV4+DELVR
LMR4=DLMR40*CNV
DPMR1=DLMR1+DLMR2+DLMR3+DLMR4
DMRT0=DPMR10*CNV
PDPA40=PDPA4*CNV
DPDCU0=DPDCU*CNV
PRINT 2240
PRINT 2250
PRINT 2260, TAUP4, PDPA40, DPDCU0, DLMR40, TTP4, DMRT0, 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-PI) 480, 490, 490
480 PHIT1=PHIT1-PI2
DPA1=PHIT1-PHIP1
GO TO 500
490 DPA1=PHIT1-PHIP1
500 IF (DPA1-DPMR1) 510, 520, 520
510 DPA1=DPA1+PI2
GO TO 530
520 DPA1=DPA1
530 DT1=SFO3*TAUP4+TAUP1/TWO+TAUP3*SFO2
DPMR1=DLMR1+DLMR3+DPDCU*TAUP4*SFO3
DPA10=DPA1*CNV
PRINT 1910, DPA10
DHR2=DPA1-DPH1-DHR
DT2=DPH2/DLPD2
TTEST1=T1+TAUP1/TWO-200.
PROGRAM TARG

TTEST2= T1+TAUP1/TWO+DT2
TSBST=T1+DT1+DT2
PRINT 1920, SFN01, SFN02, SFN03
PRINT 2120
CALL PRINT(T1,XT,XDT, AZ, PH1, TULO)
CALL RKG(PHIO, AZO, XT, XDT, T1, TSBST)
PRINT 2320
CALL PRINT(TSBST, XT, XDT, AZ, PH1, TULO)
PRINT 2280
DPH10=DPH1*CNV
DPH20=DPH2*CNV
PRINT 2290, DPH10, DPH20, DT2, TSBST, DT1, T1, TTEST1, TTEST2
IF (ILIG=1) 630, 540, 630
TULO=S H U T L E L I F T-O F F T I M E I N S E C O N D S U N I V E R S A L T I M E
TY=NUMBER OF DAYS PAST JAN. 1 OF LAUNCH YEAR
LA=HDA,L = L O N G I T U D E O F L A U N C H S I T E
AZ, B1, C1= INPUT CONSTANTS
OMEGA = E A R T H S # R O T A T I O N

TSBST=T

DUM= A1+XLAMAL-OMEGA * TULO
PHSV=DUM
CALL MAROT (AAA, DUM, 2, -1)
DUM=A1-COS(B1+C1*TY)
ALSV=DUM
CALL MAROT (BBB, DUM, 3, -1)
CALL MAMUL ( CCC, BBB, AAA)
CALL MAROT ( AAA, AZ-P1/THO, 1, 1)
CALL MAROT ( BBB, PHI, 3, 1)
CALL MAMUL ( DDD, BBB, AAA)
CALL MAMUL ( AAA, CCC, DDD)
CALL FATT ( BBB, AAA)
TEMP1(1)=ONE
TEMP1(2)=ZERO
TEMP1(3)=ZERO
CALL FATHU ( TEMP2, BBB, TEMP1)
JFLAG=0

CALL VCROSS ( TEMP3, XT, XDT)
BD0VMA G ( TEMP3) / VDOT(XT, XT)
CALL VUNIT ( TEMP4, TEMP3)
CALL VCROSS ( TEMP5, TEMP4, TEMP2)
CALL VUNIT ( TEMP5, TEMP5)
CALL VCROSS ( TEMP2, TEMP5, TEMP4)
BSVPT=ARATAN ( VDOT(XT, TEMP5), VDOT(XT, TEMP2), 1)
IF ( J LIGHT=1) 570, 1450, 570
IF ( (BSVPT=BSVD)-.0001) 580, 580, 610
IF ( JFLAG=1) 590, 620, 590
CHECK=BSVPT*BSD*DT
IF ( CHECK=BSVD) 610, 600, 600
JFLAG=1
DT=(BSVD-BSVPT)/BSD
PROGRAM TARG

610 T2=T+DT
    CALL RKG (PHIO, AZO, XT, XDT, T, T2)
    T=T2
    GO TO 560
620 PRINT 2320
    CALL PRINT (T2, XT, XDT, AZ, PHI, TULO)
    PRINT 2300
    PHSVO=PHSV*CNV
    ALSVO=ALSV*CNV
    BSVPTO=BSVPT*CNV
    AO=A1*CNV$BO=B1*CNV$CO=C1*CNV
    XLMADO=XLMAL*CNV
    PRINT 2310, AO, BO, CO, TY, XLMADO, PHSVO, ALSVO, BSVPTO
    TUTP=T
    DT3=T-TSBST
    DPH1=DPHI+DPDCU*DT3
    DPH2=DPA1-DPH1-DPHR
    DT2=DPH2/DLDP2
    TTEST2=T1+TAUP1+DT2
    GO TO 640
630 TUTP=TSBST
640 DO 650 I=1,3
    XT(I)=XTS1(I)
650 XDT(I)=XDTS1(I)
    CALL RKG (PHIO, AZO, XT, XDT, T, T1, TTEST1)
    CALL RKG (PHIO, AZO, XP, XDP, T, TTEST1)
    PRINT 2320
    CALL PRINT (TTEST1, XT, XDT, AZ, PHI, TULO)
    PRINT 2330
    CALL PRINT (TTEST1, XP, XDP, AZ, PHI, TULO)
    T=TTEST1
660 CALL ECCV (GM, XP, XDP, TEMP3)
    CALL TRUE (XP, XDP, TEMP3, PTA)
    EPS=VMAG(TEMP3)
    RPM=VMAG(XP)
    AP=RPM*GM/(GM2-VDOT(XDP,XDP)*RPM)
    CALL TIME (AP, EPS, PTA, PI, GM, PI, TGP2)
    IF (TGP2-30.0) 670, 670, 680
670 DT12=ONE
    IF (TGP2-TWO) 690, 690, 680
680 T12=T+DT12
    CALL RKG (PHIO, AZO, XT, XDT, T, T12)
    CALL RKG (PHIO, AZO, XP, XDP, T, T12)
    T=T12
    GO TO 660
690 RAP=VMAG(XP)
    PRINT 2320
    CALL PRINT (T12, XT, XDT, AZ, PHI, TULO)
    PRINT 2330
    CALL PRINT (T12, XP, XDP, AZ, PHI, TULO)

