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M-244-1082
MAY 1972

SHUTTLE ON-ORBIT RENDEZVOUS TARGETING: CIRCULAR ORBITS

Prepared for:

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

UNDER CONTRACT NAS8-21810

CR-123713

N72-25836
(NASA-CR-123713) SHUTTLE ON-ORBIT RENDEZVOUS TARGETING: CIRCULAR ORBITS E.L. Bentley (Northrop Services, Inc., Huntsville, Ala.) May 1972 120 p CSCL 22A
Unclas
G3/30 31361

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by

Earle L. Bentley

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FOREWORD

This memorandum presents the results of work performed by Northrop Services, Inc. while under contract to the Aero-Astrodynamics Laboratory of the Marshall Space Flight Center (NAS8-21810). This task was conducted in response to the requirements of Appendix E-1, Schedule Order No. 3, Technical Directive No. 1. Technical Coordination was provided by Mr. Wayne Deaton of the Guidance Applications Section (R-AERO-GG).

ABSTRACT

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

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LIST OF ILLUSTRATIONS

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

Δi	Wedge angle between planes at TPI
$\Delta \Phi$	Range angle difference at TPI after isolation
$\Delta \theta_N$	Nodal difference at TPI
$\Delta T_{L\phi}$	Lift-off time correction to compensate for nodal regression
$\Delta \phi_{TB}$	First pass Range angle difference using first guess two-body targeting
X_S, Y_S, Z_S	Space fixed launch coordinate system
A_Z	Launch aximuth
ϕ_L	Geodetic latitude of launch site (28.608°)
$\phi_{\overline{SV}}$	Sun vector right ascension
$\alpha_{\overline{SV}}$	Sun vector declination
U.T.	Universal Time measured from midnight Greenwich to launch meridian
λ_L	longitude of launch site
$\Delta \phi$	difference in range angles of orbiter and space station at time of orbiter insertion
ψ	insertion latitude, a function of inclination of the space station
I_D	desired inclination for targeting purposes
P_S	Semi-latus rectum of CDH orbit
e_S	eccentricity of CDH orbit
$\bar{\omega}, \lvert\bar{\omega}\rvert$	earths rotational velocity
P_P	Semi-latus rectum of orbiter on-orbit during Hohmann transfer
e_P	eccentricity of orbiter on-orbit during Hohmann transfer
TULO	Universal time of lift-off
Φ_T	Range angle
ϕ	true anomaly
α_{PL}	argument of perigee

SYMBOLS (Continued)

a	Semi-major axis
e	eccentricity
Ψ_{DS}	desired insertion latitude for southerly launch
Ψ_{DN}	desired insertion latitude for northerly launch
ϕ_{LS}	Range angle at the desired latitude
$\bar{X}_P, \dot{\bar{X}}_P$	State vector position and velocity of orbiter
$\bar{X}_T, \dot{\bar{X}}_T$	State vector position and velocity of space station
T_1	Time of orbit insertion
β_{SVPT}	instantaneous angle from the suns projection vector on orbital plane to the TPI point
β_{SVPD}	same as above but is the desired input value
$\hat{E}_{RA}$	Unit vector in the equatorial plane and through the launch longitude
θ_{NT}	descending node of space station referenced from space-fixed shuttle launch meridian in the equatorial plane
θ_{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
ϕ_T	Range angle of space station measured from the descending node w.r.t. equatorial plane
ϕ_P	Range angle of orbiter measured from descending node w.r.t. equatorial plane
ϕ_{NT}	Range angle of the space station measured from the common (ascending) node of the space station and the orbiter planes
ϕ_{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 < .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 thursting 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 ($\simeq$ 100 x 265 n mi)
- Coelliptic impulse ($\simeq$ 260 n mi)

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

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

**This targeting procedure is developed with impulsive maneuver simulations. Using these targeting values on-orbit will result in ignition time deviations for each maneuver. This could be alleviated by simulating finite burns with the targeting deck itself.*

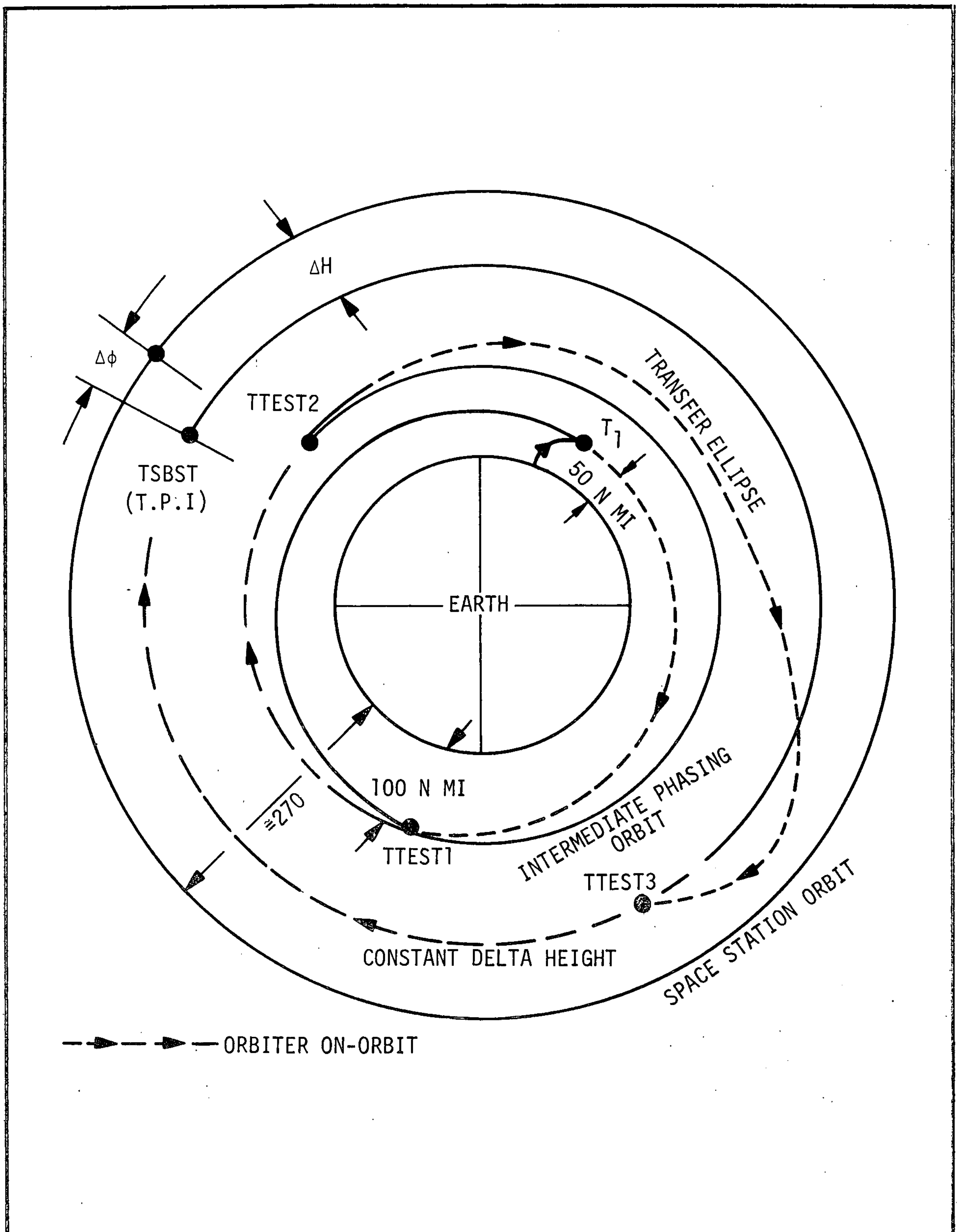


Figure 1-1. COPLANAR PROFILE DEPICTING TIME BASES FOR NEAR-CIRCULAR RENDEZVOUS

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

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 liftimes), 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, eccentricty, 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 emphérical curve-fit coefficients.

Section III
RENDEZVOUS TARGETING TECHNIQUES

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

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

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

The time bases for each on-orbit maneuver are given in Table 3-1. These time bases occur approximately 200 seconds prior to the actual maneuver. The actual times will be presented in Section IV. This timeline includes the insertion time, the time of circularization, time of perigee burn out of the

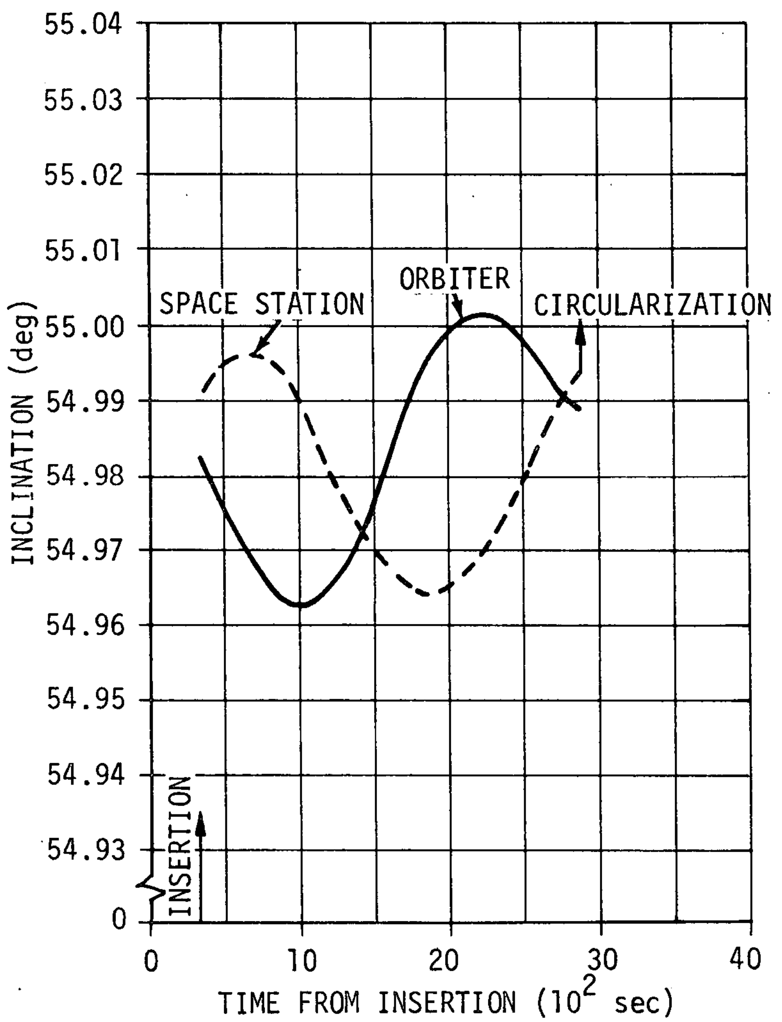


Figure 3-1. ORBITER AFTER INSERTION WITH APPROXIMATE SAME MEAN INCLINATION

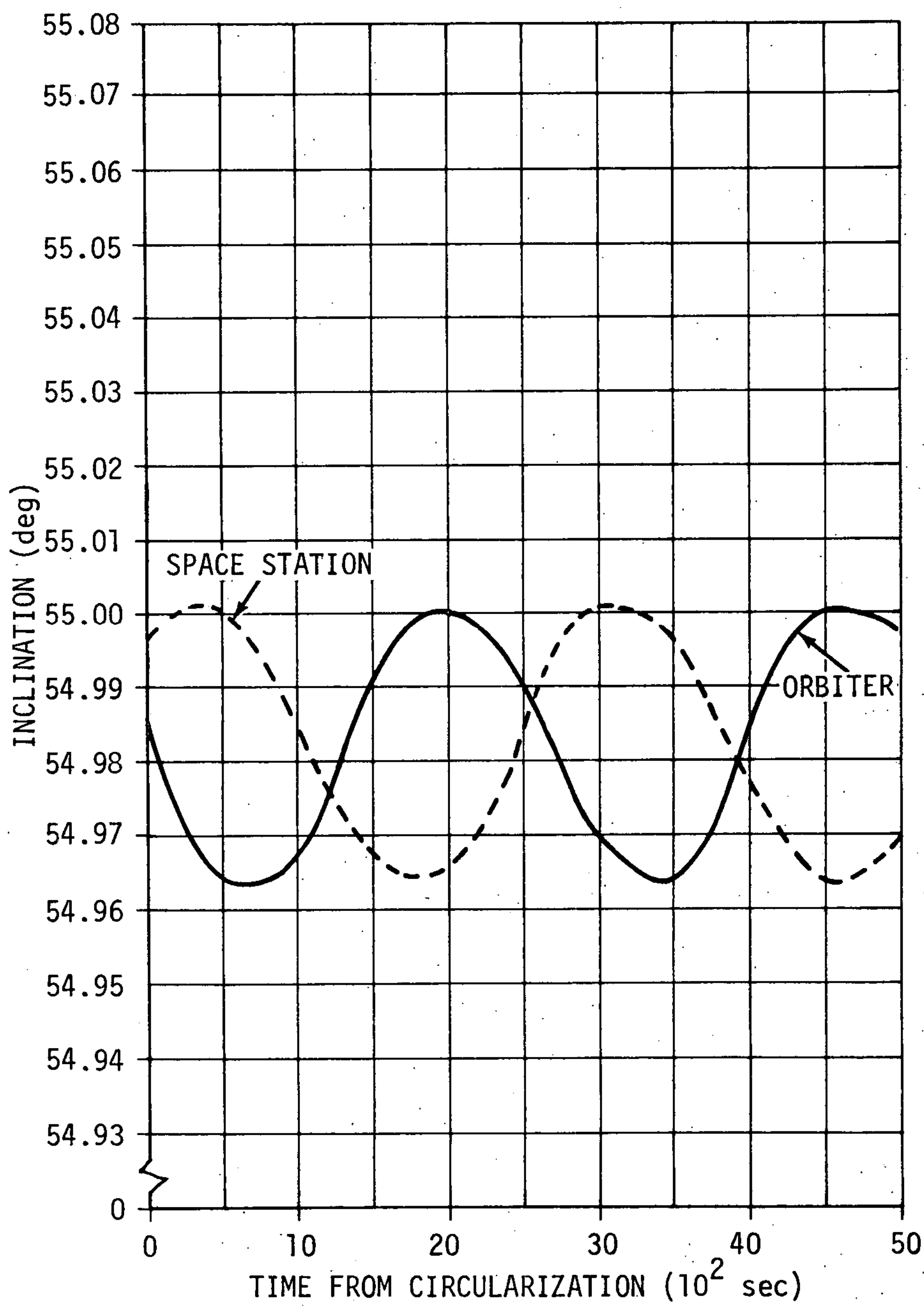


Figure 3-2. ORBITER AFTER CIRCULARIZATION WITH APPROXIMATE SAME MEAN INCLINATION

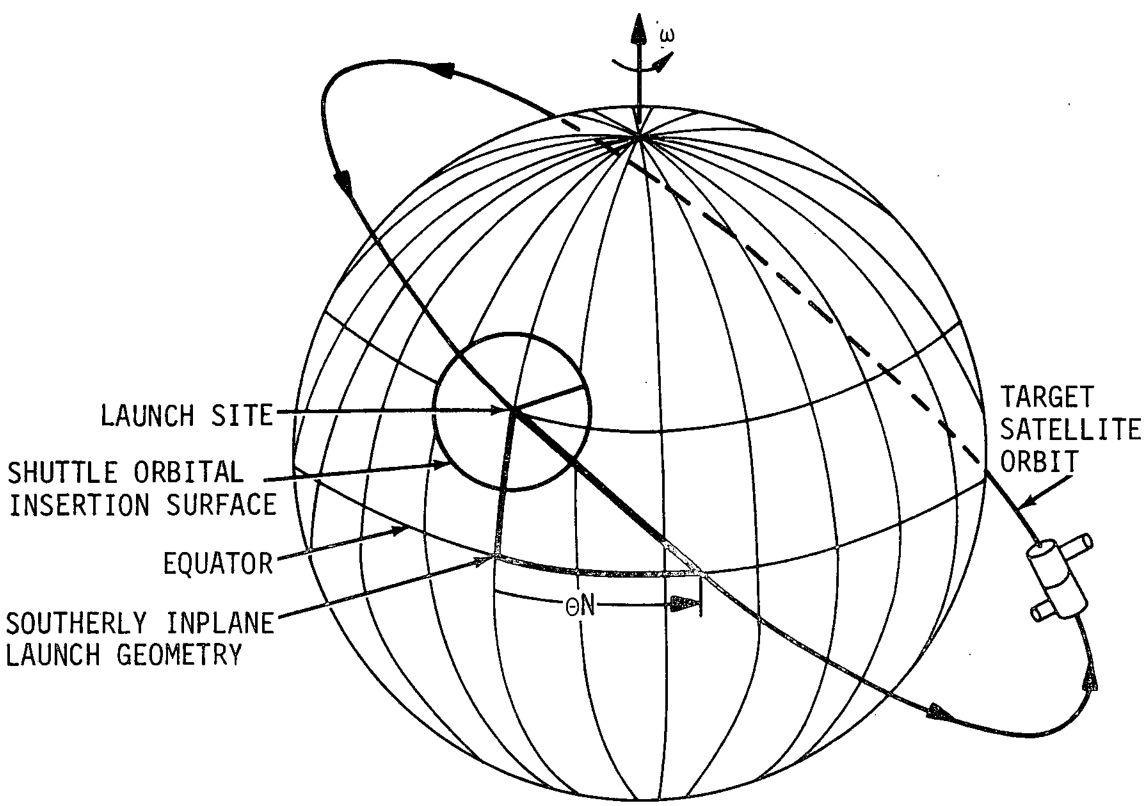


Figure 3-3. SHUTTLE RENDEZVOUS INPLANE LAUNCH GEOMETRY

100 n mi intermediate orbit, time of coelliptic maneuver, and the time of Transfer Phase Initiation (TPI).

Table 3-1. TIME BASES FOR PREPARATION OF MANEUVERS

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

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.

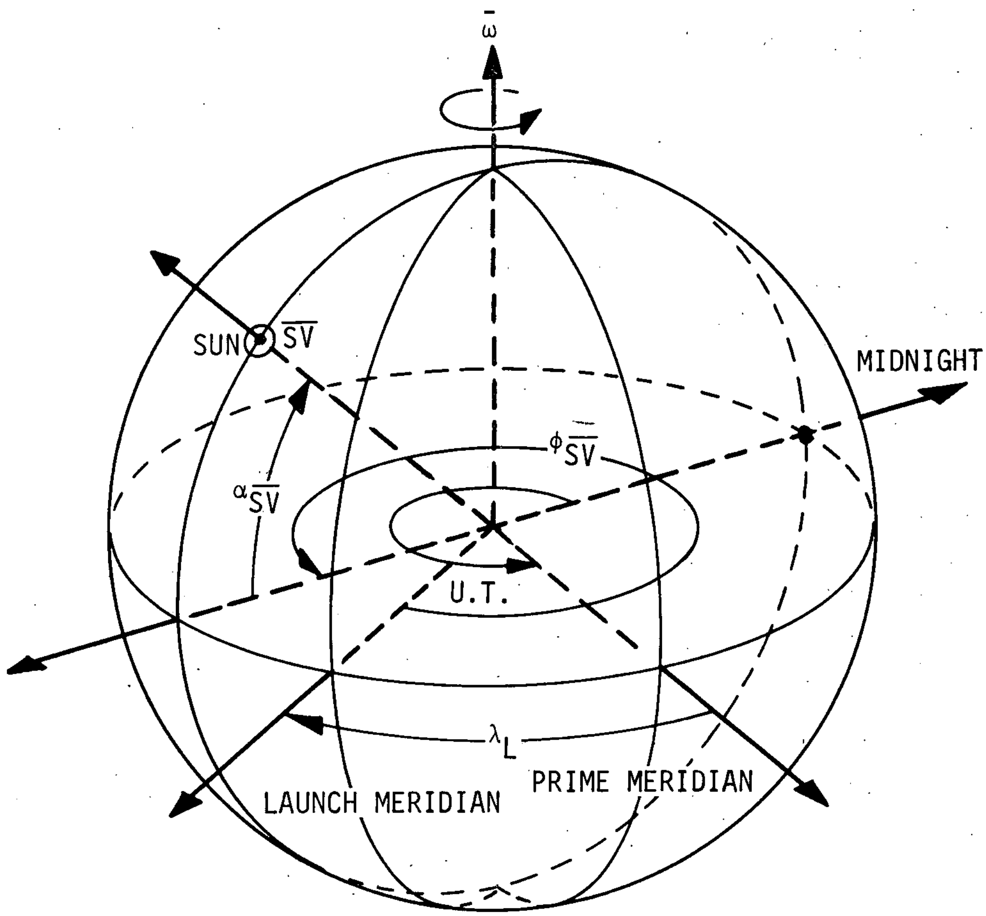
The effects of orbital nodal regression are corrected by adjusting the shuttle lift-off time. Once the desired phase angle ($\Delta\phi_D$) at TPI is isolated, then the existing nodal error is mapped into a Universal Time correction at lift-off. This is demonstrated on page D-18 of the flowchart.

The manner in which the sun's declination and right ascension are evaluated is illustrated in Figure 3-4, and the suns position in the launch coordinate system is depicted in Figure 3-5. Knowledge of the suns 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.