E-11
PROGRAM TARG

TSTI = T
VC = SQRT(GM/RAP)
CALL VCROSS (TMP1,XDP,XP)
CALL VCROSS (TMP2,XP,TMP1)
CALL VUNIT (TMP2,TMP2)
DO 700 I = 1, 3

700 TEMP3(I) = VC * TEMP2(I)
DO 710 I = 1, 3

710 TMP1(I) = TEMP3(I) * XDP(I)
TMP3 = TEMP2 * XDP(1)
PRINT 1990
PRINT 2000
PRINT 2330
CALL PRINT (TSTI,XP,XDP,AZ,PHI,TULO)
CALL VCROSS (AM,XP,TEMP3)
CALL ECCV (GH,XP,TEMP3,EV)
PRINT 2010, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2),

END

DO 720 I = 1, 3

720 XDP(I) = TEMP3(I)
DO 730 I = 1, 3

730 XDT(I) = XDP(I)
XPS(I) = XP(I)
XTS(I) = X(T(I))

740 CALL RKG (PHIO,AZO,XT,XDT,TSTI,TTEST2)
CALL RKG (PHIO,AZO,XP,XDP,TSTI,TTEST2)
PRINT 2330
CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
PRINT 2320
CALL PRINT (TTEST2,XT,XDT,AZ,PHI,TULO)
CALL ECCV (GH,XT,XDT,TEMP3)
RTH=VMAG(XT)
AZ=AVEC(GH2=VDOT(XDT,XDT)*RTH)
ET=VMAG(TEMP3)
RPP=VMAG(XP)
RATD=ATC*(ONE=ET)-DLHD
RPTD=ATC*(ONE=ET)-DLHD
ETD=(RATD+RPTD)/(RATD+RPTD)
DO 750 I = 1, 3

750 TEMP2(I) = XDP(I)
RPP=VMAG(XP)
CTYAPA=VDOT(TMP3,TEMP2)/(ET*RPP)
RAPRTH=RATD+RPTD/((RATD+RPTD)*(RATD+RPTD)*CTTAPA)*DLHB
EP0=(RPP)*RPP/(RPP)
VPP=SQRT((CM/RPP)*(ONE=EP))
PRINT 2330
CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
PRINT 2330
CALL VCROSS (TEMP1, XDP, XP)
CALL VCROSS (TEMP3, XDP, TEMP1)
CALL VUNIT (TEMP3, TEMP3)
Do 760 I=1,3

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

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

780 PRINT 2020
PRINT 2000
PRINT 2330
CALL PRINT (TTEST2, XP, XDP, AZ, PHI, TULO)
CALL VCROSS (AM, XP, TEMP2)
CALL ECCV (GM, XP, TEMP3, EV)
PRINT 2010, AM(1), AM(2), AM(3), EV(1), EV(2), EV(3), TEMP1(1), TEMP1(2), TEMP1(3)
CONTINUE I=569

800 XDP(I)=TEMP2(I)
PRINT 1940
PRINT 2330
CALL PRINT (TTEST2, XP, XDP, AZ, PHI, TULO)
AP=(RPP*RAP)/TWO
TAUP2=PI2*SQR(TAP*AP*AP/GM)
TTEST3=T+(TAUP2*SPN02)-250.
JPAS=0
KPA=0
CALL RKG (PHIO, AZO, XT, XDT, TTEST2, TTEST3)
CALL RKG (PHIO, AZO, XP, XDP, TTEST2, TTEST3)
PRINT 2320
CALL PRINT (TTEST3, XT, XDT, AZ, 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/(GM2-VDOT(XDP,XDP)*RMT)
RAP=AP*(ONE*EP)
DRTEST=RAP*VMAG(XT)*DLHD-100.
CALL TRUE (XP, XDP, TEMP1, PTA)
IF (ET-TOLE) 820, 940, 940

820 IF (DRTEST) 830, 900, 900
830 IF (PTA-PI) 840, 870, 870

840 CALL TIME (AP, EP, PTA, PI, GM, PHI, TG3)
PRINT 1720, TG3
IF (TG3-10.) 860, 850, 850
850 T18=TT+DT22
CALL RKG (PHIO, AZO, XP, XDP, T, T18)
CALL RKG (PHIO, AZO, XT, XDT, T, T18)
T=T18
IF (JPAS=1) 810, 870, 810
860 DT22=TG3
JPAS=1
GO TO 850
870 RCP=VMAG(XP)
PRINT 1730
VCP=SQRT(GM/RCP)
CALL VCROSS (TEMPI, XDP, XP)
CALL VCROSS (TEMP4, XP, TEMPI)
CALL VUNIT (TEMP4, TEMP4)
DO 880 I=1, 3
880 TEMP2(I)=VCP*TEMP4(I)
DO 890 I=1, 3
890 TEMP3(I)=TEMP2(I)-XDP(I)
V03=VMAG(TEMP3)
GO TO 1140
900 RS=VMAG(XT)-DLHD
PTASI=ARCOS((PP-RS)/(EP*RS))*PI2
PRINT 1900
CALL ECCV (GM, XP, XDP, TEMPI)
CALL TRUE (XP, XDP, TEMPI, 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=TT+DT22
CALL RKG (PHIO, AZO, XT, XDT, T, T18)
CALL RKG (PHIO, AZO, XP, XDP, T, T18)
T=T18
IF (KPAS=1) 810, 870, 810
930 DT22=TG3
KPAS=1
GO TO 920
940 RMT=VMAG(XT)
AT=RMT*GM/(GM2-VDOT(XDT, XDP)*RMT)
RAD=AT*(ONE+ET)-DLHD
RPT=AT*(ONE+ET)-DLHD
ATD=(RATD*RPTD)/TWO
E0D=(RAD*RPTD)/(RATD*RPTD)
PD=ATD*(ONE-ETD+ETD)
DO 950 I=1, 3
950 TEMP2(I)=TEMP1(I)
GYPAR=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,XP2)
CALL VCROSS (TEMP3,TEMP2,XOMEGA)
CALL VCROSS (TEMP5,TEMP3,TEMP2)
STNAP=VDOT(TEMP1,TEMP5)/(ET*MAG(TEMP5))
COSAP=VDOT(TEMP1,TEMP3)/(ET*MAG(TEMP3))
ALFAP=ARTAN(STNAP,COSAP,1)
CALL VCROSS (TEMP2,XT,XT1)
CALL VCROSS (TEMP3,TEMP2,XOMEGA)
CALL VCROSS (TEMP5,TEMP3,TEMP2)
STNAT=VDOT(TEMP4,TEMP5)/(ET*MAG(TEMP5))
COSAT=VDOT(TEMP4,TEMP3)/(ET*MAG(TEMP3))
ALFAT=ARTAN(STNAT,COSAT,1)
DELAL=ALFAT-ALFAP
DEL=ETD*PP*COS(DELAL)-PTD*EP
E=ETD*PP*SIN(DELAL)
F=PTD*PP
A=(E*E+D*D)
B=400*F*E
C=D*D-F*F
RAD=(B*B-4*A*C)
STI=(-B+SQRT(RAD))/(TWO*A)
STII=(-B-SQRT(RAD))/(TWO*A)
IF (STI) 970,970,980
970 PTASI=-PI-ARSIN(STI)
GO TO 990
980 PTASI=-PI-ARSIN(STII)
990 CALL TIME (AP,EP,PTA,PTASI,GM,PI,TG3)
IF (TG3=10) 1000,1000,1010
1000 DT22=TG3
IPASSI=1
1010 T18=T+DT22
CALL RKG (PHIO,AZO,XP,XP2,T,T18)
1020 IF (IPASSI=1) 810,1040,810
1030 IF (PTA=PI) 1030,1030,1040
1040 RPM=MAG(XP)
PRINT 2320
CALL PRINT (T18,XT,XT1,XT2,PHI,TULO)
PRINT 2330
CALL PRINT (T18,XP,XP2,AZ,PHI,TULO)
CALL ECCV (GM,XT,XT1,TEMP1)
RTM=MAG(XT)
AT=RTM*GM/(GM2-VDOT(XDT,XDT)*RTM)
**PROGRAM TARG**

```plaintext
ET=VMAG(TEMP1)
RAT=AT*(ONE-ET)
RPT=AT*(ONE-ET)
CALL VCROSS (TEMP2,XDP,XP)
CALL VCROSS (TEMP3,TEMP1,TEMP2)
CTTAPP=VDOT(TEMP1,XP)/(RPM*ET)
STTAPP=VDOT(TEMP3,XP)/(VMAG(TEMP3)*RPM)
PT=AT*(ONE-ET*ET)
R=PT/(ONE-ET*CTTAPP)
DELRA=RRT/ET
IF (DELR) 1050,1050,1060

B=b

1060 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)
DELRA=ABS(DELR)
DRT1=ABS(DELR-MLH1)
DRT2=ABS(DELR-MLH2)
IF (DRT1>DRT2) 1070,1070,1080

1070 DLHDP=DLH1
GO TO 1090

1080 DLHDP=DLH2
1090 IF (DELR) 1100,1100,1110
1100 DLHDP=-DLHDP

1110 RPP=RPT-MLHDP
RAP=RAT-MLHDP
EP=(RAP=RPP)/(RAP*RPP)
AP=(RAP*RPP)/TWO
VP=SQRT(GM/PP)*SQRT(ONE.EP*EP*CTTAPP)
GAMMP=ARTAN(EP*STTAPP,ONE-EP*CTTAPP,-1)
CALL VCROSS (TEMP1,XDP,XP)
CALL VCROSS (TEMP2,XP,TEMP1)
CALL VUNIT (TEMP3,TEMP2)
CALL VUNIT (TEMP1,XP)
DO 1120 I=1,3

1120 TEMP2(I)=VP*COS(GAMMP)*TEMP3(I)+VP*SIN(GAMMP)*TEMP1(I)
DO 1130 I=1,3

1130 TEMP1(I)=TEMP2(I)-XDP(I)

G3=VMAG(TEMP1)

1140 IF (ISOLAS1) 1160,1150,1150

1150 PRINT 2030
PRINT 2000
PRINT 2330
CALL PRINT (T1,XP,XDP,AZ,PHI,TU0)
CALL VCROSS (AM,XP,TEMP2)
CALL ECCV (GH,XP,TEMP2,EV)
PRINT 2010, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2),
1TEMP1(3)
```
* T I D Y *