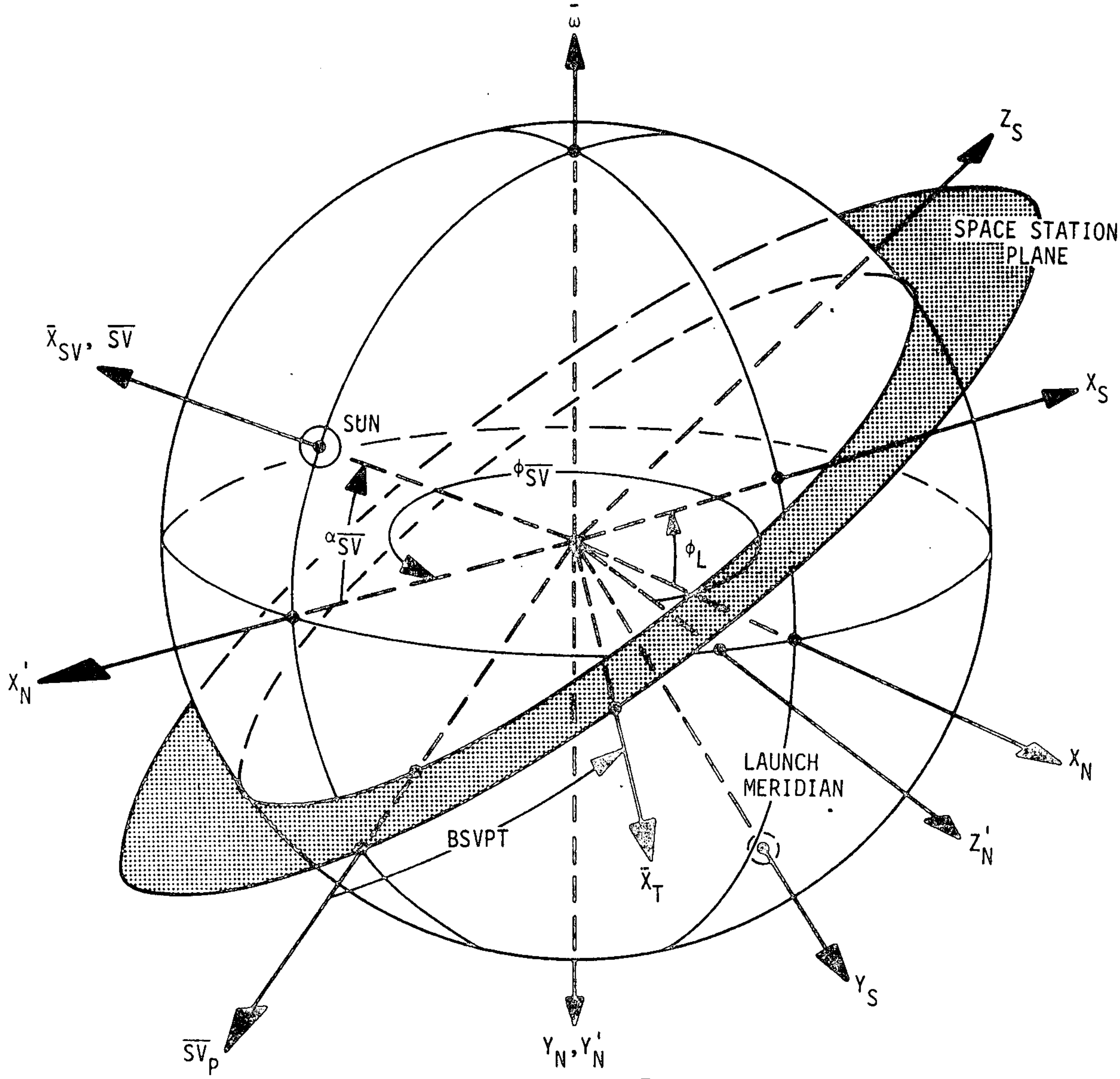
After the perigee maneuver at time base TTEST2, a coast of approximately a half an orbit brings the vehicle to an intersection with the coelliptic orbit. The derivation of the equations for determining the intersection of the near-Hohmann transfer with the Constant Delta Height (CDH) orbit at time base TTEST3 is presented in Appendix A. The equations necessary for determining the desired values for the differential height are included in Appendix



$$\phi_{SV} = \pi + \lambda_L - U.T.|\bar{\omega}|$$

$$\alpha_{SV} = a\ COS(b + c \cdot T_Y)$$

Figure 3-4. RIGHT ASCENTION AND DECLINATION OF SUN WITH RESPECT TO LAUNCH MERIDIAN



$$X_N = [\phi_L]_3 \, [A_Z - \tfrac{\pi}{2}]_1 \, \bar{X}_S$$

$$\bar{X}_{SV} = [-\alpha_{SV}]_3 \, [-\phi_{SV}]_2 \, \bar{X}_N$$

Figure 3-5. ROTATIONS FROM LAUNCH COORDINATE SYSTEM TO SUN VECTOR

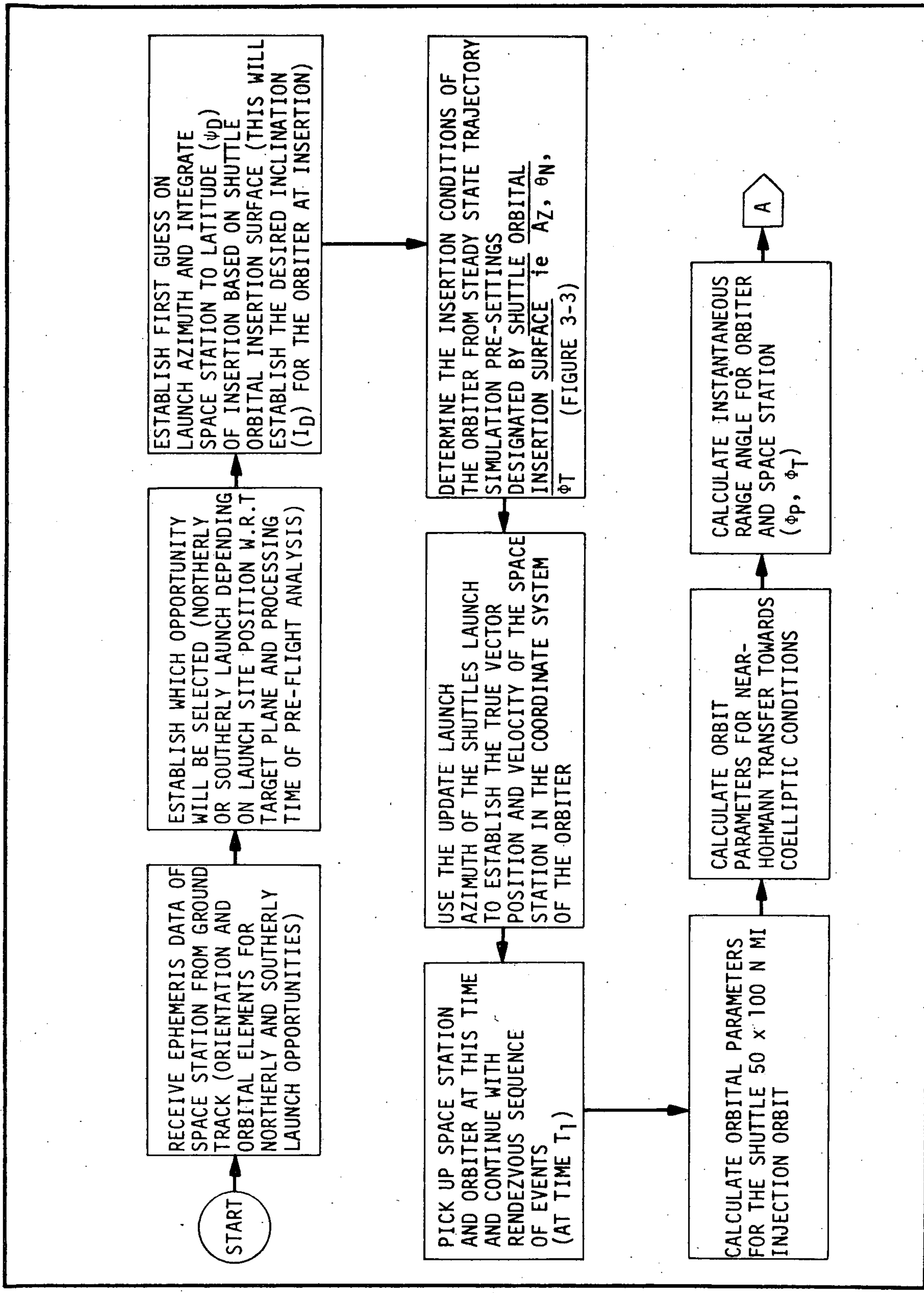


Figure 3-6. GENERAL FLOWCHART TO CORRECT LIFT-OFF TIME FOR NO PLANE CHANGE ON-TIME SHUTTLE ASCENT TARGETING

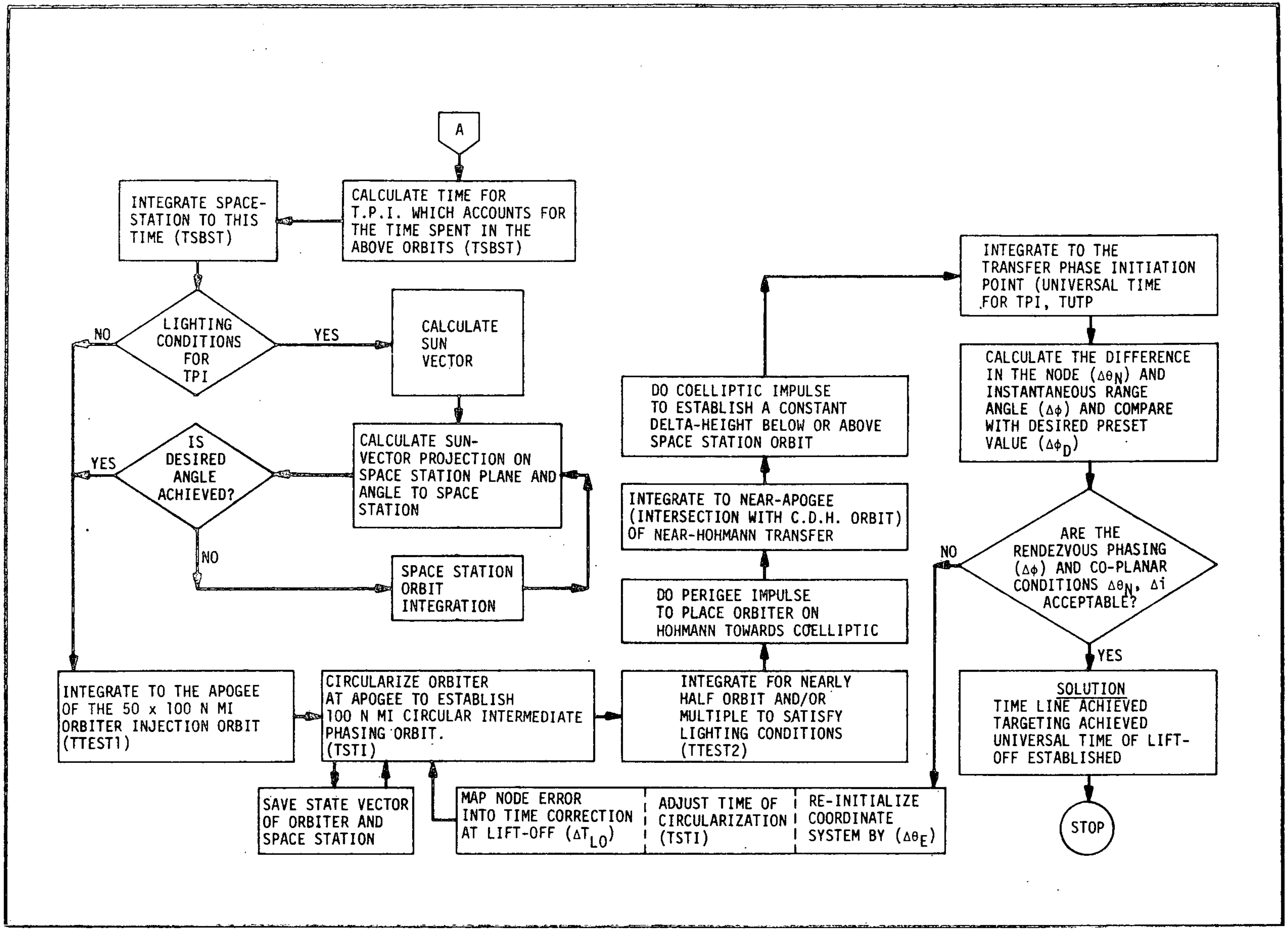


Figure 3-6. GENERAL FLOWCHART TO CORRECT LIFT-OFF TIME FOR NO PLANE CHANGE ON-TIME SHUTTLE ASCENT TARGETING (Concluded)

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 (ΔT_{LO}) for lift-off from this in-plane time (T_N) which will result in coplanar on-orbit phasing near the rendezvous point. It is not a necessary criterion, as stated earlier, that this be a rendezvous compatible orbit, so any $\Delta\phi$ relation may exist at lift-off/insertion and rendezvous can be accomplished through proper on-orbit phasing.

1. *Wessel, V. W., Bentley, E. L., and Sport, R. H., "Guidance Equations for AAP-4 S-IVB/LM-ATM Unmanned Rendezvous", Northrop-Huntsville Technical Report* *TR-795-9-531, April 1969.*

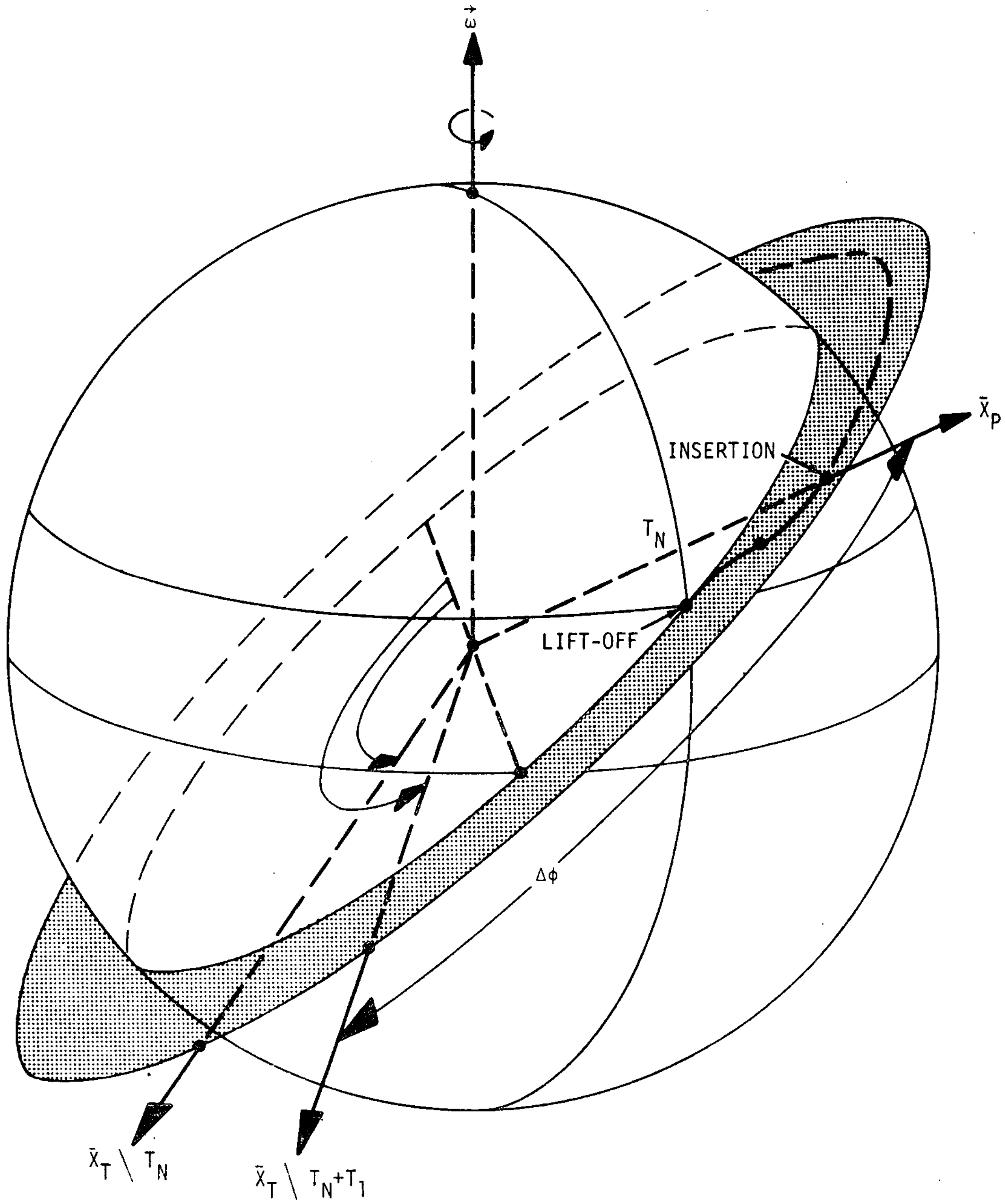


Figure 3-7. SPACE STATION AT ACQUISITION TIME (T_N) AND AT INSERTION ($T_N + T_1$)

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 Δi 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 ΔT_{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.

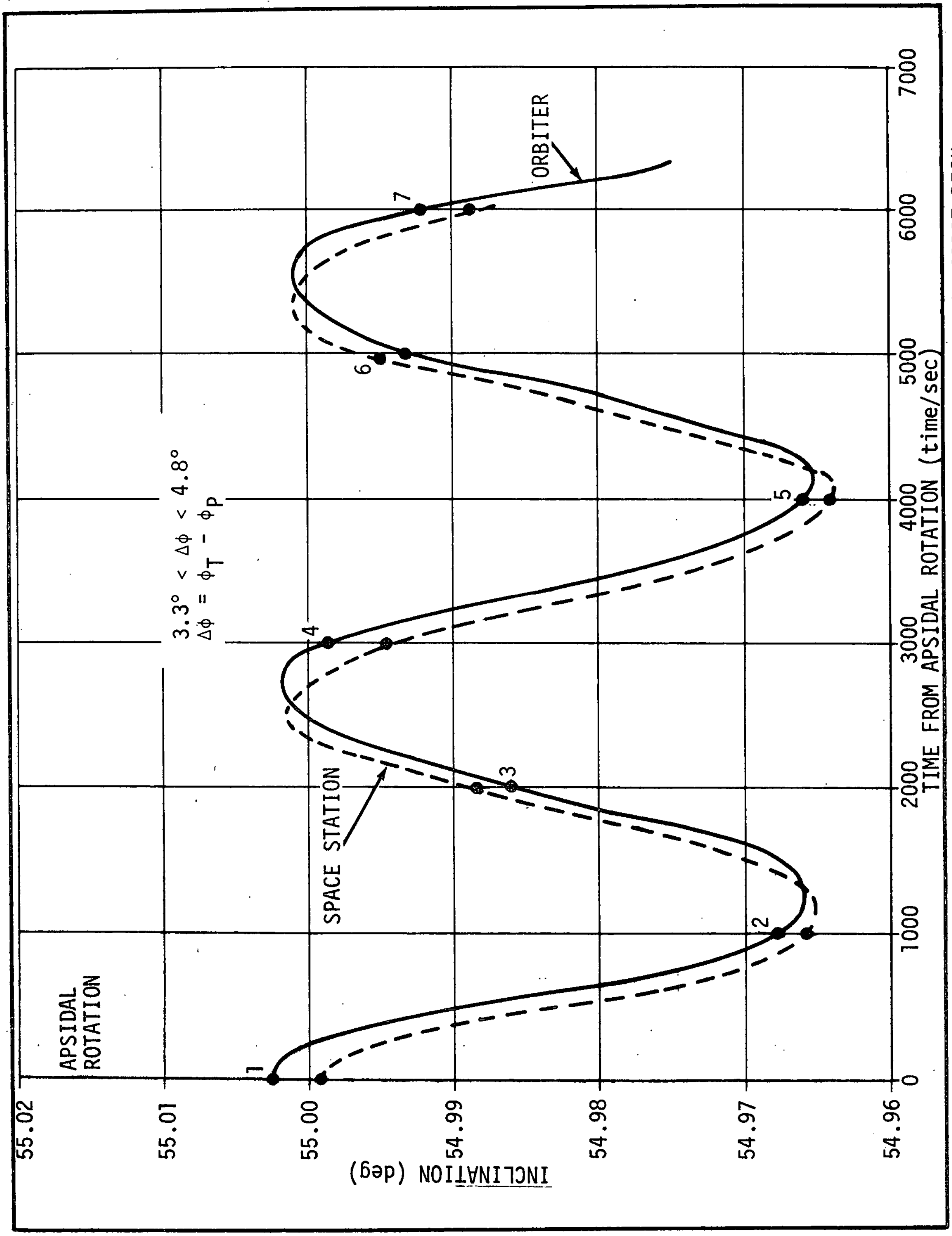


Figure 4-1. INCLINATION SYNCHRONIZATION DURING COELLIPTIC COAST ~ON-ORBIT DECK~

Table 4-1. LIFT-OFF TIME CORRECTION FOR NEAR-CIRCULAR TARGET ORBITS FOR NORTHERLY LAUNCH WITH NO LIGHTING CONSTRAINT

TRUE ANOMALY	45°	135°	255°	315°
ABOVE AND AHEAD / RANGE ANGLE	255°	345°	75°	165°
Insertion	0 hr. 6 m. 11 s.	0 hr. 6 m. 11 s.	0 hr. 6 m. 11 s.	0 hr. 6m 11 s.
Circularization	0 hr. 48 m. 27 s.	0 hr. 48 m. 27 s.	0 hr. 48 m. 27 s.	0 hr. 48 m. 27 s.
Perigee	1 hr. 26 m. 7 s.	7 hr. 14 m. 41 s.	12 hr. 23 m. 5 s.	18 hr. 36 m. 11 s.
Constant Delta Height	2 hr. 14 m. 33 s.	8 hr. 4 m. 42 s.	13 hr. 13 m. 17 s.	19 hrs. 27 m. 3 s.
Transfer Phase Initiation	5 hr. 48 m. 19 s.	11 hr. 10 m. 59 s.	16 hr. 37 m. 46 s.	21 hr. 58 m. 17 s.
Sun Angle (deg)	N. A.	N. A.	N. A.	N. A.
Δi (deg)	5.3×10^{-4}	1.1×10^{-2}	6.9×10^{-4}	4.4×10^{-4}
$\Delta\Phi$ (deg)	0.29	0.32	0.28	0.24
$\Delta\theta_N$ (deg)	-4.0×10^{-4}	-1.3×10^{-2}	-2.8×10^{-4}	4.6×10^{-4}
ΔT_{LO} (sec)	-284.7	-226.4	-199.06	-143.6
$\Delta\Phi_{TB}$ (deg)	-.81	-2.21	-4.43	5.94
SFN03 (unitless)	1.5	1.5	1.5	1.5

Table 4-2. LIFT-OFF TIME CORRECTION FOR NEAR-CIRCULAR TARGET ORBITS FOR SOUTHERLY LAUNCH WITH LIGHTING CONSTRAINT

TRUE ANOMALY	45°	135°	225°	315°
ABOVE AND AHEAD / RANGE ANGLE	255°	345°	75°	165°
Insertion	0 hr. 6 m. 11 s.	0 hr. 6 m. 1111 s.	0 hr. 6 m. 11 s.	0 hr. 6 m 11 s.
Circularization	0 hr. 50 m. 48 s.	0 hr. 60 m. 4 48 s.	0 hr. 50 m. 48 s.	0 hr. 50 m. 48 s.
Perigee	18 hr. 27 m. 36 s.	2 hr. 39 m. 29 s.	7 hr. 51 m. 52 s.	13 hr. 30 m. 17 s.
Constant Delta Height	19 hr. 16 m. 59 s.	3 hr. 30 m. 3 s.	8 hr. 42 m. 23 s.	14 hr. 19 m. 59 s.
Transfer Phase Initiation	26 hr. 22 m. 50 s.	8 hr. 37 m. 27 s.	14 hr. 33 m. 22 s.	18 hr. 50 m. 34 s.
Sun Angle (deg)	109.91	109.88	109.92	109.84
Δi (deg)	8.17×10^{-4}	2.8×10^{-3}	7.9×10^{-3}	1.27×10^{-3}
$\Delta\Phi$ (deg)	-.332	-.256	-.317	-.278
$\Delta\theta_N$ (deg)	-1.87×10^{-4}	-2.53×10^{-3}	-9.3×10^{-3}	5.2×10^{-4}
ΔT_{LO} (sec)	319.65	190.1	235.9	275.42
$\Delta\Phi_{TB}$ (deg)	35.5	13.36	22.7	16.11
SFN03 (unitless)	4.0	3.0	3.5	2.5

The results presented in Tables 4-1 and 4-2 are for effecting rendezvous with the baseline target in a 270 n mi orbit with an approximate 55 degree inclination. Rendezvous targeting was accomplished in all cases considered, with a time constraint of approximately 24 hours to the TPI point.

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

The executed listing presented as an example in Appendix C gives the eccentricity vector $\bar{e}$, angular momentum ($\bar{h}$) and delta velocity required ($\overline{\Delta V_R}$) 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

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

Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS (Continued)

MATH SYMBOL	FORTRAN ALFA-NUMERIC NAME	DEFINITION OF SYMBOL; SCALE FACTOR, FLAG, VARIABLE, ETC.	UNITS
T_N	TN	The universal time of the in-plane opportunity for northerly launch.	Sec
T_S	TS	The universal time of the in-plane opportunity for southerly launch	Sec
TTOL	TTOL	Maximum time necessary to perform pre-flight analysis using this targeting deck.	Sec
HAP	HAP	Altitude of apogee of orbiter insertion ellipse	N MI
H_{PER}	HPER	Altitude of perigee of orbiter insertion.	N MI
A_N	AN	Semi-major axis of space station received from tracking network for northerly opportunity (T_N).	M
e_N	EN	Eccentricity of space station received from tracking network for northerly opportunity (T_N).	Unitless
i_N	X_{ENCN}	Inclination of space station received from tracking network for northerly opportunity (T_N).	Deg
θ_{NN}	TNNN	Descending node for northerly launch (TN).	Deg
α_{PLN}	ALFAN	Argument of perigee for northerly launch (measured from descending node opposite direction of flight).	Deg
Φ_N	PNIN	True anomally of space station for northerly launch.	Deg
A_S	AS	Semi-major axis for southerly launch.	M
e_S	ES	Eccentricity for southerly launch	Unitless
i_S	XENCS	Inclination for southerly launch.	Deg
θ_{NS}	THNS	Node for southerly launch.	Deg
α_{PLS}	ALFAS	Argument of perigee for southerly launch.	Deg
Φ_S	PHIS	True anomally for southerly launch.	Deg
ϕ_L	PHI	Geodetic latitude of launch site measured from equatorial plane.	Deg

Table 5-1. INPUTS FOR NEAR-CIRCULAR RENDEZVOUS (Concluded)

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

The <u>first</u> <u>input</u> <u>card</u> contains two fixed point options with a 2I2 format. Presently the first option ISURF is flaged 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 β_{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 ϕ_L, longitude λ_L, desired sun angle β_{SVD}, and coefficients for calculation of the suns declination A1, B1, C1 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 (ΔH) for the final phasing orbit (coelliptic) before TPI. The desired phase angle ($\Delta\phi$) at TPI is determined as a function of ΔH and is presently read in as a linear function with a slope SLM.

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

A list of sample input data is presented in Table 5-2. It should be noted that only two coefficients are listed for each surface or polynomial curve fit variable.

Table 5-2. INPUT LISTING OF DATA

CARD						
1	1 1					
2	27.785842	.15193435				
3						
4	16.249967	.069000928				
5						
6	106.6733954	-1.2483319				
7						
8	113.74390	.81471544				
9						
10	361.2315599	.19373362				
11						
12	71.972429	1.2579258				
13						
14	69.504248	-.842646				
15						
16	359.43239	.2231473				
17						
18	250.25958	-.43718955				
19						
20	309.06871	.47380784				
21						
22	1000.0	2000.0	3000.	900.	100.	50.0
23	6878206.0	0.00001	55.0	157.3	150.0	135.0
24	6878206.0	0.00001	55.0	23.9	150.0	315.0
25	28.608	-80.0	110.	23.444	192.4205	.9703504
26	.0000074	300.	10.0	4.0	.5	.5
27	1.5	.029				

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 $(\bar{e},\bar{h},\overline{\Delta v})$. Both Universal Time and mission time from lift-off for each maneuver is located at the top of the page, along with the state variables of the orbiter and space station.

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

Appendix A

INTERSECTION OF NEAR-HOHMANN TRANSFER WITH CDH ORBIT

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

Considering the equation

$$\Delta\alpha = \alpha_T - \alpha_P$$

where α_T is the argument of perigee of the space station orbit and α_P is the argument of perigee of the orbiter orbit, then

$$\theta_S = \theta_P + \Delta\alpha$$

where θ_S is the true anomaly of the CDH orbit and θ_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 trigometric 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

$$(-\beta^2-\Delta^2)\sin^2\theta_P + 2P_o\beta\sin\theta_P + \Delta^2 - P_o = 0 \quad .$$

In order to sove this quadratic, let

$$A = -\beta^2 - \Delta^2$$

$$B = 2P_o\beta$$

$$C = \Delta^2 - P_o^2$$

and the equation is solved by

$$\sin \theta_P = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

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 ΔH is computed it is utilized to construct the conic parameters of the CDH orbit.

Appendix C

SAMPLE OUTPUT: NORTHERLY LAUNCH

```
NORTHERLY LAUNCH

ORBITAL ELEMENTS OF SPACE STATION IN-PLANE POINT
  TIME 2.00000000E 03      AT 6.87820600E 06     ET 1.00000000E-05 XENCTO 5.50000000E 01
 THNTO 1.57300000E 02 ALFATO 1.50000000E 02  PHIIO 1.35000000E 02

FIRST GUESS OF THE LAUNCH AZIMUTH= 4.07937885E 01

THIS IS THE SOLUTION
INSTANTANEOUS LATITUDE OF INSERTION= 3.61399589E 01

DESIRED LATITUDE FOR INSERTION= 3.61397361E 01

DESIRED VALUE OF INCLINATION FOR TARGETING PURPOSE= 5.49829971E 01

ACTUAL LAUNCH AZIMUTH FROM ORBITER INSERTION= 3.80363512E 01

STATE VARIABLES OF ORBITER AT INSERTION
    XP 6.35106382E 06      YP 1.23887509E 05      ZP 1.23266090E 06
   XDP-1.50517753E 03     YDP 2.92723039E 02     ZDP 7.72573693E 03

STATE OF SPACE STATION

  TIME FROM LIFT-OFF
HRS= 0    MIN=39     SEC= 3.18836150E 01

  UNIVERSAL TIME
HRS= 0    MIN=39     SEC= 3.18836150E 01

   TIME 2.37189351E 03
      X-6.10996065E 06      Y 1.76174186E 05      Z 3.15247199E 06     XD-3.49187794E 03     YD-3.29287123E 02     ZD-6.75765994E 03
     AA 2.72289494E 02     AP 2.68349663E 02     RA 6.88244614E 06     RP 6.87514958E 06      P 6.87879592E 06      A 6.87879786E 06
      E 5.30366403E-04     C3-5.79466363E 07    ENC 5.50017214E 01    THN 1.57299353E 02     TH 2.89916810E 02  ALFAD 2.81331713E 02
  PHIIO 8.58509741E 00

THIS IS THE SOLUTION
STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSERTION
    XT-6.10996085E 06      YT 1.76174186E 05      ZT 3.15247199E 06
   XDT-3.49187794E 03     YDT-3.29287123E 02     ZDT-6.75765994E 03
```

```
PARAMETERS FOR 50X100 N.M. PHASING ORBIT/

   RHP 6.47076600E 06     VVP 7.87643684E 03 GAMMAP-2.81045834E-10      EP 7.10442689E-03
    AP 6.51706600E 06     HAP 1.00000011E 02     HPP 4.99999902E 01 PHDOTP 6.87566714E-02

PARAMETERS FOR THE TARGET ORBIT

   RRT 6.87755324E 06     VVT 7.61364626E 03 GAMATO-2.85674250E-02      ET 5.30393840E-04
    AT 6.87879782E 06     HAT 2.72289576E 02     HPT 2.68349542E 02 PHDOTT 6.34051019E-02

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

ORBITAL CATCH UP RATE= 5.35156949E-03
ANGLE OF CATCH UP= 1.40100222E 01

TIME AT APOGEE OF 50X100 ORBIT= 2.98981135E 03
FIRST MANUVER TO CIRCULARIZE 80X100 AT ITS APOGEE/
   RCP 6.56336602E 06     VCP 7.79304310E 03  TAUCP 5.29175108E 03 PDOTCO 6.80304097E-02
 DLPD2 8.07268494E-05 DLMR20 1.22379887E 01  DELV2 2.77318951E 01      T3 5.63568689E 03

SECOND BURN TRANSFER OUT OF 100 NM CIRCULAR TOWARDS    COELLIPTIC

ORBITAL PERIOD= 5.47460173E 03
MEAN ORBITAL RATE= 6.57582070E-02
CATCH UP RATE= 2.35310504E-03
IMPULSE REQUIREMENT= 3.67692838E 01
TIME INTO FLIGHT= 8.37298775E 03
 DPHR3 6.44115645E 00

COELLIPIC ORBIT PLACING VEHICLE IN CDH ORBIT

   EP3 2.29233454E-02   HPP4 6.85662935E 06   RAP4 6.86392630E 06    AP4 6.86027782E 06
   EP4 5.31825699E-04   TH40 1.62350487E 02     R4 6.86375438E 06     V4 7.53710346E 03
GAMA40 4.07103849E-01    VT4 7.61867509E 03 GAMT40 9.24340470E-03  DELV4 9.70709611E 01

THE TPI IGNITION ANGLE IN RELATION TO THE TAAGET= 2.90000000E-01
THIS SECTION DETERMINES THE CATCH UP RATE IN THE CDH   ORBIT
IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE  FOR THE TOTAL MISSION

 TAUP4 5.65466220E 03 PDPA40 6.36620277E-02 DPDCUO 2.56925742E-04 DLMR40 3.92219917E 00
  TTPI 2.36786741E 04  DMRTO 3.66113665E 01   DVIT 2.11572140E 02
```

```
RANGE ANGLE OF PURSUIT= 2.26221587E 02

RANGE ANGLE OF TARGET= 8.58509741E 00


PHASE ANGLE DPA1= 1.42363504E 02

 5.00000000E-01  5.00000000E-01  1.50000000E 00


STATE OF SPACE STATION


  TIME FROM LIFT-OFF
HRS= 0    MIN= 6    SEC= 1.18836149E 01


  UNIVERSAL TIME
HRS= 0    MIN=39    SEC= 3.18836150E 01


  TIME 3.71883615E 02
     X-6.10996085E 06      Y 1.76174186E 05      Z 3.15247199E 06     XD-3.49187794E 03     YD-3.29287123E 02     ZD-6.75765994E 03
    AA 2.72289494E 02     AP 2.68349663E 02     RA 6.88244614E 06     RP 6.87514958E 06      P 6.87879592E 06      A 6.87879786E 06
     E 5.30366403E-04     C3-5.79466363E 07    ENC 5.50017214E 01    THN 1.57299353E 02     TH 2.89916810E 02  ALFAD 2.81331713E 02
 PHI10 8.58509741E 00


STATE OF SPACE STATION


  TIME FROM LIFT-OFF
HRS=11    MIN= 7    SEC= 1.32018452E 01


  UNIVERSAL TIME
HRS=11    MIN=40    SEC= 3.32018452E 01


  TIME 4.00332018E 04
     X-5.99729311E 06      Y 3.82867813E 05      Z 3.34508126E 06     XD-3.71859883E 03     YD-3.50232201E 02     ZD-6.63429090E 03
    AA 2.72292962E 02     AP 2.68494074E 02     RA 6.88228589E 06     RP 6.87541702E 06      P 6.87884974E 06      A 6.87885145E 06
     E 4.99273760E-04     C3-5.79461848E 07    ENC 5.50016631E 01    THN 1.55278602E 02     TH 2.88375993E 02  ALFAD 2.80565071E 02
 PHI10 7.81092163E 00


COMPUTATIONS FOR SECTION 4-8


 DPH10 2.26304981E 01  DPH20 1.19443006E 02     DT2 2.58237963E 04  TSBST 4.00332018E 04
   DT1 1.38375219E 04     T1 3.71883615E 02  TTEST1 2.78981135E 03 TTEST2 2.88136077E 04


STATE OF SPACE STATION
```

```
  TIME FROM LIFT-OFF
HRS=11    MIN=24    SEC= 3.24192667E 01

  UNIVERSAL TIME
HRS=11    MIN=57    SEC= 5.24192667E 01

  TIME 4.10724193E 04
     X-5.50931649E 06     Y-1.35183987E 05     Z-4.10361166E 06     XD 4.55098060E 03     YD-5.35778388E 02     ZD-6.08128540E 03
    AA 2.67853936E 02    AP 2.60261634E 02    RA 6.87423149E 06    RP 6.86017055E 06      P 6.86719382E 06      A 6.86720102E 06
     E 1.02377549E-03    C3-5.80444925E 07   ENC 5.49678252E 01   THN 1.55231753E 02     TH 2.37361915E 02  ALFAD 1.63578714E 02
 PHIIO 7.37832010E 01

COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10

     AO 2.34440000E 01     BO 1.92420500E 02     CO 9.70350400E-01     TY 3.00000000E 02
LAMDAO-8.00000000E 01  PHSVO 9.16438477E 01  ALSVO-1.29483511E 01 BSVPTO 1.10000066E 02
STATE OF SPACE STATION

  TIME FROM LIFT-OFF
HRS= 0    MIN=46    SEC= 2.98113475E 01

  UNIVERSAL TIME
HRS= 1    MIN=19    SEC= 4.98113475E 01

  TIME 2.78981135E 03
     X 4.06068973E 06     Y-3.03268806E 05     Z-5.53177943E 06     XD 6.14933835E 03     YD 2.03665611E 02     ZD 4.50003544E 03
    AA 2.74826287E 02    AP 2.64850041E 02    RA 6.88714428E 06    RP 6.86866828E 06      P 6.87789387E 06      A 6.87790628E 06
     E 1.34314185E-03    C3-5.79541479E 07   ENC 5.49990900E 01   THN 1.57155695E 02     TH 1.28212523E 01  ALFAD 2.10585245E 02
 PHIIO 1.62236007E 02

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 0    MIN=46    SEC= 2.98113475E 01

  UNIVERSAL TIME
HRS= 1    MIN=19    SEC= 4.98113475E 01

  TIME 2.78981135E 03
     X-6.55652100E 06     Y-5.20270137E 04     Z 3.04111482E 05     XD-3.65055461E 02     YD-3.23571831E 02     ZD-7.75136347E 03
    AA 1.00504806E 02    AP 5.28489690E 01    RA 6.56430090E 06    RP 6.47604229E 06      P 6.51987292E 06      A 6.52017160E 06
     E 6.76812013E-03    C3-6.11338509E 07   ENC 5.49926519E 01   THN 1.58388500E 02     TH 1.71215141E 02  ALFAD 1.38559892E 02
 PHIIO 3.26552490E 01
```

```
STATE OF SPACE STATION

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

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

  TIME 2.90781135E 03
     X 4.74950011E 06   Y-2.76728243E 05   Z-4.95491811E 06   XD 5.50868893E 03   YD 2.45559879E 02     ZD 5.26329056E 03
    AA 2.75539094E 02  AP 2.64993047E 02  RA 6.88846440E 06   RP 6.86893312E 06    P 6.87868490E 06      A 6.87869876E 06
     E 1.41969277E-03  C3-5.79474711E 07 ENC 5.50013969E 01  THN 1.57154975E 02   TH 1.27562463E 01  ALFAD 2.03017000E 02
 PHI10 1.69739246E 02

STATE OF ORBITER

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

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

  TIME 2.90781135E 03
     X-6.53519538E 06   Y-8.96246900E 04   Z-6.10475675E 05   XD 7.25775072E 02   YD-3.12665863E 02     ZD-7.72473163E 03
    AA 1.00482044E 02  AP 5.09504960E 01  RA 6.56425875E 06   RP 6.47252632E 06    P 6.51806980E 06      A 6.51839253E 06
     E 7.03643014E-03  C3-6.11505361E 07 ENC 5.49871015E 01  THN 1.58383434E 02   TH 1.79888744E 02  ALFAD 1.39231967E 02
 PHI10 4.06567772E 01
```

```
TARGETING VALUES FOR THE COV 100 NM CIRCULARZATION AT  APOGEE

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

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

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

  TIME 2.90781135E 03
     X-6.53519538E 06    Y-8.96246900E 04     Z-6.10475675E 05    XD 7.25775072E 02    YD-3.12665063E 02     ZD-7.72473163E 03
    AA 1.00482044E 02   AP 5.09504960E 01    RA 6.56425875E 06    RP 6.47252632E 06     P 6.51806980E 06      A 6.51839253E 06
     E 7.03643014E-03   C3-6.11505361E 07   ENC 5.49871015E 01   THN 1.58383434E 02    TH 1.79888744E 02  ALFAD 1.39231967E 02
 PHIIO 4.06567772E 01

TARGETING VALUES FOR DESIRED ELLIPSE
ANGULAR MOMENTUM VECTOR
 AM(1) 5.03225843E 08  AM(2)-5.11058170E 10  AM(3) 2.11583172E 09
ECCENTRICITY VECTOR
 EV(1) 5.82076609E-11  EV(2) 9.09494702E-13  EV(3) 1.81898940E-12
VELOCITY TO BE GAINED VECTOR
 VG(1) 2.67373496E 00  VG(2)-1.10439716E 00  VG(3)-2.73115345E 01

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 8     MIN=42     SEC= 5.38091555E 01

  UNIVERSAL TIME
HRS= 9     MIN=16     SEC= 1.38091555E 01

  TIME 3.13738092E 04
     X 5.16290575E 06    Y-2.78978799E 05     Z-4.04594755E 06    XD 4.81240415E 03    YD 2.90706534E 02     ZD 6.12480542E 03
    AA 1.06330348E 02   AP 1.00816853E 02    RA 6.57508980E 06    RP 6.56487881E 06     P 6.56998834E 06      A 6.56998431E 06
     E 7.77094189E-04   C3-6.06703425E 07   ENC 5.50045691E 01   THN 1.56653152E 02    TH 3.36645865E 02  ALFAD 1.58506705E 02
 PHIIO 1.78139160E 02

STATE OF SPACE STATION

  TIME FROM LIFT-OFF
HRS= 8     MIN=42     SEC= 5.38091555E 01
```

```
THIS IS THE SOLUTION

THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO=-2.29565903E 02
STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 7    MIN= 8    SEC= 6.57478285E 00

  UNIVERSAL TIME
HRS= 7    MIN=37    SEC= 3.70088792E 01

  TIME 2.56865748E 04
     X 2.76991562E 06    Y-3.33766996E 05    Z-5.94341767E 06    XD 7.06496864E 03    YD 1.27596709E 02    ZD 3.28494640E 03
    AA 1.02532416E 02   AP 1.01212106E 02   RA 6.56805603E 06    RP 6.56561082E 06     P 6.56683820E 06     A 6.56683343E 06
     E 1.86179113E-04   C3-6.06994531E 07  ENC 5.49949598E 01   THN 1.56973787E 02    TH 1.81491415E 01 ALFAD 2.27095011E 02
 PHIIO 1.51054130E 02

STATE OF SPACE STATION

  TIME FROM LIFT-OFF
HRS= 7    MIN= 8    SEC= 6.57478285E 00

  UNIVERSAL TIME
HRS= 7    MIN=37    SEC= 3.70088792E 01

  TIME 2.56865748E 04
     X 4.02865421E 06    Y-3.22552642E 05    Z-5.55397672E 06    XD 6.17507762E 03    YD 1.95149179E 02    ZD 4.46514449E 03
    AA 2.74628746E 02   AP 2.64820159E 02   RA 6.88714884E 06    RP 6.86861294E 06     P 6.87786840E 06     A 6.87788089E 06
     E 1.34750098E-03   C3-5.79543619E 07  ENC 5.49990093E 01   THN 1.56960145E 02    TH 1.22894740E 01 ALFAD 2.10270412E 02
 PHIIO 1.62019062E 02

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 7    MIN= 8    SEC= 6.57478285E 00

  UNIVERSAL TIME
HRS= 7    MIN=37    SEC= 3.70088792E 01

  TIME 2.56865748E 04
     X 2.76991562E 06    Y-3.33766996E 05    Z-5.94341767E 06    XD 7.06496864E 03    YD 1.27596709E 02    ZD 3.28494640E 03
    AA 1.02532416E 02   AP 1.01212106E 02   RA 6.56805603E 06    RP 6.56561082E 06     P 6.56683820E 06     A 6.56683343E 06
     E 1.86179113E-04   C3-6.06994531E 07  ENC 5.49949598E 01   THN 1.56973787E 02    TH 1.81491415E 01 ALFAD 2.27095011E 02
 PHIIO 1.51054139E 02
```

```
TARGETING VALUES FOR THE COV PERIGEE BURN

POSITION VECTOR FOR IGNITION

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 7    MIN= 2     SEC= 6.57478285E 00

  UNIVERSAL TIME
HRS= 7    MIN=37     SEC= 3.70088792E 01

  TIME 2.56865748E 04
     X 2.76991592E 06     Y-3.33766996E 05     Z-5.94341767E 06     XD 7.06496864E 03     YD 1.27596709E 02     ZD 3.28494640E 03
    AA 1.02532416E 02    AP 1.01212106E 02    RA 6.56805603E 06     RP 6.56561082E 06      P 6.56683320E 06      A 6.56683343E 06
     E 1.86179113E-04    C3-6.06994531E 07   ENC 5.49949598E 01    THN 1.56973787E 02     TH 1.81491415E 01  ALFAD 2.27095011E 02
 PHIIO 1.51054130E 02

TARGETING VALUES FOR DESIRED ELLIPSE
ANGULAR MOMENTUM VECTOR
 AM(1)-3.41896310E 08  AM(2)-5.16709570E 10  AM(3) 2.74236766E 09
ECCENTRICITY VECTOR
 EV(1)-4.21878392E-01  EV(2) 5.08351639E-02  EV(3) 9.05226146E-01
VELOCITY TO BE GAINED VECTOR
 VG(1) 8.02731241E 01  VG(2) 1.47648403E 00  VG(3) 3.78273233E 01

AFTER  PERIGEE BURN AT TIME TTEST2

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 7    MIN= 8     SEC= 6.57478285E 00

  UNIVERSAL TIME
HRS= 7    MIN=37     SEC= 3.70088792E 01

  TIME 2.56865748E 04
     X 2.76991592E 06     Y-3.33766996E 05     Z-5.94341767E 06     XD 7.14524177E 03     YD 1.29073193E 02     ZD 3.32277373E 03
    AA 2.60627435E 02    AP 1.01244913E 02    RA 6.87603441E 06     RP 6.56567158E 06      P 6.71726993E 06      A 6.72085299E 06
     E 2.30895417E-02    C3-5.93084238E 07   ENC 5.49949598E 01    THN 1.56973787E 02     TH                 0  ALFAD 2.08945870E 02
 PHIIO 1.51054130E 02

STATE OF SPACE STATION
```

```
  TIME FROM LIFT-OFF
HRS= 7    MIN=49    SEC= 3.82503738E 01

  UNIVERSAL TIME
HRS= 8    MIN=19    SEC= 8.68447018E 00

  TIME 2.81782504E 04
     X-1.67654559E 06     Y 3.76440938E 05     Z 6.65947105E 06   XD-7.38186265E 03   YD-3.98635850E 01   ZD-1.85246844E 03
    AA 2.70303552E 02    AP 2.64944837E 02    RA 6.87876818E 06   RP 6.86884384E 06    P 6.87380243E 06    A 6.87380601E 06
     E 7.21895552E-04    C3-5.79887180E 07   ENC 5.49871432E 01  THN 1.56824462E 02   TH 1.39485328E 02 ALFAD 1.79189130E 02
 PHIIO 3.20296197E 02

STATE OF ORBITER

  TIME FROM LIFT-OFF
HRS= 7    MIN=49    SEC= 3.82503738E 01

  UNIVERSAL TIME
HRS= 8    MIN=19    SEC= 8.68447018E 00

  TIME 2.81782504E 04
     X-1.12613093E 06     Y 3.76953900E 05     Z 6.75939382E 06   XD-7.44376687E 03   YD-4.08250986E 00   ZD-1.18791957E 03
    AA 2.65513845E 02    AP 1.00627134E 02    RA 6.86989764E 06   RP 6.56452745E 06    P 6.71374195E 06    A 6.71721255E 06
     E 2.27304248E-02    C3-5.93405665E 07   ENC 5.49844164E 01  THN 1.56833121E 02   TH 1.62996904E 02 ALFAD 2.07370283E 02
 PHIIO 3.15626220E 02

INTERSECTION ASSUMMING CIRCULAR ORBIT=
 1.89017714E 02

STATE OF SPACE STATION

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

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

  TIME 2.87700362E 04
     X-5.39273674E 06     Y 2.77366164E 05     Z 4.26035060E 06   XD-4.72355825E 03   YD-2.83600474E 02   ZD-5.96381915E 03
    AA 2.71550633E 02    AP 2.69375749E 02    RA 6.88107777E 06   RP 6.87704989E 06    P 6.87906324E 06    A 6.87906383E 06
     E 2.92764036E-04    C3-5.79443959E 07   ENC 5.50024927E 01  THN 1.56815190E 02   TH 2.96543631E 02 ALFAD 2.98717460E 02
 PHIIO 3.57826171E 02
```

```
STATE OF ORBITER

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

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

 TIME 2.87700362E 04
    X-4.96623789E 06     Y 2.97274522E 05     Z 4.69956633E 06     XD-5.13375182E 03     YD-2.56200983E 02     ZD-5.52310094E 03
   AA 2.65522633E 02    AP 1.06677036E 02    RA 6.87046952E 06     RP 6.57573187E 06      P 6.71987040E 06      A 6.72310069E 06
    E 2.19197703E-02    C3-5.92885956E 07   ENC 5.50027232E 01    THN 1.56820234E 02     TH 2.01474973E 02  ALFAD 2.08634241E 02
PHIIO 3.52840732E 02


TARGETING VALUES FOR THE CDH MANUVER FOR COV
POSITION VECTOR FOR IGNITION

STATE OF ORBITER

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

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

 TIME 2.87700362E 04
    X-4.96623789E 06     Y 2.97274522E 05     Z 4.69956633E 06     XD-5.13375182E 03     YD-2.56200983E 02     ZD-5.52310094E 03
   AA 2.65522633E 02    AP 1.06677036E 02    RA 6.87046952E 06     RP 6.57573187E 06      P 6.71987040E 06      A 6.72310069E 06
    E 2.19197703E-02    C3-5.92885956E 07   ENC 5.50027232E 01    THN 1.56820234E 02     TH 2.01474973E 02  ALFAD 2.08634241E 02
PHIIO 3.52840732E 02

TARGETING VALUES FOR DESIRED ELLIPSE
ANGULAR MOMENTUM VECTOR
 AM(1)-4.42404520E 06  AM(2)-5.22150226E 10  AM(3) 2.83332034E 09
ECCENTRICITY VECTOR
 EV(1)-2.65895258E-04  EV(2)-4.50015523E-06  EV(3)-1.24450788E-04
VELOCITY TO BE GAINED VECTOR
 VG(1)-9.73506759E 01  VG(2)-5.15995398E-02  VG(3)-1.61515980E 01
```

```
CDM HAS BEEN ACCOMPLISHED


STATE OF SPACE STATION

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

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

  TIME 2.87700362E 04
     X-5.39273674E 06      Y 2.77366164E 05      Z 4.26035060E 06     XD-4.72355825E 03     YD-2.83600474E 02     ZD-5.96381915E 03
    AA 2.71550633E 02     AP 2.69375749E 02     RA 6.88107777E 06     RP 6.87704989E 06      P 6.87906324E 06      A 6.87906383E 06
     E 2.92764036E-04     C3-5.79443959E 07    ENC 5.50024927E 01    THN 1.56815190E 02     TH 2.96543631E 02  ALFAD 2.98717460E 02
 PHI10 3.57826171E 02

STATE OF ORBITER

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

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

  TIME 2.87700362E 04
     X-4.98823759E 06      Y 2.97274522E 05      Z 4.59956633E 06     XD-5.23110250E 03     YD-2.56252183E 02     ZD-5.53925254E 03
    AA 2.61547122E 02     AP 2.59372579E 02     RA 6.86255127E 06     RP 6.85852402E 06      P 6.86053705E 06      A 6.86053764E 06
     E 2.93508668E-04     C3-5.81008689E 07    ENC 5.50027232E 01    THN 1.56820234E 02     TH 2.91561118E 02  ALFAD 2.98720386E 02
 PHI10 3.52840732E 02
```

```
UNIVERSAL TIME FOR TPI


STATE OF SPACE STATION

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

  UNIVERSAL TIME
HRS=13     MIN=32     SEC= 2.44243908E 01

  TIME 4.69739903E 04
     X-5.46202040E 06      Y-1.58579497E 05      Z-4.16551532E 06      XD 4.62264217E 03      YD-4.63984289E 02      ZD-6.03293549E 03
    AA 2.67841287E 02     AP 2.60239328E 02     RA 6.87420806E 06      RP 6.86012924E 06       P 6.86716143E 06       A 6.86716865E 06
     E 1.02508234E-03     C3-5.80447661E 07    ENC 5.49677309E 01     THN 1.55901807E 02      TH 2.37193400E 02   ALFAD 1.63133802E 02
 PHIIO 7.40595983E 01

STATE OF ORBITER

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

  UNIVERSAL TIME
HRS=13     MIN=32     SEC= 2.44243908E 01

  TIME 4.69739903E 04
     X-5.47051268E 06      Y-1.55676325E 05      Z-4.12268988E 06      XD 4.59462220E 03      YD-4.65575716E 02      ZD-6.06813479E 03
    AA 2.57734657E 02     AP 2.50545549E 02     RA 6.85549058E 06      RP 6.84217636E 06       P 6.84882700E 06       A 6.84883347E 06
     E 9.72007021E-04     C3-5.82001591E 07    ENC 5.49684297E 01     THN 1.55902394E 02      TH 2.43379710E 02   ALFAD 1.69648911E 02
 PHIIO 7.37307984E 01

DTHEO-5.87449629E-04

 WATPO 6.91166548E-04  PHIPO 7.37307984E 01  PHITO 7.40595983E 01 PHINTO 3.95154284E 01  PHINP 3.91869657E 01

DELPHO 3.28799931E-01

THE SOLAR VECTOR ANGLE ACHIEVED= 1.09900419E 02

STATE VECTOR OF TARGET AT LIFT OFF

    XT-2.91535147E 06     YT 2.38983100E 05     ZT 6.22497319E 06     XDT-6.89464216E 03     YDT-1.93938596E 02     ZDT-3.21907129E 03
```

```
  TIME FROM LIFT-OFF
HRS= 0    MIN= 0    SEC=             0

  UNIVERSAL TIME
HRS= 0    MIN=29    SEC= 3.04340965E 01

  TIME               0
     X-2.91535147E 06    Y 2.38983100E 05     Z 6.22497319E 06   XD-6.89464216E 03   YD-1.93938596E 02    ZD-3.21907129E 03
    AA 2.70323146E 02   AP 2.67213767E 02    RA 6.87880447E 06   RP 6.87304590E 06    P 6.87592398E 06     A 6.87592518E 06
     E 4.18748825E-04   C3-5.79708457E 07   ENC 5.49933452E 01  THN 1.58262600E 02   TH 1.35679948E 02 ALFAD 1.65238544E 02
 PHIIO 3.30441494E 02

STATE VECTOR OF TARGET AT INSERTION

  TIME FROM LIFT-OFF
HRS= 0    MIN= 6    SEC= 1.18836149E 01

  UNIVERSAL TIME
HRS= 0    MIN=35    SEC= 4.23177115E 01

  TIME 3.71883615E 02
     X-5.16408950E 06    Y 1.49170695E 05     Z 4.54081183E 06   XD-5.02722046E 03   YD-2.82498803E 02    ZD-5.71015338E 03
    AA 2.71210184E 02   AP 2.69578836E 02    RA 6.88044726E 06   RP 6.87742600E 06    P 6.87893630E 06     A 6.87893663E 06
     E 2.19602020E-04   C3-5.79454673E 07   ENC 5.50021319E 01  THN 1.58258634E 02   TH 3.01041145E 02 ALFAD 3.07015793E 02
 PHIIO 3.54025351E 02

THE UPDATED TIME OF LAUNCH= 1.77043419E 03
```