PROGRAM TARG

1160 CONTINUE
1170 DO 1170 I=1,3
            XDP(I)=TEMP2(I)
            ICOR=ICOR+1
            T=T+18
            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
            CALL PRINT (TUTP,XP,XDP,AZ,PHI,TULO)
            IF (T18-TUTP+SSFNO3*TAUP4=1000,1200,1200,1180)
1180 SFNO3=SFNO3+.5
            DO 1190 I=1,3
            XT(I)=XTS1(I)
            XDT(I)=XDTST1(I)
            XP(I)=XPS1(I)
            XDP(I)=XDPST1(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)
            SINPN=VDOT (TEMP2,XT)/(VMAG(TEMP2)*VMAG(XT))
            COSPN=VDOT (TEMP5,XT)/(VMAG(TEMP5)*VMAG(XT))
            PHINP=ARTAN (SINPN,COSPN)
            CALL VCROSS (TEMP1,XP,TEMP5)
            CALL VCROSS (TEMP2,TEMP5,TEMP1)
            SINPNP=VDOT (TEMP2,XP)/(VMAG(TEMP2)*VMAG(TEMP5))
            COSPNP=VDOT (TEMP5,XP)/(VMAG(TEMP5)*VMAG(TEMP5))
            PHINPP=ARTAN (SINPNP,COSPNP)
            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)
            THNINT=ARCOS (VDOT(TEMP1,TEMP3)/(VMAG(TEMP1)*VMAG(TEMP3)))
CALL VCROSS (TEMP2, XP, XDP)
CALL VCROSS (TEMP3, TEMP2, XOMEGA)
THNP = ARCOS (VDOT (TEMP1, TEMP3) / (VMAG (TEMP1) * VMAG (TEMP3)))
DTHET = THINT - THNP
DTHETO = DTHE * CNV
PRINT 2060, DTHETO
IF (WATP - WATOL) 1320, 1210, 1210
1210 IF (PHINT - PI) 1220, 1220, 1270
1220 IF (PHINP - PI) 1240, 1240, 1230
1230 DELPH = PHINT - PHINP
   GO TO 1420
1240 DELPH = PHINT - PHINP
   IF (ABS (DELPH) - PI) 1260, 1260, 1250
1250 PHINP = PHINP + PI2
   DELPH = PHINT - PHINP
   GO TO 1420
1260 DELPH = PHINT - PHINP
   GO TO 1420
1270 IF (PHINT - PI) 1290, 1290, 1280
1280 DELPH = PHINT - PHINP
   GO TO 1420
1290 DELPH = PHINT - PHINP
   IF (ABS (DELPH) - PI) 1300, 1300, 1310
1300 DELPH = PHINT - PHINP
   GO TO 1420
1310 PHINT = PHINT + PI2
   DELPH = PHINT - PHINP
   GO TO 1420
1320 IF (PHIT - PI) 1330, 1330, 1370
1330 DELPH = PHIT - PHIP
   IF (PHIP - PI) 1420, 1420, 1340
1340 IF (ABS (DELPH) - PI) 1350, 1360, 1360
1350 DELPH = PHIT - PHIP
   GO TO 1420
1360 PHIT = PHIT + PI2
   DELPH = PHIT - PHIP
   GO TO 1420
1370 IF (PHIP - PI) 1380, 1380, 1410
1380 DELPH = PHIT - PHIP
   IF (ABS (DELPH) - PI) 1390, 1400, 1400
1390 DELPH = PHIT - PHIP
   GO TO 1420
1400 PHIP = PHIP + PI2
   DELPH = PHIT - PHIP
   GO TO 1420
1410 DELPH = PHIT - PHIP
1420 DELPH = DELPH * CNV
   WATP = WATP * CNV
   PHIP = PHIP * CNV
   PHIT = PHIT * CNV
PROGRAM TARG