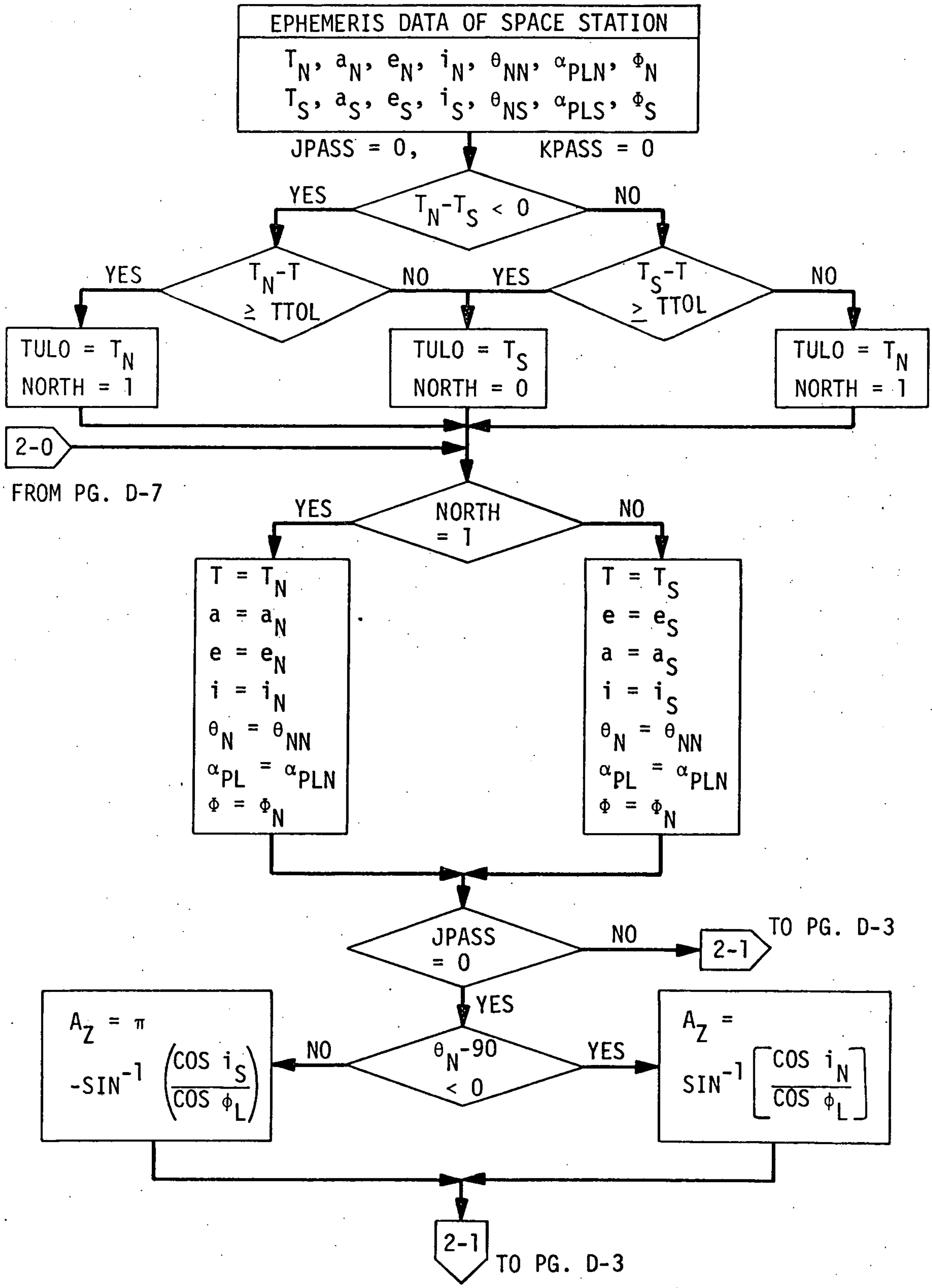
Appendix D

PROGRAM MODULES AND DETAILED FLOWCHART

D.1 PROGRAM MODULES

Name	Function or Subroutine
RK713	This is a seventh order Runge-Kutta integration routine which can integrate backward or forward
RKG	The main routine of the integration package. Integration is variable step-size with an accuracy tolerance of 0.0000005 for the state
CONIC	Computes orbital parameters given the state. (Only for elliptical orbits.)
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 2π or $-\pi$ to π according to flag
POLY	Evaluates an n^{th} order polynomial given its coefficients
ECCV	Computes eccentricity vector $\bar{e}$ $\bar{e} = \bar{v} \times \frac{\bar{h}}{\mu} - \frac{\bar{r}}{\lvert\bar{r}\rvert}$
DEG	Earth's gravitational potential function. Evaluates the acceleration due to gravity for all three components
FATT	Matrix transpose (3×3)
FATMU	Matrix multiplication (3×3 times 1×3)
PRINT	Calculates the U.T. in hours, min., sec, adds the U.T. to the mission Time "T", and prints out state and orbital parameters of each vehicle in flight. (Note: the program integrates in mission time, thus U.T. of launch is added to mission time from lift-off to obtain instantaneous U.T. time in flight)
FATMUL	Matrix multiplication (3×3 times 3×3)
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



2-1 FROM PAGE D-2, PAGE D-7

$$\phi_T = \Phi - \alpha_{PL}$$

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

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

$$[G] = [B]\,[A]$$

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

$$[K] = [\phi_T]\,[G]$$

$$\hat{\Omega} = \sin\phi_L\,\hat{i} - \cos\phi_L \sin A_Z\,\hat{j} + \cos\phi_L \cos A_Z\,\hat{k}$$

KPASS =0

NO → 2-2

YES:

$$R_o = a(1-e^2)/(1+e\cos\Phi)$$

$$V_o = \sqrt{\mu\left(\frac{2}{R_o} - \frac{1}{a}\right)}$$

$$\gamma_o = \tan^{-1}\left[\frac{e\sin\Phi}{1+e\cos\Phi}\right]$$

2-2 TO PAGE D-4

FROM PAGE D-3

2-2

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = [K]^{-1} \begin{bmatrix} R_o \\ 0 \\ 0 \end{bmatrix} \; ; \; \begin{bmatrix} \dot{X}_T \\ \dot{Y}_T \\ \dot{Z}_T \end{bmatrix} = [K]^{-1} \begin{bmatrix} V_o \text{ SIN } \gamma_o \\ 0 \\ V_o \text{ COS } \gamma_o \end{bmatrix}$$

ΔT = 100.0, MPASSI=0

JPASS =0

NO → KPASS =0

NO → 3-3 TO PAGE D-7

YES → 3-4 TO PAGE D-7

YES →

FROM PG. D-5 2-4 →

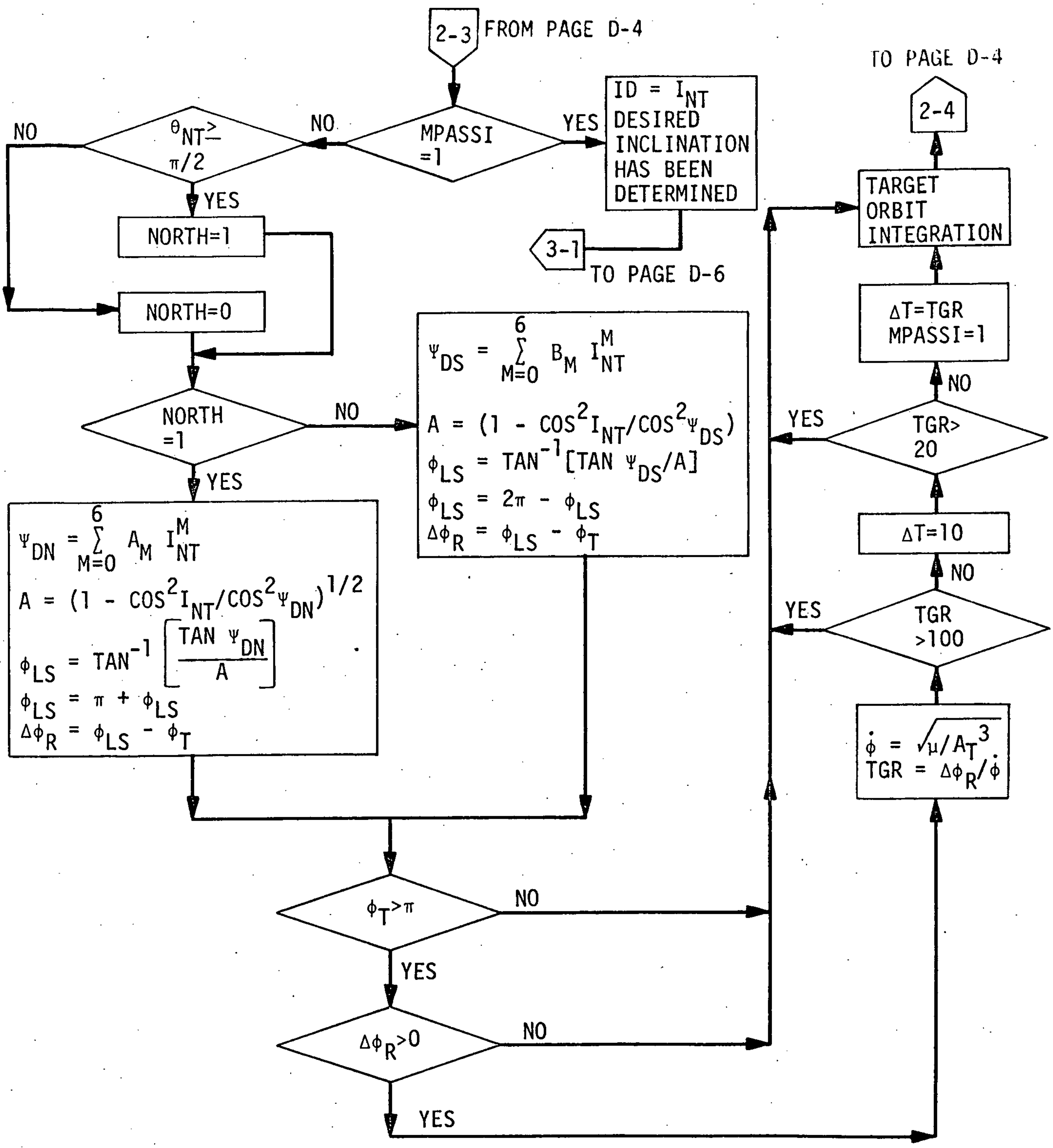
RANGA

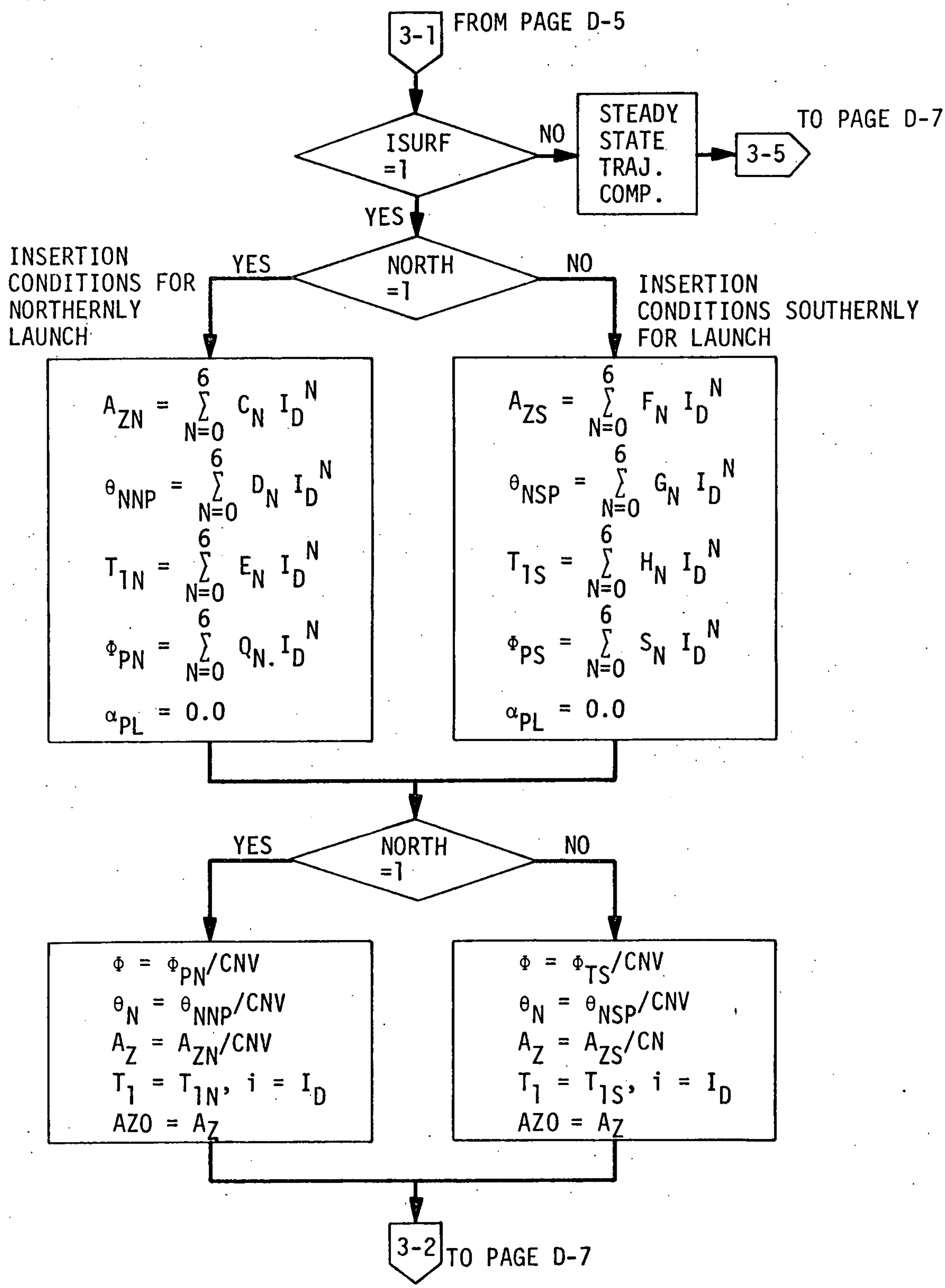
ϕ_T

$$\hat{A}_{MT} = \bar{X} \times \dot{\bar{X}} / |\bar{X}_T \times \dot{\bar{X}}_T|$$
$$\hat{D}_{NT} = \hat{A}_{MT} \times \hat{\Omega}$$
$$\hat{E}_{RA} = \text{COS } \phi_L \, \hat{i} + \text{SIN } \phi_L \text{ SIN } A_Z \, \hat{j} - \text{SIN } \phi_L \text{ COS } A_Z \, \hat{k}$$
$$\psi = \text{SIN}^{-1}(\bar{X}_T \cdot \hat{\Omega} / |\bar{X}_T|)$$
$$\theta_{NT} = \text{COS}^{-1}[\hat{E}_{RA} \cdot \bar{D}_{NT} / |\bar{D}_{NT}|]$$
$$I_{NT} = \text{TAN}^{-1}\left\{\left[(1. - (\hat{\Omega} \cdot \hat{A}_{MT})^2\right]^{1/2} / (\hat{\Omega} \cdot \hat{A}_{MT})\right\}$$
$$A_T = |\bar{X}_T| \mu / (2\mu - |\dot{\bar{X}}_T|^2 \, |\bar{X}_T|)$$

2-3 TO PAGE D-5

C.2


2-3
FROM PAGE D-4
MPASSI =1
YES
ID = I_NT
DESIRED INCLINATION HAS BEEN DETERMINED
3-1
TO PAGE D-6
NO
θ_NT ≥ π/2
NO
YES
NORTH=1
NORTH=0
NORTH =1
NO
YES
Ψ_DN = Σ_{M=0}^{6} A_M I_NT^M
A = (1 - COS² I_NT / COS² Ψ_DN)^{1/2}
φ_LS = TAN⁻¹ [TAN Ψ_DN / A]
φ_LS = π + φ_LS
Δφ_R = φ_LS - φ_T
Ψ_DS = Σ_{M=0}^{6} B_M I_NT^M
A = (1 - COS² I_NT / COS² Ψ_DS)
φ_LS = TAN⁻¹ [TAN Ψ_DS / A]
φ_LS = 2π - φ_LS
Δφ_R = φ_LS - φ_T
φ_T > π
NO
YES
Δφ_R > 0
NO
YES
TO PAGE D-4
2-4
TARGET ORBIT INTEGRATION
ΔT=TGR
MPASSI=1
NO
YES
TGR> 20
ΔT=10
NO
YES
TGR >100
φ̇ = √(μ/A_T³)
TGR = Δφ_R/φ̇


3-1
FROM PAGE D-5
ISURF =1
NO
STEADY STATE TRAJ. COMP.
3-5
TO PAGE D-7
YES
NORTH =1
YES
INSERTION CONDITIONS FOR NORTHERNLY LAUNCH
NO
INSERTION CONDITIONS SOUTHERNLY FOR LAUNCH
$A_{ZN} = \sum_{N=0}^{6} C_N I_D^N$
$\theta_{NNP} = \sum_{N=0}^{6} D_N I_D^N$
$T_{1N} = \sum_{N=0}^{6} E_N I_D^N$
$\Phi_{PN} = \sum_{N=0}^{6} Q_N . I_D^N$
$\alpha_{PL} = 0.0$
$A_{ZS} = \sum_{N=0}^{6} F_N I_D^N$
$\theta_{NSP} = \sum_{N=0}^{6} G_N I_D^N$
$T_{1S} = \sum_{N=0}^{6} H_N I_D^N$
$\Phi_{PS} = \sum_{N=0}^{6} S_N I_D^N$
$\alpha_{PL} = 0.0$
NORTH =1
YES
NO
$\Phi = \Phi_{PN}/CNV$
$\theta_N = \theta_{NNP}/CNV$
$A_Z = A_{ZN}/CNV$
$T_1 = T_{1N}, i = I_D$
$AZO = A_Z$
$\Phi = \Phi_{TS}/CNV$
$\theta_N = \theta_{NSP}/CNV$
$A_Z = A_{ZS}/CN$
$T_1 = T_{1S}, i = I_D$
$AZO = A_Z$
3-2
TO PAGE D-7

3-2 FROM PAGE D-6

KPASS = 1, JPASS = 1

R_o = HPER * CF + $R_\oplus$

R_A = HAP * CF + $R_\oplus$

$e = (R_A - R_o)/(R_A + R_o)$

$V_o = \sqrt{\mu(1 + e)/R_o}$

$a = (R_A - R_o)/2$

$\gamma_o = 0.0$

2-1 TO PAGE D-3

FROM PG. D-4 3-3

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

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

3-5 FROM PAGE D-6

KPASS=0
JPASS=1

2-0 TO PAGE D-2

3-4 FROM PG. D-4

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

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

$$\bar{X}_T = \int_T^{T+T_1} \dot{\bar{X}}_T \, dt$$

$$\dot{\bar{X}}_T = \int_T^{T+T_1} \ddot{\bar{X}}_T \, dt$$

4-0 TO PAGE D-8

FROM PG. D-7

4-0

$T, T_1, \bar{X}_P, \dot{\bar{X}}_P, \bar{X}_T, \dot{\bar{X}}_T$

T_1 = TIME OF ORBITER INSERTION

$R_{RP} = |\bar{X}_P|$, $V_{VP} = |\dot{\bar{X}}_P|$

$A_P = R_{RP}\mu/(2\mu - V_{VP}^2\ R_{RP})$

$R_{RT} = |\bar{X}_T|$, $V_{VT} = |\dot{\bar{X}}_T|$

$A_T = R_{RT}\mu/(2\mu - V_{VT}^2\ R_{RP})$

$\dot{\phi}_{PA1} = (\mu/A_P^3)^{1/2}$, $\dot{\phi}_{TA1} = [\mu/A_T^3]^{1/2}$

$\Delta\dot{\phi}_1 = \dot{\phi}_{PA1} - \dot{\phi}_{TA1}$

$\Delta\phi_{MR1} = \Delta\dot{\phi}_1(\pi)[A_P^3/\mu]^{1/2}$

$H_P = R_{RP}\ V_{VP}\ \text{COS}\ \gamma_P$, $E_P = \left[1 - \frac{H_P^2}{A_P\mu}\right]^{1/2}$

$\gamma_P = \text{SIN}^{-1}\ [(\bar{X}_P \cdot \dot{\bar{X}}_P)/(R_{RP} \cdot V_{VP})]$

$R_{AP} = A_P(1 + E_P)$, $V_{AP} = \sqrt{\frac{\mu}{A_P}}\ \sqrt{\frac{1-E_P}{1+E_P}}$

$H_T = R_{RT}\ V_{VT}\ \text{COS}\ \gamma_T$, $E_T = \left[1 - \frac{H_T^2}{A_T\mu}\right]^{1/2}$

$R_{AT} = A_T(1 + E_T)$, $\tau_{P1} = 2\pi\sqrt{\frac{A_P^3}{\mu}}$

$R_{PT} = A_T(1 - E_T)$, $\Delta R_T = R_{AT} - R_{PT}$

$T_2 = T_1 + \tau_{P1}/2$

JLIGHT = 0, SSFN03 = SFN03

TULOS = TULO

$\bar{X}_{TS1} = \bar{X}_T$, $\bar{X}_{PS1} = \bar{X}_P$

$\dot{\bar{X}}_{TS1} = \dot{\bar{X}}_T$, $\dot{\bar{X}}_{PS1} = \dot{\bar{X}}_P$

4-10 FROM PAGE D-15

$R_{CP} = R_{AP}$, $V_{CP} = [\mu/R_{CP}]^{1/2}$

$\tau_{CP} = 2\pi\ [R_{CP}^3/\mu]^{1/2}$

$\dot{\phi}_{CP} = [\mu/R_{CP}^3]^{1/2}$

$\Delta\dot{\phi}_2 = \dot{\phi}_{CP} - \dot{\phi}_{TA1}$, $\Delta\phi_{MR2}$ $\Delta\dot{\phi}_2$ (SFN01) τ_{CP}, $\Delta V_2 = V_{CP} - V_{AP}$, $T_3 = T_2 +$ (SFN01) τ_{CP}

ILIG =1

YES: XN =1.0

NO: XN= 0.0

RPP3 = R_{CP}, RAP3 = R_{PT} - ΔHD - ΔHB

AP3 = (RPP3 + RAP3)/2, $\tau_{P3} = 2\pi\left[\frac{AP3^3}{\mu}\right]^{1/2}$

$\dot{\phi}$PA3 = $[A_P^3/\mu]^{1/2}$, $\Delta\dot{\phi}3 = \dot{\phi}_{PA3} - \dot{\phi}_{TA1}$,

$\Delta\phi_{MR3} = \Delta\dot{\phi}_3$(SFN02) τ_{P3}, $T_4 = T_3 +$ (SFN02) τ_{P3}

RAP3 = R_{AT} - ΔHD + ΔHB, VPP3 =

$[2\mu$ RAP3/RPP3(RAP3 + RPP3$]^{1/2}$, ΔV_3 = VPP3 - V_{CP}

RAP4 = R_{AT} - ΔHD, AP4 = (RPP4 + RAP4)/2

EP4 = (RAP4 - RPP4)/(RAP4 + RPP4)

$\theta_4 = \text{COS}^{-1}\left[\frac{AP3(1 - EP3^2) - AP4(1 - EP4^2)}{EP3AP4(1 - EP4^2) - EP4AP3(1 - EP3^2)}\right]$

R4 = AP4(1 - EP4^2)/(1 + EP4 COS (θ_4))

V4 = $\{[2\mu AP3/R4) - \mu]/AP3\}^{1/2}$

$\gamma_4 = \text{TAN}^{-1}\ \{(R4\ EP3\ \text{SIN}(\theta_4)/(AP3(1 - EP3^2))\}$

VT4 = $\{[(2\mu AP4)/(R4) - \mu]/AP4\}^{1/2}$

$\gamma_{T4} = \text{TAN}^{-1}\ \{(R4\ EP4\ \text{SIN}\ \theta_4]/[AP4(1 - EP4^2)]\}$

ΔV4 = $[VT4^2 + V4^2 - 2VT4(V4)\ \text{COS}(\gamma_{T4} - \gamma_4)]^{1/2}$

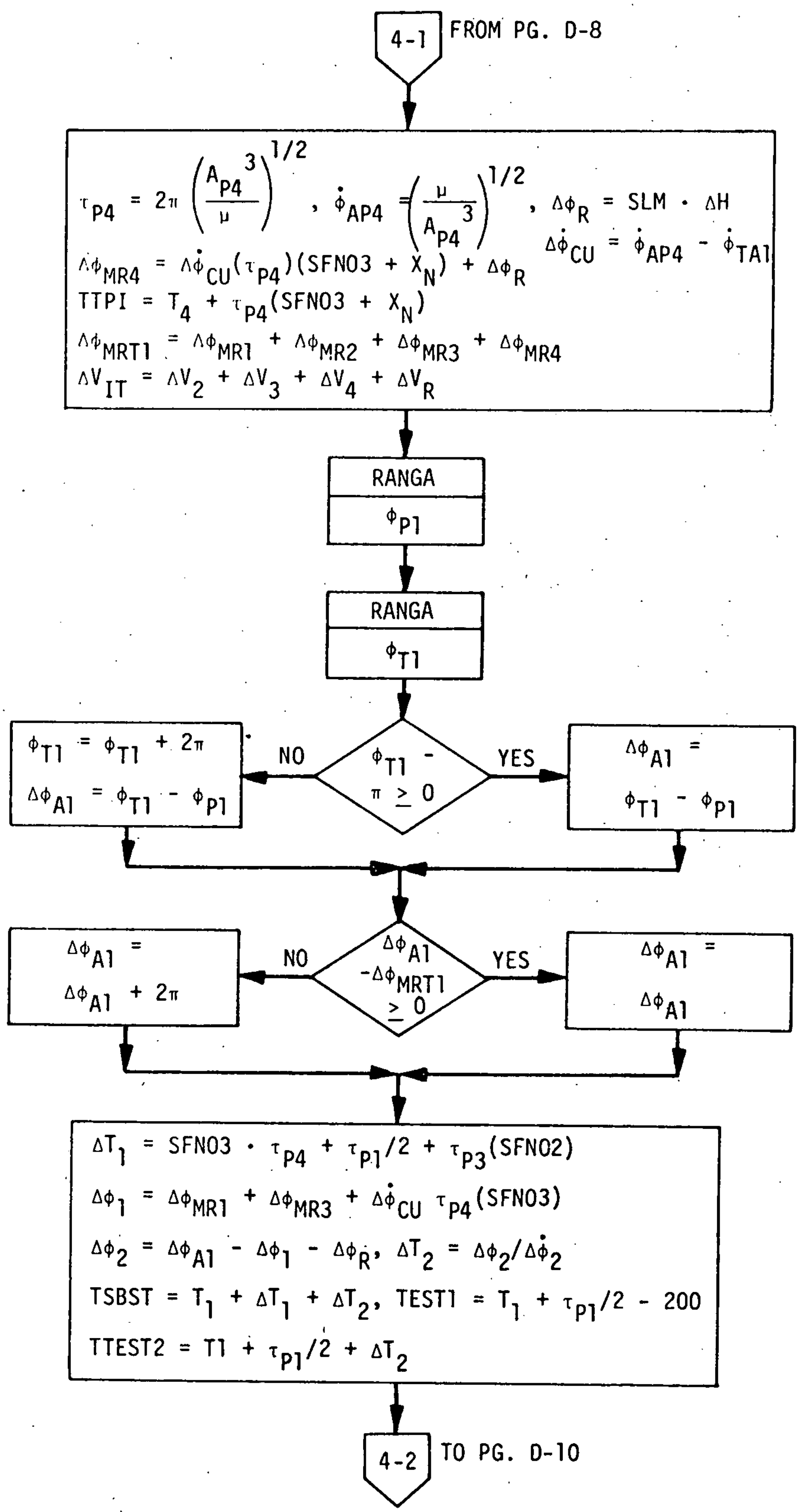
ΔVR = f(ΔHD)