PHINTO=PHINT*CNV
PHINPO=PHINP*CNV
PRINT 1970, WATPO, PHIP0, PHITO, PHINTO, PHINPO
PRINT 2070, DELPHO
IF (ILIG-1) 1460, 1430, 1460
1430 IF (ISOLAS-1) 1460, 1440, 1460
1440 JLIGHT=1
GO TO 550
1450 BSVPAO=BSVPT*CNV
PRINT 1960, BSVPAO
GO TO 1650
1460 CONTINUE
PRINT 2080, ICOR
IF (ICOR-2) 1470, 1530, 1560
1470 IF (ABS(DTHE)-.02/CNV) 1530, 1480, 1480
1480 DLTL0=DTHE/OMEGA
TULO=TULO*DLTL0
T=TSTI
PRINT 1980, DLTL0
TUTP=TUTP*DLTL0
DO 1490 I=1,3
XTR(I)=XTS(I)
XT(I)=XTS(I)
1490 XDT(I)=XDT(I)
DPHEE=DELPH-DPHR
TDTL0=T*DLTL0
CALL RKG (PHIO, AZ0, XT, XDT, TSTI, TDTL0)
PRINT 2320
CALL PRINT (TDTL0, XT, XDT, AZ, PHI, TULO)
DO 1500 I=1,3
1500 XTR2(I)=XT(I)
DLPLOC=ARCOS(VDOT(XTR1, XTR2)/(VMAG(XTR1)*VMAG(XTR2)))
DLPLOC=(DLTL0/ABS(DLTL0))*DLPLOC
DLTT1=(DLPLOC-(DLPL0*DPDCU)/DLPD2)-DLTL0*DPDCU)/DLPD2
DLTT2=DPHEE/(DLPD2*DPDCU)
DLTTT2=DLTT1+DLTT2
TTEST2=TTEST2+DLTTT2
1510 CALL RANGA (XT, XDT, XOMEGA, PHITT)
CALL VCROSS (TEMP1, XT, XDT)
CALL VCROSS (TEMP2, TEMP1, XOMEGA)
CALL VUNIT (TEMP4, TEMP1)
DUM=VDOT(XOMEGA, TEMP4)
DUM=DUM1*DUM1
XINT=ARTAN(SQRD(ONE-DUM), DUM1")
TEMP1(1)=COS(PHI)
TEMP1(2)=SIN(PHI)*SIN(AZ)
TEMP1(3)=SIN(PHI)*COS(AZ)
THTN=ARCOS(VDOT(TEMP1, TEMP2)/(VMAG(TEMP2)))
THTN=THTN=DTHE
CALL MAROT (AAA, AZ-P1/2", 1, 1)
CALL MAROT (BBB, PHI, 3, 1)
CALL MAMUL (CCC, BBB, AAA)
CALL MAROT (AAA, THTE, 2, -1)
CALL MAROT (BBB, XINT, 1, -1)
CALL MAMUL (DDD, BBB, AAA)
CALL MAMUL (AAA, DDD, CCC)
CALL MAROT (BBB, PHITT, 2, -1)
CALL MAMUL (CCC, BBB, AAA)
CALL FATU (DDD, CCC)

RRT = VMAG(XT)
VVT = VMAG(XDT)

GAMMA = ARSIN(VDOT(XT, XDT) / (RRT * VVT))

TEMP1(1) = RRT
TEMP1(2) = ZERO
TEMP1(3) = ZERO

CALL FAMU (XT, DDD, TEMP1)
TEMP1(1) = VVT * SIN(GAMMA)
TEMP1(2) = ZERO
TEMP1(3) = VVT * COS(GAMMA)

CALL FAMU (XDT, DDD, TEMP1)

T = TSTI

DO 1520 I = 1, 3
XDP(I) = XDP(I)
XTS(I) = XT(I)

1520 XP(I) = XP(I)
TU = TSTI + TULO

IF (JINS) 1670, 740, 1670

1530 DPHEE = DELPH - DPHR
IF (ABS(DPHEE) < 0.05/CNV) 1580, 1580, 1540

1540 DD2 = DPHEE / (DLD2 - DPD2)

1550 XDT(I) = XDT(I)

1560 DPHEE = DELPH - DPHR
IF (ABS(DPHEE) < 0.05/CNV) 1570, 1570, 1540

1570 IF (ABS(DTHE) < 0.02/CNV) 1580, 1610, 1610

1580 PRINT 2090
IF (ISOLAS = 1) 1590, 1650, 1650

1590 ISOLAS = 1
DTULOR = TULO - TULOS
PRINT 1980, DTULOR
T = TSTI

1600 DO 1520 I = 1, 3
PROGRAM TARG

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

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

1610 DLTLO=DTHE/OMEGA
DO 1620 I=1,3
XTR(I)=XTS(I)
XT(I)=XTS(I)

1620 XDT(I)=XDTS(I)
TULO=TULO+DLTLO
T=TSTI
PRINT 1980, DLTLO
TUTP=TUTP- DL TLO
Do 1630 I=1,3
XTR1(I)=XTS(I)
XT(I)=XTS(I)

1630 XDT(I)=XDTS(I)
TF=TSTI+DLTLO
CALL RKG (PHIO, AZO, XT, XDT, TST'I, TF)
PRINT 2320
CALL PRINT (TF, XT, XDT, AZ, PHI, TULO)
DO 1640 I=1,3