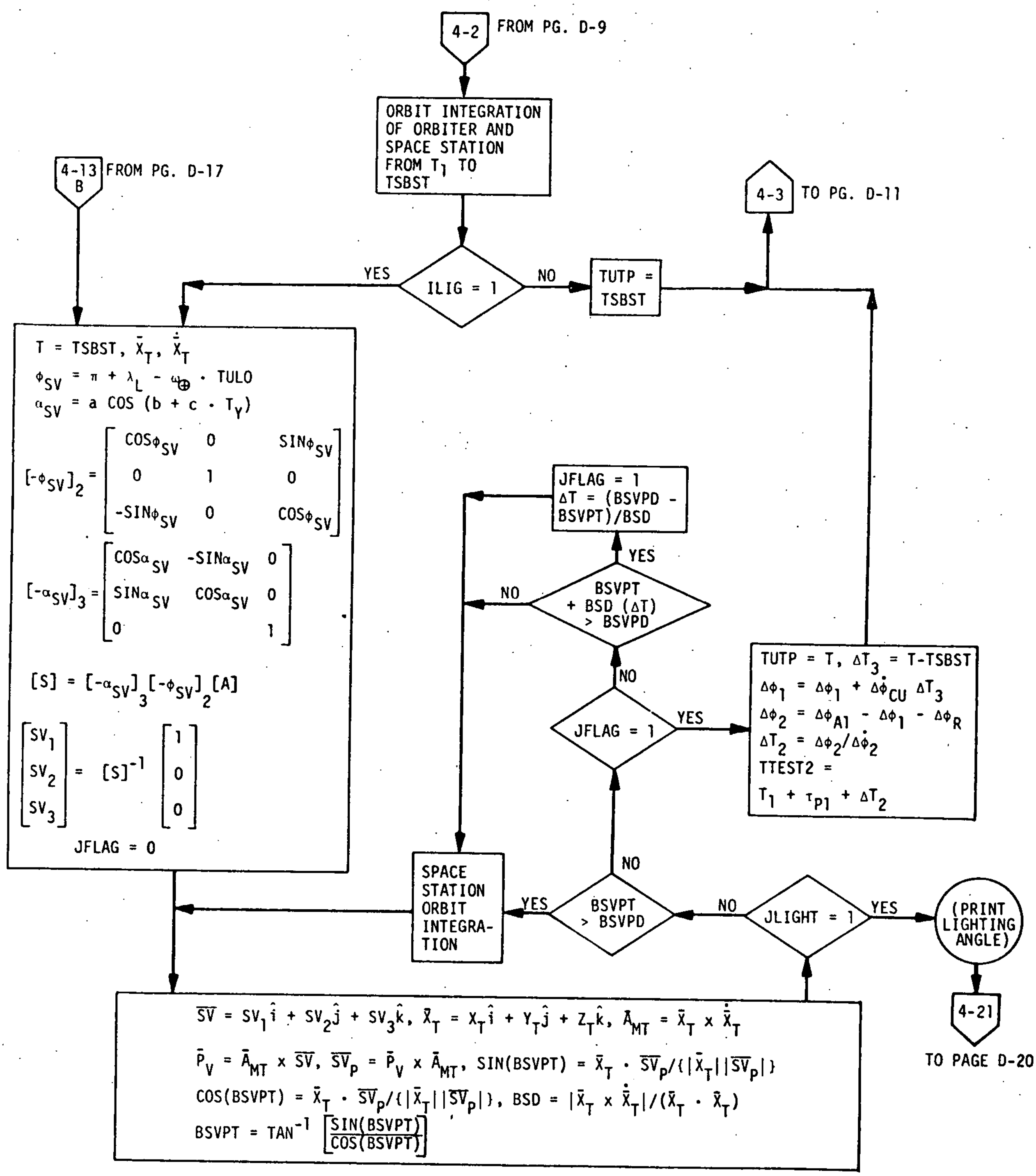
RAP3 = R_{AT} - ΔHD + ΔHB, RPP3 = R_{CP}, AP3 =

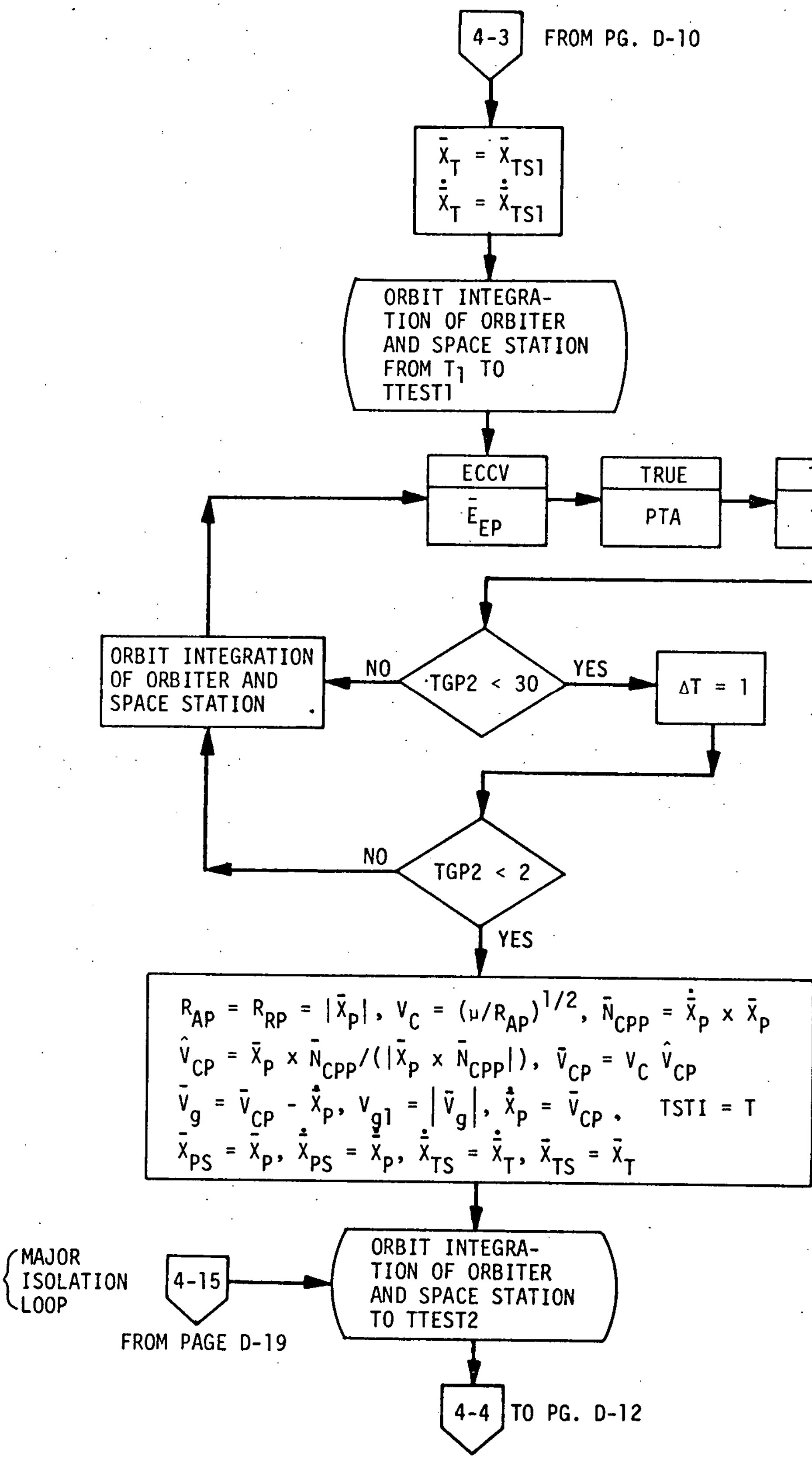
(RPP3 + RAP3)/2. EP3 = (RAP3 - RPP3)/

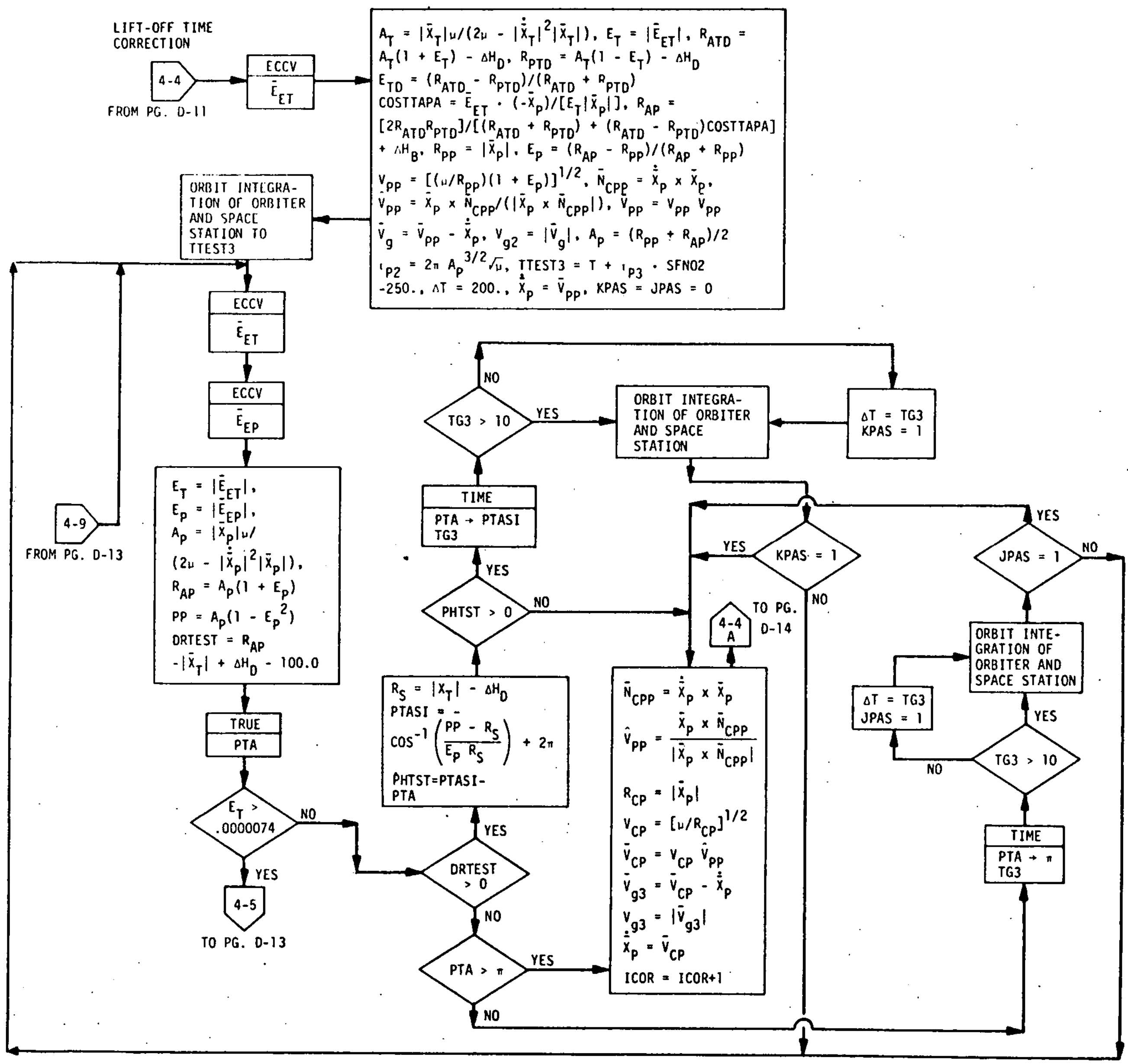
(RAP3 + RPP3), RPP4 = R_{PT} - ΔHD

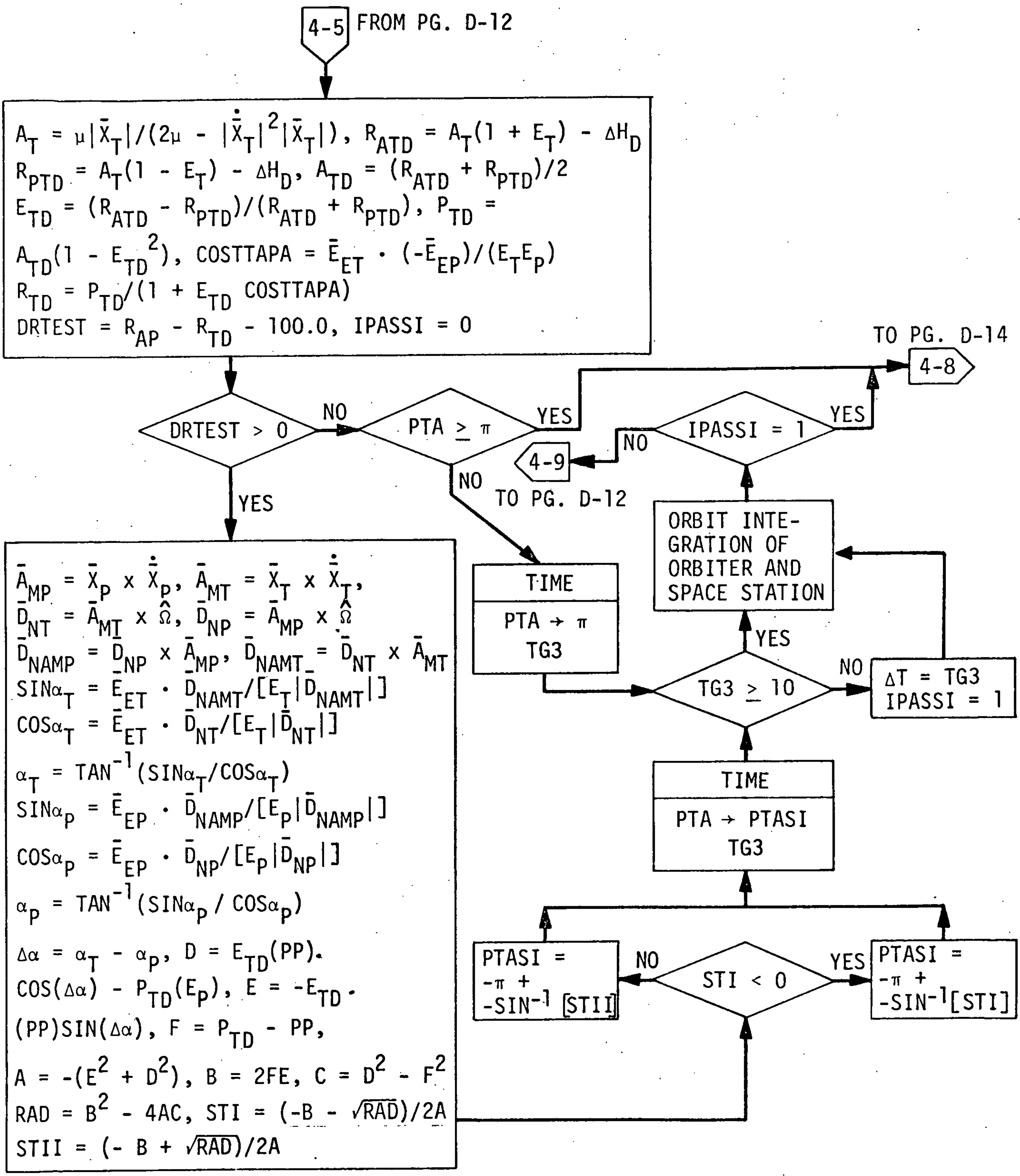
4-1 TO PAGE D-9

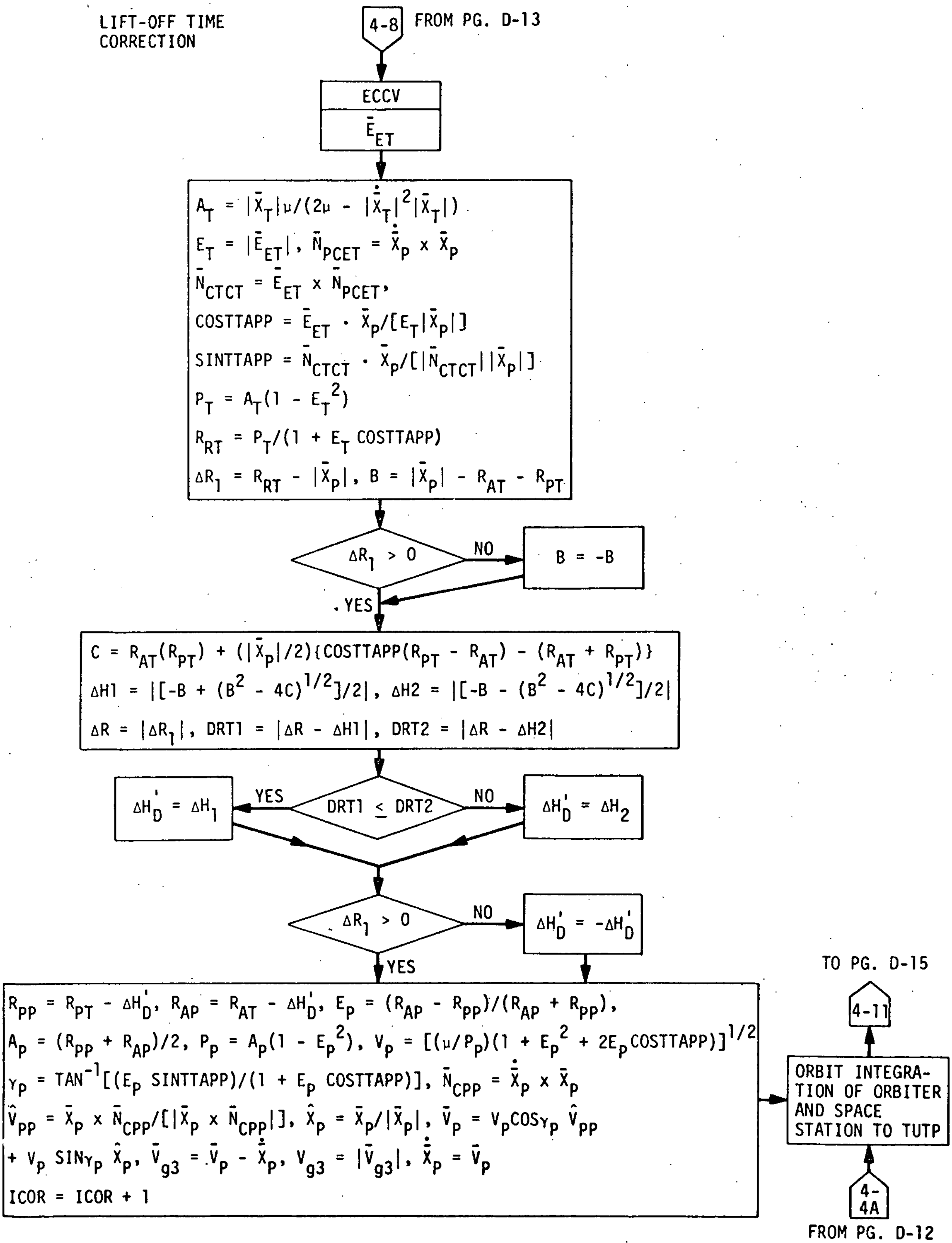

4-1
FROM PG. D-8
$\tau_{P4} = 2\pi \left(\frac{A_{P4}^{3}}{\mu}\right)^{1/2}$, $\dot{\phi}_{AP4} = \left(\frac{\mu}{A_{P4}^{3}}\right)^{1/2}$, $\Delta\phi_R = SLM \cdot \Delta H$
$\Delta\dot{\phi}_{CU} = \dot{\phi}_{AP4} - \dot{\phi}_{TA1}$
$\Delta\phi_{MR4} = \Delta\dot{\phi}_{CU}(\tau_{P4})(SFN03 + X_N) + \Delta\phi_R$
$TTPI = T_4 + \tau_{P4}(SFN03 + X_N)$
$\Delta\phi_{MRT1} = \Delta\phi_{MR1} + \Delta\phi_{MR2} + \Delta\phi_{MR3} + \Delta\phi_{MR4}$
$\Delta V_{IT} = \Delta V_2 + \Delta V_3 + \Delta V_4 + \Delta V_R$
RANGA
ϕ_{P1}
RANGA
ϕ_{T1}
$\phi_{T1} - \pi \geq 0$
NO
YES
$\phi_{T1} = \phi_{T1} + 2\pi$
$\Delta\phi_{A1} = \phi_{T1} - \phi_{P1}$
$\Delta\phi_{A1} = \phi_{T1} - \phi_{P1}$
$\Delta\phi_{A1} - \Delta\phi_{MRT1} \geq 0$
NO
YES
$\Delta\phi_{A1} = \Delta\phi_{A1} + 2\pi$
$\Delta\phi_{A1} = \Delta\phi_{A1}$
$\Delta T_1 = SFN03 \cdot \tau_{P4} + \tau_{P1}/2 + \tau_{P3}(SFN02)$
$\Delta\phi_1 = \Delta\phi_{MR1} + \Delta\phi_{MR3} + \Delta\dot{\phi}_{CU}\,\tau_{P4}(SFN03)$
$\Delta\phi_2 = \Delta\phi_{A1} - \Delta\phi_1 - \Delta\phi_R$, $\Delta T_2 = \Delta\phi_2/\Delta\dot{\phi}_2$
$TSBST = T_1 + \Delta T_1 + \Delta T_2$, $TEST1 = T_1 + \tau_{P1}/2 - 200$
$TTEST2 = T1 + \tau_{P1}/2 + \Delta T_2$
4-2
TO PG. D-10


4-2 FROM PG. D-9
ORBIT INTEGRATION OF ORBITER AND SPACE STATION FROM T_1 TO TSBST
4-13 B FROM PG. D-17
4-3 TO PG. D-11
ILIG = 1
YES
NO
TUTP = TSBST
T = TSBST, $\bar{X}_T$, $\dot{\bar{X}}_T$
$\phi_{SV} = \pi + \lambda_L - \omega_\oplus \cdot TULO$
$\alpha_{SV} = a\ COS\ (b + c \cdot T_Y)$
$[-\phi_{SV}]_2 = \begin{bmatrix} COS\phi_{SV} & 0 & SIN\phi_{SV} \\ 0 & 1 & 0 \\ -SIN\phi_{SV} & 0 & COS\phi_{SV} \end{bmatrix}$
$[-\alpha_{SV}]_3 = \begin{bmatrix} COS\alpha_{SV} & -SIN\alpha_{SV} & 0 \\ SIN\alpha_{SV} & COS\alpha_{SV} & 0 \\ 0 & & 1 \end{bmatrix}$
$[S] = [-\alpha_{SV}]_3 [-\phi_{SV}]_2 [A]$
$\begin{bmatrix} SV_1 \\ SV_2 \\ SV_3 \end{bmatrix} = [S]^{-1} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$
JFLAG = 0
JFLAG = 1
ΔT = (BSVPD - BSVPT)/BSD
YES
NO
BSVPT + BSD (ΔT) > BSVPD
NO
JFLAG = 1
YES
TUTP = T, ΔT_3 = T-TSBST
$\Delta\phi_1 = \Delta\phi_1 + \Delta\dot{\phi}_{CU}\ \Delta T_3$
$\Delta\phi_2 = \Delta\phi_{A1} - \Delta\phi_1 - \Delta\phi_R$
$\Delta T_2 = \Delta\phi_2 / \Delta\dot{\phi}_2$
TTEST2 =
$T_1 + \tau_{P1} + \Delta T_2$
NO
SPACE STATION ORBIT INTEGRA-TION
YES
BSVPT > BSVPD
NO
JLIGHT = 1
YES
(PRINT LIGHTING ANGLE)
4-21
TO PAGE D-20
$\overline{SV} = SV_1\hat{i} + SV_2\hat{j} + SV_3\hat{k}$, $\bar{X}_T = X_T\hat{i} + Y_T\hat{j} + Z_T\hat{k}$, $\bar{A}_{MT} = \bar{X}_T \times \dot{\bar{X}}_T$
$\bar{P}_V = \bar{A}_{MT} \times \overline{SV}$, $\overline{SV}_P = \bar{P}_V \times \bar{A}_{MT}$, SIN(BSVPT) $= \bar{X}_T \cdot \overline{SV}_P / (|\bar{X}_T||\overline{SV}_P|)$
COS(BSVPT) $= \bar{X}_T \cdot \overline{SV}_P / (|\bar{X}_T||\overline{SV}_P|)$, BSD $= |\bar{X}_T \times \dot{\bar{X}}_T| / (\bar{X}_T \cdot \bar{X}_T)$
BSVPT $= TAN^{-1} \left[\frac{SIN(BSVPT)}{COS(BSVPT)}\right]$


4-3
FROM PG. D-10
$\bar{X}_T = \bar{X}_{TS1}$
$\dot{\bar{X}}_T = \dot{\bar{X}}_{TS1}$
ORBIT INTEGRATION OF ORBITER AND SPACE STATION FROM T_1 TO TTEST1
ECCV
$\bar{E}_{EP}$
TRUE
PTA
TIME
TGP2
ORBIT INTEGRATION OF ORBITER AND SPACE STATION
NO
TGP2 < 30
YES
$\Delta T = 1$
NO
TGP2 < 2
YES
$R_{AP} = R_{RP} = |\bar{X}_P|$, $V_C = (\mu/R_{AP})^{1/2}$, $\bar{N}_{CPP} = \dot{\bar{X}}_P \times \bar{X}_P$
$\hat{V}_{CP} = \bar{X}_P \times \bar{N}_{CPP}/(|\bar{X}_P \times \bar{N}_{CPP}|)$, $\bar{V}_{CP} = V_C\,\hat{V}_{CP}$
$\bar{V}_g = \bar{V}_{CP} - \dot{\bar{X}}_P$, $V_{g1} = |\bar{V}_g|$, $\dot{\bar{X}}_P = \bar{V}_{CP}$, TSTI = T
$\bar{X}_{PS} = \bar{X}_P$, $\dot{\bar{X}}_{PS} = \dot{\bar{X}}_P$, $\dot{\bar{X}}_{TS} = \dot{\bar{X}}_T$, $\bar{X}_{TS} = \bar{X}_T$
MAJOR ISOLATION LOOP
4-15
FROM PAGE D-19
ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TTEST2
4-4
TO PG. D-12


LIFT-OFF TIME CORRECTION
4-4
FROM PG. D-11
ECCV
$\bar{E}_{ET}$
$A_T = |\bar{X}_T|\mu/(2\mu - |\dot{\bar{X}}_T|^2|\bar{X}_T|)$, $E_T = |\bar{E}_{ET}|$, $R_{ATD} = A_T(1 + E_T) - \Delta H_D$, $R_{PTD} = A_T(1 - E_T) - \Delta H_D$
$E_{TD} = (R_{ATD} - R_{PTD})/(R_{ATD} + R_{PTD})$
COSTTAPA = $\bar{E}_{ET} \cdot (-\bar{X}_P)/[E_T|\bar{X}_P|]$, $R_{AP} = [2R_{ATD}R_{PTD}]/[(R_{ATD} + R_{PTD}) + (R_{ATD} - R_{PTD})$COSTTAPA$] + \Delta H_B$, $R_{PP} = |\bar{X}_P|$, $E_P = (R_{AP} - R_{PP})/(R_{AP} + R_{PP})$
$V_{PP} = [(\mu/R_{PP})(1 + E_P)]^{1/2}$, $\bar{N}_{CPP} = \dot{\bar{X}}_P \times \bar{X}_P$,
$\hat{V}_{PP} = \bar{X}_P \times \bar{N}_{CPP}/(|\bar{X}_P \times \bar{N}_{CPP}|)$, $\bar{V}_{PP} = V_{PP}\hat{V}_{PP}$
$\bar{V}_g = \bar{V}_{PP} - \dot{\bar{X}}_P$, $V_{g2} = |\bar{V}_g|$, $A_P = (R_{PP} + R_{AP})/2$
$\tau_{P2} = 2\pi A_P^{3/2}/\sqrt{\mu}$, TTEST3 = T + τ_{P3} · SFNO2 -250., ΔT = 200., $\dot{\bar{X}}_P = \bar{V}_{PP}$, KPAS = JPAS = 0
ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TTEST3
ECCV
$\bar{E}_{ET}$
ECCV
$\bar{E}_{EP}$
4-9
FROM PG. D-13
$E_T = |\bar{E}_{ET}|$,
$E_P = |\bar{E}_{EP}|$,
$A_P = |\bar{X}_P|\mu/(2\mu - |\dot{\bar{X}}_P|^2|\bar{X}_P|)$,
$R_{AP} = A_P(1 + E_P)$
$PP = A_P(1 - E_P^2)$
DRTEST = $R_{AP} - |\bar{X}_T| + \Delta H_D$ - 100.0
TRUE
PTA
E_T > .0000074
NO
YES
4-5
TO PG. D-13
NO
TG3 > 10
YES
ORBIT INTEGRATION OF ORBITER AND SPACE STATION
ΔT = TG3
KPAS = 1
TIME
PTA → PTASI
TG3
YES
PHTST > 0
NO
$R_S = |\bar{X}_T| - \Delta H_D$
PTASI = $-\cos^{-1}\left(\frac{PP - R_S}{E_P R_S}\right) + 2\pi$
PHTST=PTASI-PTA
YES
DRTEST > 0
NO
PTA > π
YES
NO
YES
KPAS = 1
NO
4-4 A
TO PG. D-14
$\bar{N}_{CPP} = \dot{\bar{X}}_P \times \bar{X}_P$
$\hat{V}_{PP} = \frac{\bar{X}_P \times \bar{N}_{CPP}}{|\bar{X}_P \times \bar{N}_{CPP}|}$
$R_{CP} = |\bar{X}_P|$
$V_{CP} = [\mu/R_{CP}]^{1/2}$
$\bar{V}_{CP} = V_{CP}\hat{V}_{PP}$
$\bar{V}_{g3} = \bar{V}_{CP} - \dot{\bar{X}}_P$
$V_{g3} = |\bar{V}_{g3}|$
$\dot{\bar{X}}_P = \bar{V}_{CP}$
ICOR = ICOR+1
YES
JPAS = 1
NO
ORBIT INTEGRATION OF ORBITER AND SPACE STATION
ΔT = TG3
JPAS = 1
YES
TG3 > 10
NO
TIME
PTA → π
TG3


4-5 FROM PG. D-12
$A_T = \mu|\bar{X}_T|/(2\mu - |\dot{\bar{X}}_T|^2|\bar{X}_T|)$, $R_{ATD} = A_T(1 + E_T) - \Delta H_D$
$R_{PTD} = A_T(1 - E_T) - \Delta H_D$, $A_{TD} = (R_{ATD} + R_{PTD})/2$
$E_{TD} = (R_{ATD} - R_{PTD})/(R_{ATD} + R_{PTD})$, $P_{TD} =$
$A_{TD}(1 - E_{TD}^2)$, COSTTAPA $= \bar{E}_{ET} \cdot (-\bar{E}_{EP})/(E_T E_P)$
$R_{TD} = P_{TD}/(1 + E_{TD}$ COSTTAPA)
DRTEST $= R_{AP} - R_{TD} - 100.0$, IPASSI = 0
DRTEST > 0
NO
YES
PTA $\geq \pi$
YES
NO
TO PG. D-14
4-8
IPASSI = 1
YES
NO
4-9
TO PG. D-12
$\bar{A}_{MP} = \bar{X}_P \times \dot{\bar{X}}_P$, $\bar{A}_{MT} = \bar{X}_T \times \dot{\bar{X}}_T$,
$\bar{D}_{NT} = \bar{A}_{MT} \times \hat{\Omega}$, $\bar{D}_{NP} = \bar{A}_{MP} \times \hat{\Omega}$
$\bar{D}_{NAMP} = \bar{D}_{NP} \times \bar{A}_{MP}$, $\bar{D}_{NAMT} = \bar{D}_{NT} \times \bar{A}_{MT}$
$\text{SIN}\alpha_T = \bar{E}_{ET} \cdot \bar{D}_{NAMT}/[E_T|\bar{D}_{NAMT}|]$
$\text{COS}\alpha_T = \bar{E}_{ET} \cdot \bar{D}_{NT}/[E_T|\bar{D}_{NT}|]$
$\alpha_T = \text{TAN}^{-1}(\text{SIN}\alpha_T/\text{COS}\alpha_T)$
$\text{SIN}\alpha_P = \bar{E}_{EP} \cdot \bar{D}_{NAMP}/[E_P|\bar{D}_{NAMP}|]$
$\text{COS}\alpha_P = \bar{E}_{EP} \cdot \bar{D}_{NP}/[E_P|\bar{D}_{NP}|]$
$\alpha_P = \text{TAN}^{-1}(\text{SIN}\alpha_P / \text{COS}\alpha_P)$
$\Delta\alpha = \alpha_T - \alpha_P$, $D = E_{TD}(PP) \cdot$
$\text{COS}(\Delta\alpha) - P_{TD}(E_P)$, $E = -E_{TD} \cdot$
$(PP)\text{SIN}(\Delta\alpha)$, $F = P_{TD} - PP$,
$A = -(E^2 + D^2)$, $B = 2FE$, $C = D^2 - F^2$
$RAD = B^2 - 4AC$, $STI = (-B - \sqrt{RAD})/2A$
$STII = (-B + \sqrt{RAD})/2A$
TIME
PTA → π
TG3
ORBIT INTE-GRATION OF ORBITER AND SPACE STATION
YES
TG3 $\geq$ 10
NO
ΔT = TG3
IPASSI = 1
TIME
PTA → PTASI
TG3
PTASI = $-\pi$ + $-\text{SIN}^{-1}$ [STII]
NO
STI < 0
YES
PTASI = $-\pi$ + $-\text{SIN}^{-1}$[STI]


LIFT-OFF TIME CORRECTION
4-8
FROM PG. D-13
ECCV
$\bar{E}_{ET}$
$A_T = |\bar{X}_T|\mu/(2\mu - |\dot{\bar{X}}_T|^2|\bar{X}_T|)$
$E_T = |\bar{E}_{ET}|$, $\bar{N}_{PCET} = \dot{\bar{X}}_P \times \bar{X}_P$
$\bar{N}_{CTCT} = \bar{E}_{ET} \times \bar{N}_{PCET}$,
$COSTTAPP = \bar{E}_{ET} \cdot \bar{X}_P/[E_T|\bar{X}_P|]$
$SINTTAPP = \bar{N}_{CTCT} \cdot \bar{X}_P/[|\bar{N}_{CTCT}||\bar{X}_P|]$
$P_T = A_T(1 - E_T^2)$
$R_{RT} = P_T/(1 + E_T\ COSTTAPP)$
$\Delta R_1 = R_{RT} - |\bar{X}_P|$, $B = |\bar{X}_P| - R_{AT} - R_{PT}$
$\Delta R_1 > 0$
NO
B = -B
YES
$C = R_{AT}(R_{PT}) + (|\bar{X}_P|/2)\{COSTTAPP(R_{PT} - R_{AT}) - (R_{AT} + R_{PT})\}$
$\Delta H1 = |[-B + (B^2 - 4C)^{1/2}]/2|$, $\Delta H2 = |[-B - (B^2 - 4C)^{1/2}]/2|$
$\Delta R = |\Delta R_1|$, $DRT1 = |\Delta R - \Delta H1|$, $DRT2 = |\Delta R - \Delta H2|$
$\Delta H_D' = \Delta H_1$
YES
$DRT1 \leq DRT2$
NO
$\Delta H_D' = \Delta H_2$
$\Delta R_1 > 0$
NO
$\Delta H_D' = -\Delta H_D'$
YES
$R_{PP} = R_{PT} - \Delta H_D'$, $R_{AP} = R_{AT} - \Delta H_D'$, $E_P = (R_{AP} - R_{PP})/(R_{AP} + R_{PP})$,
$A_P = (R_{PP} + R_{AP})/2$, $P_P = A_P(1 - E_P^2)$, $V_P = [(\mu/P_P)(1 + E_P^2 + 2E_P COSTTAPP)]^{1/2}$
$\gamma_P = TAN^{-1}[(E_P\ SINTTAPP)/(1 + E_P\ COSTTAPP)]$, $\bar{N}_{CPP} = \dot{\bar{X}}_P \times \bar{X}_P$
$\hat{V}_{PP} = \bar{X}_P \times \bar{N}_{CPP}/[|\bar{X}_P \times \bar{N}_{CPP}|]$, $\hat{X}_P = \bar{X}_P/|\bar{X}_P|$, $\bar{V}_P = V_P COS\gamma_P\ \hat{V}_{PP}$
$+ V_P\ SIN\gamma_P\ \hat{X}_P$, $\bar{V}_{g3} = \bar{V}_P - \dot{\bar{X}}_P$, $V_{g3} = |\bar{V}_{g3}|$, $\dot{\bar{X}}_P = \bar{V}_P$
ICOR = ICOR + 1
TO PG. D-15
4-11
ORBIT INTEGRATION OF ORBITER AND SPACE STATION TO TUTP
4-4A
FROM PG. D-12

LIFT-OFF TIME CORRECTION

4-11 FROM PG. D-14

TCDH-TUTP +SSFN03 $*\tau_{P4}$-1000. >0

YES:

$SFN03 = SFN03 + .5$
$\bar{X}_T = \bar{X}_{TS1}$
$\dot{\bar{X}}_T = \dot{\bar{X}}_{TS1}$
$\bar{X}_P = \bar{X}_{PS1}$
$\dot{\bar{X}}_P = \dot{\bar{X}}_{PS1}$
TULO = TULOS
DT = DTS

4-10 TO PG. D-8

NO:

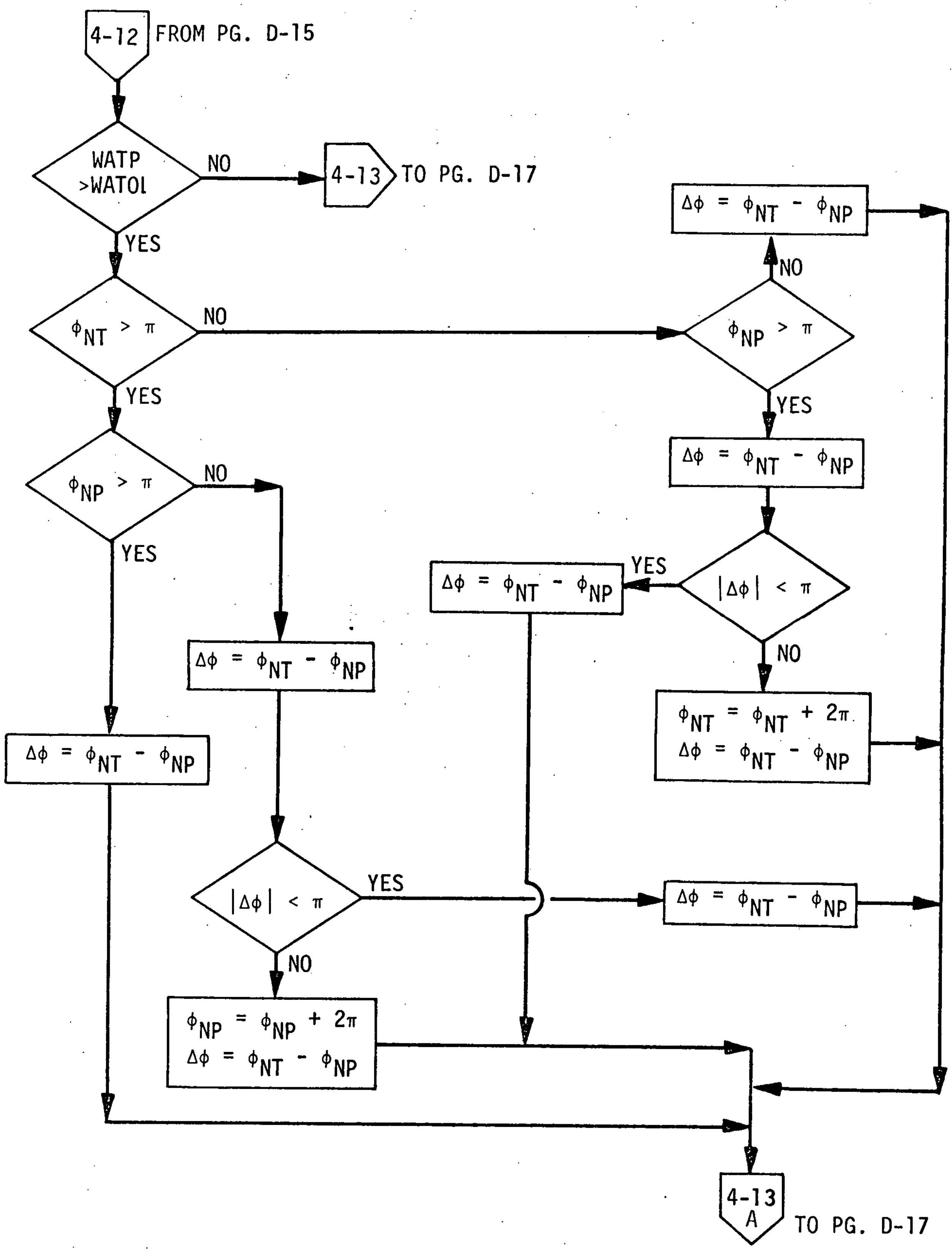
$\bar{A}_{MP} = \bar{X}_P \times \dot{\bar{X}}_P$, $\bar{A}_{MT} = \bar{X}_T \times \dot{\bar{X}}_T$
$\bar{N}_{TP} = \bar{A}_{MP} \times \bar{A}_{MT}$
$$W_{ATP} = \cos^{-1}\left[\frac{\bar{A}_{MP} \cdot \bar{A}_{MT}}{|\bar{A}_{MP}||\bar{A}_{MT}|}\right]$$