1640 XTR2(I)=XT(I)
DLPLOC=ARCOS(VDOT(XTR1, XTR2)/VMAG(XTR1)*VMAG(XTR2))
DLPLOC=(DLTLO/ABS(DLTLO))*DLPLOC
DLT1=(DLPLOC-DPDCU)/DLPD2-DLTLO*DPDCU)/DLPD2
TTEST2=TTEST2+DLT1
GO TO 1510

1650 TIMLAU=TULOS+DTULOT
TIMIN=TULOS+DTULOT+T1
CALL RKG (PHIO, AZO, XT, XDT, TULOS, TIMLAU)
DO 1660 I=1,3
XT(I)=XTLO(I)

JINS=1
KINS=0
DTHE=OMEGA+DTULOT
GO TO 1510

1670 IF (KINS) 1680, 1690, 1680

1680 PRINT 2340
PUNCH 2350, XT, XDT
PUNCH 2350, XT, XDT
PUNCH 2100, XT, XDT
CALL PRINT (T1, XT, XDT, AZ, PHI, TULOS+DTULOT)
GO TO 1710

1690 CALL RKG (PHIO, AZO, XTS1, XDT, 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)=XTS(I)
   XDT(I)=XDTS(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 (7H TIME15.8, 7H ATM15.8, 7H XE15.8, 7H XE15.8, 7H XD15.8, 7H XD15.8, 7H XE15.8, 7H XD15.8, 7H)

1800 FORMAT (49H ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT//)
1810 FORMAT (35H FIRST GUESS ON THE LAUNCH AZIMUTH=E15.8//)
1820 FORMAT (38H INSTANTANEOUS LATITUDE OF INSERTION=E15.8//)
1830 FORMAT (32H DESIRED LATITUDE FOR INSERTION=E15.8//)
1840 FORMAT (21H THIS IS THE SOLUTION)
1850 FORMAT (52H DESIRED VALUE OF INCLINATION FOR TARGETING PURPOSE=E15.8//)
1860 FORMAT (61H INSERTION CONDITIONS DETERMINED FROM STEADY STATE TRAJECTORY//)
1870 FORMAT (46H ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION=E15.8//)
1880 FORMAT (40H STATE VARIABLES OF ORBITER AT INSERTION/7H XPE15.8
   1.7H YPE15.8, 7H ZPE15.8, 7H XDPE15.8, 7H YDPE15.8, 7H)

1890 FORMAT (59H STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSERTION/7H XTE15.8, 7H YTE15.8, 7H ZTE15.8, 7H XDTE15.8, 7H YDTE15.8)
1900 FORMAT (39H INTERSECTION ASSUMING CIRCULAR ORBIT=E15.8//)
1910 FORMAT (18H PHASE ANGLE DPA1=E15.8//)
1920 FORMAT (3E16.8//)
1930 FORMAT (35H BEFORE PERIGEE BURN AT TIME TTEST2//)
1940 FORMAT (35H AFTER PERIGEE BURN AT TIME TTEST2//)
1950 FORMAT (72H SFCO3 HAS BEEN BUMPED BY .5 BECAUSE THE TIME OF TPI OCCURRED BEFORE CDH//)
1960 FORMAT (33H THE SOLAR VECTOR ANGLE ACHIEVED=E15.8//)
1970 FORMAT (7H WATPOE15.8, 7H PHITOPE15.8, 7H PHITOPE15.8, 7H PHITOPE15.8)
1980 FORMAT (50H THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO=E15.8)
1990 FORMAT (62H TARGETING VALUES FOR THE 500 NM CIRCULARIZATION AT 1 APOGEE//)
2000 FORMAT (29H POSITIVE VECTOR FOR IGNITION//)
2010 FORMAT (37H TARGETING VALUES FOR DESIRED ELLIPSE/24H ANGULAR MOMENTUM

E-22
PROGRAM TARG

1. TARGETING VALUES FOR THE COV PERIGEE BURN

2. TARGETING VALUES FOR THE CDH MANUVER FOR COV

3. UNIVERSAL TIME FOR TPI

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

5. CATCH UP RATE IN THE CDH ORBIT

6. COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TIDY

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

TARGETING VALUES FOR THE COV PERIGEE BURN

TARGETING VALUES FOR THE CDH MANUVER FOR COV

UNIVERSAL TIME FOR TPI

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

CATCH UP RATE IN THE CDH ORBIT

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10
PROGRAM TARG

18/7H LAMDAOE15,8,7H PHSVOE15,8,7H ALSVOE15,8,7H BSVPTOE15,8/) A1101
2320 FORMAT (23H STATE OF SPACE STATION//) A1102
2330 FORMAT (17H STATE OF ORBITER/) A1103
2340 FORMAT (36H STATE VECTOR OF TARGET AT INSERTION/) A1104
2350 FORMAT (6E13,6) A1105
2360 FORMAT (7H XTE15,8,7H YTE15,8,7H ZTE15,8,7H XDTE15. A1106
18,7H YDTE15,8,7H ZDTE15,8/) A1107
2370 FORMAT (35H STATE VECTOR OF TARGET AT LIFT OFF/) A1108
2380 FORMAT (28H THE UPDATED TIME OF LAUNCH=E15,8//) A1109
END A1110
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 FEHLBERGS
F(0) IN FEHLBERGS REPORT IS IN F(1, J)
F(1) IN F(I+1, J)
FEHLBERGS 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(1, I)=TE(I)
  DO 70 K=2, 13
    DO 40 I=1, N
      XDUM(I)=X(I)
40    NN=K-1
      DO 50 I=1, NN
        NN=K-1
      DO 50 J=1, NN
        F(J, I)=TE(I)
50    CONTINUE
    DO 80 I=1, N
      XDUM(I)=X(I)
80    CONTINUE
    DO 90 L=1, 13
      X(I)=X(I)+DT*CH(L)*F(L, I)
90    CONTINUE
  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.
  100 A=EPS
    GO TO 120

GO TO 10
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
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
195 XI(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)
10 X(I*3)=DXI(I)

GM=3.9860319E14
RCONV=.1745329252E-01
RPHIL=PHIL*RCONV
HAZ=AZ*RCONV
AC3=COS(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.
20 CH(I)=0.
CH(6)=34./105.
CH(7)=9./35.
CH(8)=CH(7)
CH(9)=9./280.
CH(10)=CH(9)
CH(12)=41./840.
CH(13)=CH(12)
ALPH(2)=2./27.
ALPH(3)=1./9.
ALPH(4)=1./6.
ALPH(5)=5./12.
ALPH(6)=5
ALPH(7)=5./6.
ALPH(8)=1./6.
ALPH(9)=2./3.
ALPH(10)=1./3.
ALPH(11)=1.
ALPH(13)=1.
BETA(2,1)=2./27.
BETA(3,1)=1./36.
BETA(4,1)=1./24.
BETA(5,1)=5./12.
BETA(6,1)=.05
BETA(7,1)=-25./108.
BETA(8,1)=31./300.
BETA(9,1)=2.
BETA(10,1)=-91./108.
BETA(11,1)=23*3./4100.
BETA(12,1)=3./205.
BETA(13,1)=1777./4100.
BETA(3,2)=1./12.
SURROUTINE RKG (PHIL, 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) = -299./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 DEQ (X, TI, DX, AB, TI)
TOL = 5E-06
Tl = TI
CALL RK713 (TO, TF, TOL, X, X, 6, 2000, M, BETA, ALPH, CH, TI, AB)
CALL DEQ (X, TF, DX, AB, TI)
UN 40 I = 1 - 3
X(1) = X(I)
40 D XI(I) = X(I + 3)
SURROUNTE 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)

! QU(3), PU(3), XI(3), T(3), SU(3), B(3), CU(3)

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 (THTV, H, W)
CALL VUNIT (THTN, THTV)
CALL VCROSS (WU, HU, RU)
CALL VCROSS (B, SU, T)

GM = 3.9860321979E14
PR = SQRT(VDOT(R, R))
P = VDOT((H, H)) / GM
PD = VDOT(V, RU)
A = GM * PR / (2. * GM - RM * VDOT(V, V))
TEST = (lo - P / A)
IF (TEST) 20, 20, 10
10 E = SQRT(TEST)
GO TO 30
20 E = 0.0
30 CONTINUE
COSTH = (P * RM) / (E * RM)
SINTH = (R / 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, THTN), 1)
TH = ARTAN(SINTH, COSTH, 1)
CALL VCROSS (CU, HU, THTN)
PHII = ARTAN(VDOT(CU, RU), VDOT(THTN, RU), 1)
T1 = COS(PHI)
T2 = SIN(AZ) * SIN(PHI)
T3 = -COS(AZ) * SIN(PHI).
CALL VCROSS (SU, W, T)
THTN = ARTAN(VDOT(THTN, SU), VDOT(THTN, T), 1)
CALL VCROSS (B, W, THTN)
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)

SUBROUTINE GMAT (PHI, AZI, THTN, ENC, G, PI)
DIMENSION AA(3,3), B(3,3), C(3,3), D(3,3), TE(3,3), G(3,3)
CALL MAROT (AA, AZI - PI/2, 1, 1)
CALL MAROT (B, PHI, 3, 1)
CALL MAROT (C, THTN, 2, -1)
CALL MAROT (D, ENC, 1, -1)
CALL MAMUL (G, B, AA)
CALL MAMUL (TE, C, G)
CALL MAMUL (G, D, TE)
RETURN
END
SUBROUTINE MAROT (A, ANGLE, K, L)
DIMENSION A(3,3), C(3,3)
SANG=SIN(ANGLE)
CANG=COS(ANGLE)
DO 10 I=1,3
DO 10 J=1,3
10 A(I,J)=0.
M=(-3*K**2+11*K-4)/2
N=(3*K**2-13*K+16)/2
A(K,K)=1.0
A(M,M)=CANG
A(N,N)=CANG
A(M,N)=SANG
A(N,M)=SANG
IF (L) 20,20,50
20 DO 30 I=1,3
DO 30 J=1,3
30 C(I,J)=A(J,I)
DO 40 I=1,3
DO 40 J=1,3
40 A(I,J)=C(I,J)
50 RETURN
END
FUNCTION ARTAN (SANG, CANG, ISW)

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

If ISW=1 the angle is put between 0 and 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+ATAN(SANG/CANG)
   GO TO 5
3 ARTAN=PI/2.
   GO TO 5
4 ARTAN=ATAN(SANG/CANG)
5 IF (ISW) 14,14,6
6 ARTAN=2*PI*ARTAN
   GO TO 14
7 IF (CANG) 8,9,9
8 ARTAN=PI/2.
   GO TO 5
9 ARTAN=0.
   GO TO 14
10 IF (CANG) 11,12,13
11 ARTAN=PI+ATAN(SANG/CANG)
   GO TO 14
12 ARTAN=PI/2.
   GO TO 5
13 ARTAN=ATAN(SANG/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
   TEMP1(I)=-(TEMP2(I)*TEMP3(I))/GM
360 RETURN
END
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
  DX(I)=X(1+3)
R2=X(I)*X(I)+X(2)*X(2)+X(3)*X(3)
R=SQRT(R2)
RI=1./R
R21=1./R2
B=AA*AA*R21
BB=AA*RI
A=(AB(1)*X(1)+AB(2)*X(2)+AB(3)*X(3))*RI
A2=AA*AA
A4=A2*A2
GR=B*(FJ*(1.-5.*A2)+3.*FD*(1./7.-2.*A2+3.*A4)*B+FH*BB*A*(3.-7.*A2)
  1)
GP=B*(2.*FJ*A+4.*FD*A*(3./7.-A2)*B+3.*FH*BB*(A2-1./5.,))

DO 30 I=1,3
  DX(I+3)=-GM*R2I*(1.+GR)*X(I)*RI+GP*AB(I)
RETURN
END
SUBROUTINE FATT (BBB, AAA)

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

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

20 RETURN

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

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

T = T
ICOR = 0

10 HR = T/T/3600.
IHR = HR
XMIN = (T - IHR * 3600.) / 60.
MIN = XMIN
SEC = T - IHR * 3600. - MIN * 60.
IF (ICOR = 1) 20, 30, 30
20 PRINT 40, IHR, MIN, SEC
T = TULO
ICOR = 1
GO TO 10
30 PRINT 50, IHR, MIN, SEC
CNV = 57.29579513
CALL CONIC (RI, VI, AZ, PH, AA, AP, ENC, THN, TH, E, P, A, ALF, RA, RP, C3, PHI1)
ENC1 = ENC * CNV
THN1 = THN * CNV
TH1 = TH * CNV
ALF1 = ALF * CNV
PHI1 = PHI1 * CNV
PRINT 60, T, RI, VI, AA, AP, RA, RP, P, A, E, C3, ENC1, THN1, TH1, ALF1, PHI1
RETURN

40 FORMAT (2X, 1H TIME FROM LIFT-OFF/5H HRS=, I2, 3X, 5H MIN=, I2, 3X, 5H SEC=, 1E15.8//)
50 FORMAT (2X, 15H UNIVERSAL TIME/5H HRS=, I2, 3X, 5H MIN=, I2, 3X, 5H SEC=, 1E15.8//)
60 FORMAT (/3X, 4HTIME, E15.8/5X, 2H X, E15.8, 6X, 1HY, E15.8, 6X, 1HZ, E15.8, 5X, 1HYD, E15.8, 5X, 2HVD, E15.8, 5X, 2HZD, E15.8, 5X, 2H, AA, E15.8, 4X, 3H AP, E15.8, 4X, 3H RA, E15.8, 4X, 3H RP, E15.8, 5X, 2H P, E15.8, 2X, 5H A, E15.8, 3/5X, 2H E, E15.8, 4X, 3H C3, E15.8, 4X, 3H ENC, E15.8, 4X, 3HTH, E15.8, 5X, 2HT H, E15.8, 2X, 5H A, E15.8, 2X, 5H PHI10, E15.8, PHII10, E15.8////)
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))
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=TFB-TFA
RETURN
END
SUBROUTINE HANGLA(T, DT, OMEGA, PHIT)
DIMENSION TEMP1(3), TEMP2(3), TEMP3(3), OMEGA(3), XT(3), XDT(3)

CALL VCROSS (TEMP1, XT, XDT)              A 119
CALL VCROSS (TEMP2, TEMP1, OMEGA)         A 120
CALL VCROSS (TEMP3, TEMP1, TEMP2)         A 121
RRT=VMAG(XT)                               A 122
SINPHI=VDOT(TEMP3,XT)/(VMAG(TEMP3)*RRT)    A 123
COSPHT=VDOT(TEMP2,XT)/(VMAG(TEMP2)*RRT)    A 124
PHIT=ARTAN(SINPHI,COSPHT,1)
RETURN
END
SUBROUTINE TRUE(XP,XDP,TEMP1,PTA)
DIMENSION XP(3),XDP(3),TEMP1(3),TEMP2(3),TEMP3(3)

EP=VMAG(TEMP1)
RMP=VMAG(XP)
CALL VCROSS (TEMP2,XDP,XP) A 549
CALL VCROSS (TEMP3,TEMP1,TEMP2) A 550

COSPTA=V DOT(TEMP1,XP)/(EP*RMP) A 551
SINPTA=V DOT(TEMP3,XP)/(VMAG(TEMP3)*RMP) A 552
PTA=ARTAN(SINPTA,COSPTA,1) A 553
RETURN A 554
END