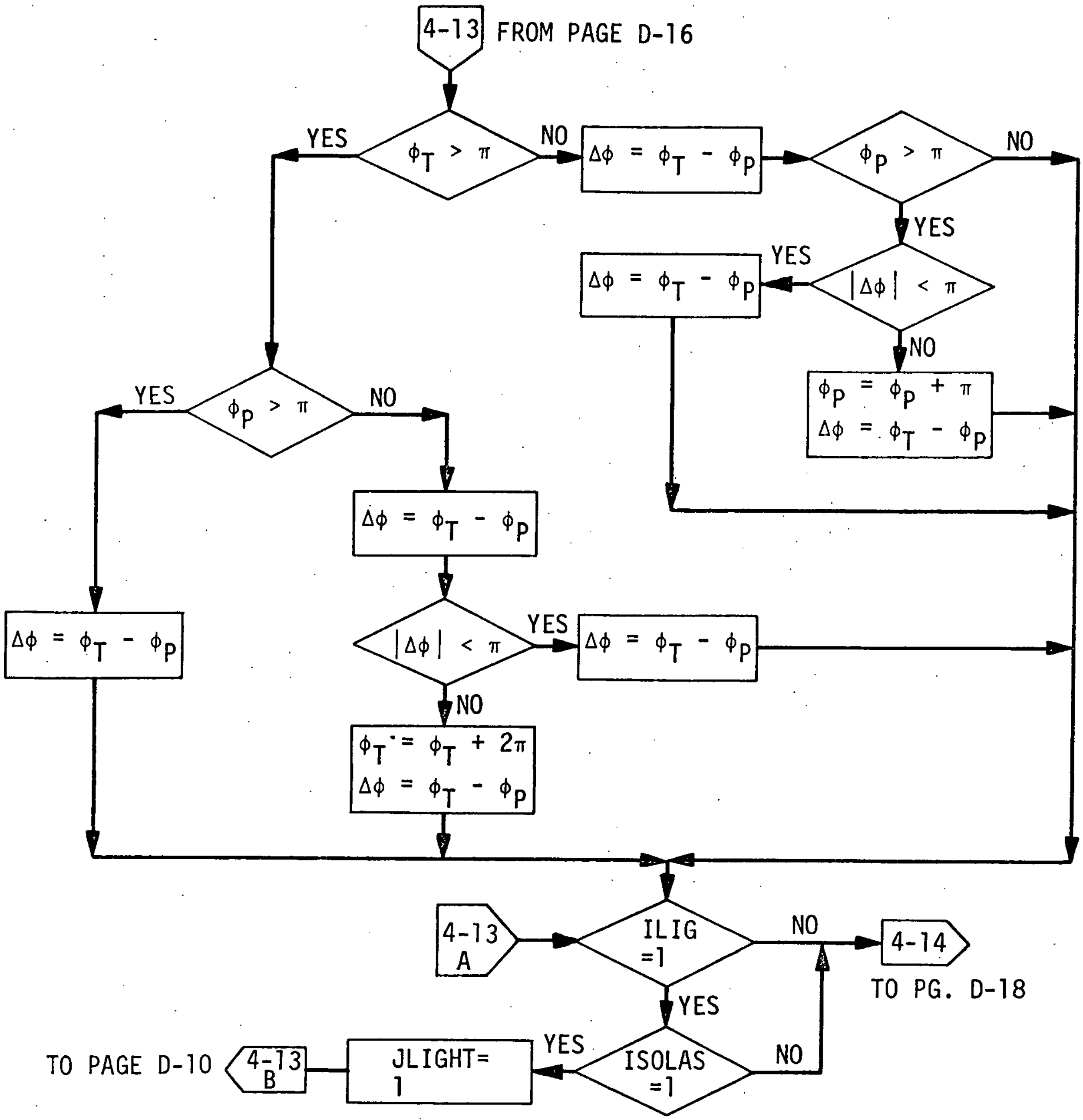
RANGA
ϕ_P

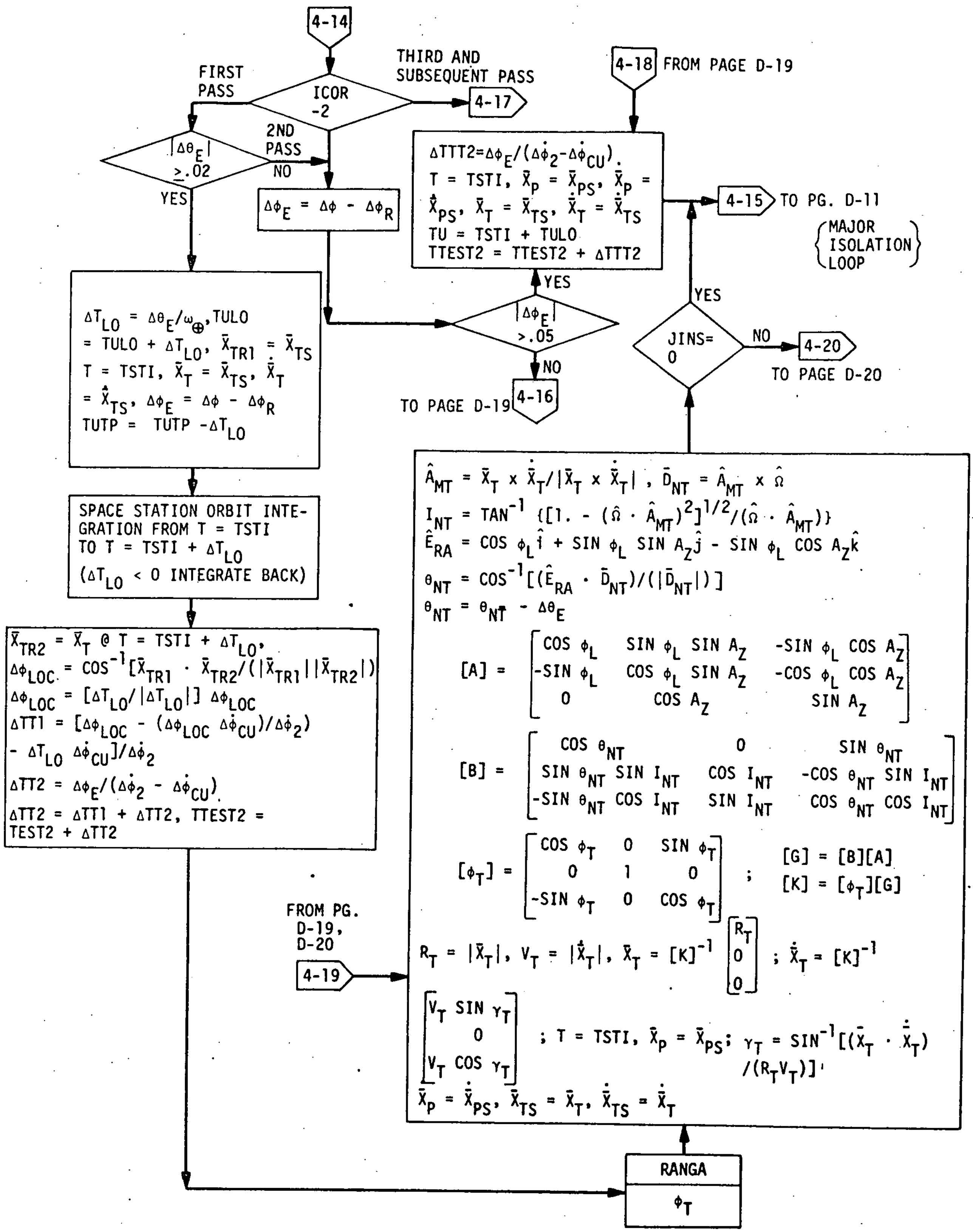
RANGA
ϕ_T

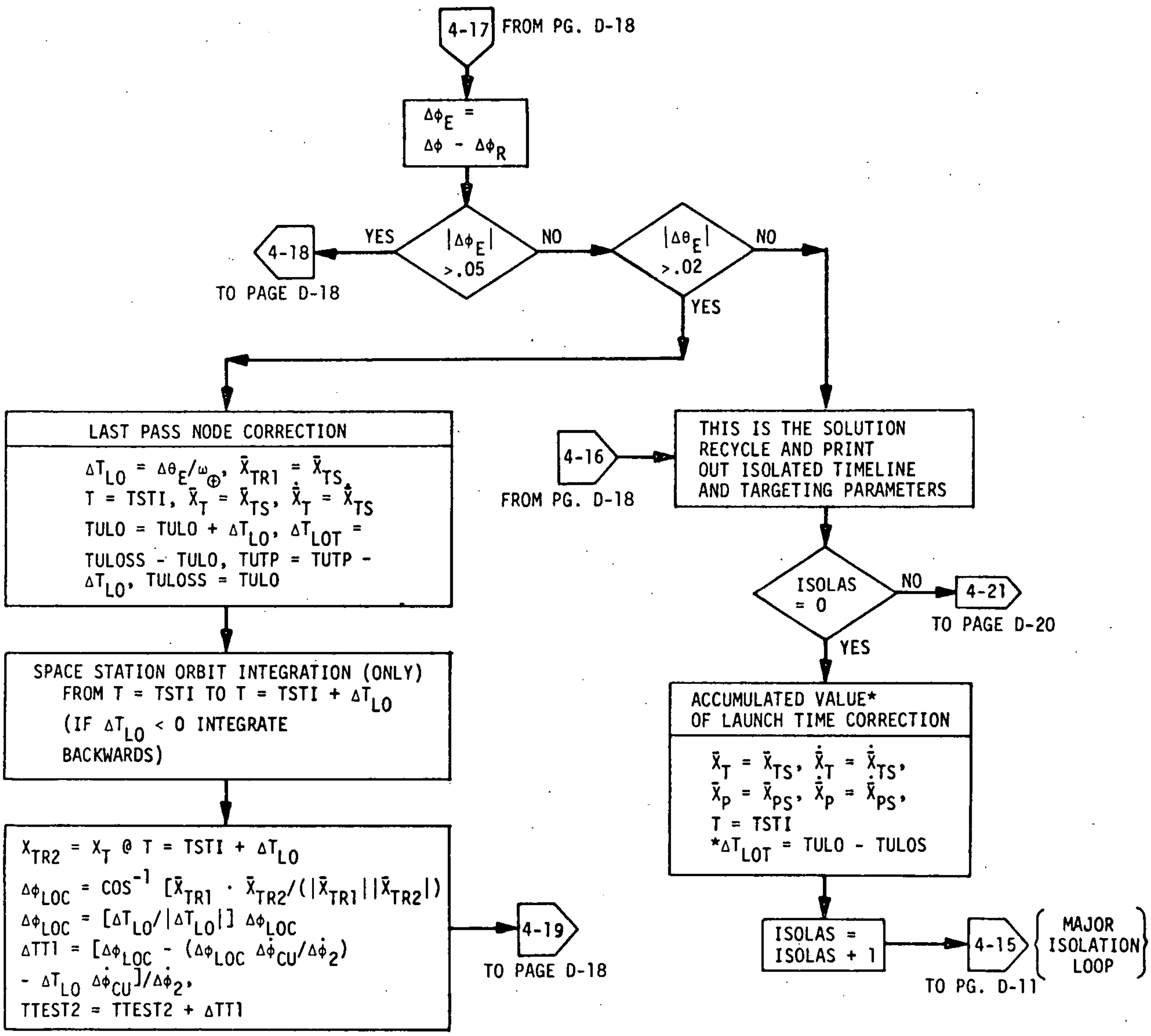
$\bar{N}_{CXT} = \bar{X}_T \times \bar{N}_{TP}$, $\bar{N}_{CTCT} = \bar{N}_{TP} \times \bar{N}_{CXT}$
$\text{SIN } \phi_{NT} = [\bar{N}_{CTCT} \cdot \bar{X}_T/\{|\bar{N}_{CTCT}| \cdot |\bar{X}_T|\}]$
$\text{COS } \phi_{NT} = [\bar{N}_{PT} \cdot \bar{X}_T/[|\bar{N}_{TP}||X_T|]]$
$\phi_{NT} = \text{TAN}^{-1}(\text{SIN } \phi_{NT}/\text{COS } \phi_{NT})$
$\bar{N}_{CXP} = \bar{X}_P \times \bar{N}_{TP}$, $\bar{N}_{CPCP} = \bar{N}_{TP} \times N_{CXP}$, $\text{SIN } \phi_{NP} =$
$\bar{N}_{CPCP} \cdot \bar{X}_P/\{|\bar{N}_{CPCP}||\bar{X}_P|\}$, $\text{COS } \phi_{NP} = \bar{N}_{TP} \cdot \bar{X}_P$
$/\{|N_{TP}||X_P|\}$, $\phi_{NP} = \text{TAN}^{-1}(\text{SIN } \phi_P/ \text{COS } \phi_P)$
$\hat{E}_{RA} = \text{COS } \phi_L \hat{i} + \text{SIN } \phi_L \text{ SIN } A_Z \hat{j} - \text{SIN } \phi_L \text{ COS } A_Z \hat{k}$
$\theta_{NT} = \text{COS}^{-1}(\hat{E}_{RA} \cdot \bar{D}_{NT}/|\bar{D}_{NT}|)$, $\theta_{NP} = \text{COS}^{-1}(\hat{E}_{RA} \cdot \bar{D}_{NP}/|\bar{D}_{NP}|)$
$\Delta\theta_E = \theta_{NT} - \theta_{NP}$

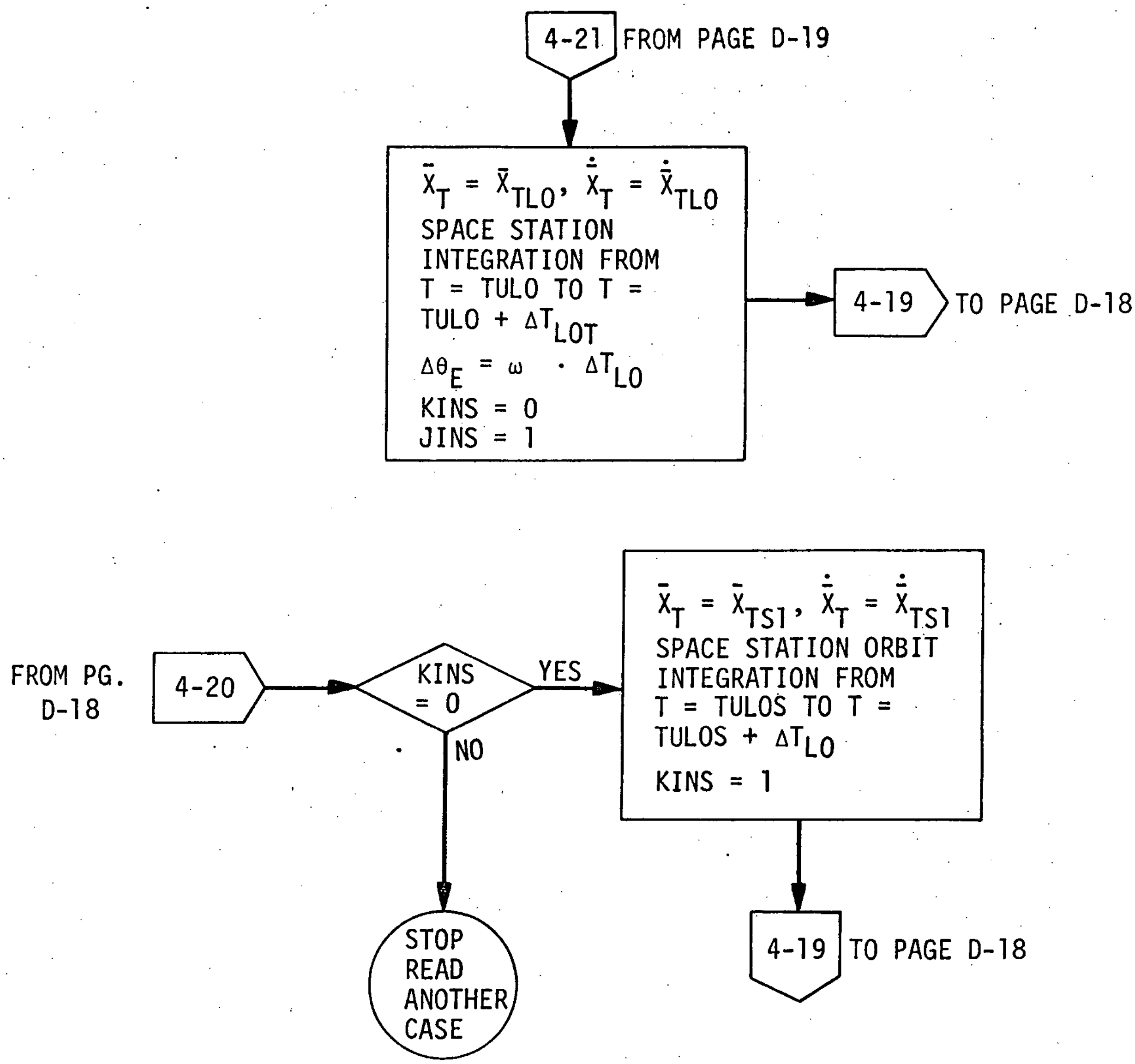
4-12 TO PG. D-16


4-12
FROM PG. D-15
WATP >WATOL
NO
4-13
TO PG. D-17
YES
ϕNT > π
NO
YES
ϕNP > π
NO
YES
Δϕ = ϕNT - ϕNP
Δϕ = ϕNT - ϕNP
|Δϕ| < π
YES
NO
ϕNP = ϕNP + 2π
Δϕ = ϕNT - ϕNP
Δϕ = ϕNT - ϕNP
NO
ϕNP > π
YES
Δϕ = ϕNT - ϕNP
|Δϕ| < π
YES
Δϕ = ϕNT - ϕNP
NO
ϕNT = ϕNT + 2π
Δϕ = ϕNT - ϕNP
Δϕ = ϕNT - ϕNP
4-13 A
TO PG. D-17

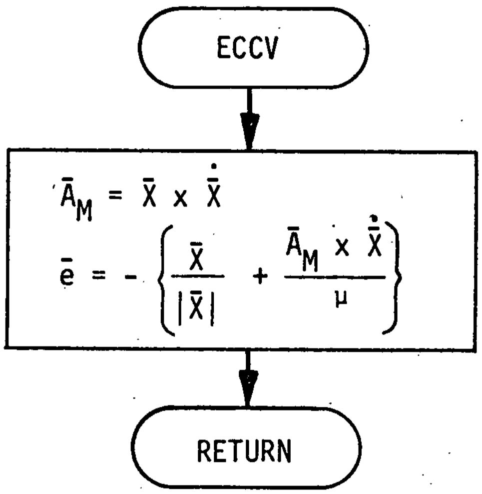

4-13
FROM PAGE D-16
$\phi_T > \pi$
YES
NO
$\Delta\phi = \phi_T - \phi_P$
$\phi_P > \pi$
NO
YES
$\Delta\phi = \phi_T - \phi_P$
YES
$|\Delta\phi| < \pi$
NO
$\phi_P = \phi_P + \pi$
$\Delta\phi = \phi_T - \phi_P$
YES
$\phi_P > \pi$
NO
$\Delta\phi = \phi_T - \phi_P$
$\Delta\phi = \phi_T - \phi_P$
$|\Delta\phi| < \pi$
YES
$\Delta\phi = \phi_T - \phi_P$
NO
$\phi_T = \phi_T + 2\pi$
$\Delta\phi = \phi_T - \phi_P$
4-13 A
ILIG =1
NO
4-14
TO PG. D-18
YES
TO PAGE D-10
4-13 B
JLIGHT= 1
YES
ISOLAS =1
NO


4-14
FIRST PASS
ICOR -2
THIRD AND SUBSEQUENT PASS
4-17
2ND PASS
4-18 FROM PAGE D-19
$|\Delta\theta_E| \geq .02$
NO
YES
$\Delta\phi_E = \Delta\phi - \Delta\phi_R$
$\Delta TTT2 = \Delta\phi_E/(\Delta\dot{\phi}_2 - \Delta\dot{\phi}_{CU})$. $T = TSTI$, $\bar{X}_P = \bar{X}_{PS}$, $\dot{\bar{X}}_P = \dot{\bar{X}}_{PS}$, $\bar{X}_T = \bar{X}_{TS}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TS}$
TU = TSTI + TULO
TTEST2 = TTEST2 + ΔTTT2
4-15 TO PG. D-11
MAJOR ISOLATION LOOP
YES
YES
$\Delta T_{LO} = \Delta\theta_E/\omega_\oplus$, TULO = TULO + ΔT_{LO}, $\bar{X}_{TR1} = \bar{X}_{TS}$
$T = TSTI$, $\bar{X}_T = \bar{X}_{TS}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TS}$, $\Delta\phi_E = \Delta\phi - \Delta\phi_R$
TUTP = TUTP $-\Delta T_{LO}$
$|\Delta\phi_E| > .05$
JINS= 0
NO
4-20
TO PAGE D-20
NO
TO PAGE D-19
4-16
SPACE STATION ORBIT INTEGRATION FROM T = TSTI TO T = TSTI + ΔT_{LO}
(ΔT_{LO} < 0 INTEGRATE BACK)
$\bar{X}_{TR2} = \bar{X}_T$ @ $T = TSTI + \Delta T_{LO}$,
$\Delta\phi_{LOC} = \cos^{-1}[\bar{X}_{TR1} \cdot \bar{X}_{TR2}/(|\bar{X}_{TR1}||\bar{X}_{TR2}|)]$
$\Delta\phi_{LOC} = [\Delta T_{LO}/|\Delta T_{LO}|]\ \Delta\phi_{LOC}$
$\Delta TT1 = [\Delta\phi_{LOC} - (\Delta\phi_{LOC}\ \Delta\dot{\phi}_{CU})/\Delta\dot{\phi}_2) - \Delta T_{LO}\ \Delta\dot{\phi}_{CU}]/\Delta\dot{\phi}_2$
$\Delta TT2 = \Delta\phi_E/(\Delta\dot{\phi}_2 - \Delta\dot{\phi}_{CU})$
$\Delta TT2 = \Delta TT1 + \Delta TT2$, TTEST2 = TEST2 + $\Delta TT2$
$\hat{A}_{MT} = \bar{X}_T \times \dot{\bar{X}}_T/|\bar{X}_T \times \dot{\bar{X}}_T|$, $\bar{D}_{NT} = \hat{A}_{MT} \times \hat{\Omega}$
$I_{NT} = \tan^{-1}\{[1. - (\hat{\Omega} \cdot \hat{A}_{MT})^2]^{1/2}/(\hat{\Omega} \cdot \hat{A}_{MT})\}$
$\hat{E}_{RA} = \cos\phi_L \hat{i} + \sin\phi_L \sin A_Z \hat{j} - \sin\phi_L \cos A_Z \hat{k}$
$\theta_{NT} = \cos^{-1}[(\hat{E}_{RA} \cdot \bar{D}_{NT})/(|\bar{D}_{NT}|)]$
$\theta_{NT} = \theta_{NT} - \Delta\theta_E$
$[A] = \begin{bmatrix} \cos\phi_L & \sin\phi_L \sin A_Z & -\sin\phi_L \cos A_Z \\ -\sin\phi_L & \cos\phi_L \sin A_Z & -\cos\phi_L \cos A_Z \\ 0 & \cos A_Z & \sin A_Z \end{bmatrix}$
$[B] = \begin{bmatrix} \cos\theta_{NT} & 0 & \sin\theta_{NT} \\ \sin\theta_{NT} \sin I_{NT} & \cos I_{NT} & -\cos\theta_{NT} \sin I_{NT} \\ -\sin\theta_{NT} \cos I_{NT} & \sin I_{NT} & \cos\theta_{NT} \cos I_{NT} \end{bmatrix}$
$[\phi_T] = \begin{bmatrix} \cos\phi_T & 0 & \sin\phi_T \\ 0 & 1 & 0 \\ -\sin\phi_T & 0 & \cos\phi_T \end{bmatrix}$; $[G] = [B][A]$, $[K] = [\phi_T][G]$
FROM PG. D-19, D-20
4-19
$R_T = |\bar{X}_T|$, $V_T = |\dot{\bar{X}}_T|$, $\bar{X}_T = [K]^{-1} \begin{bmatrix} R_T \\ 0 \\ 0 \end{bmatrix}$; $\dot{\bar{X}}_T = [K]^{-1} \begin{bmatrix} V_T \sin\gamma_T \\ 0 \\ V_T \cos\gamma_T \end{bmatrix}$; $T = TSTI$, $\bar{X}_P = \bar{X}_{PS}$; $\gamma_T = \sin^{-1}[(\bar{X}_T \cdot \dot{\bar{X}}_T)/(R_T V_T)]$
$\bar{X}_P = \bar{X}_{PS}$, $\bar{X}_{TS} = \bar{X}_T$, $\dot{\bar{X}}_{TS} = \dot{\bar{X}}_T$
RANGA
ϕ_T


4-17
FROM PG. D-18
$\Delta\phi_E = \Delta\phi - \Delta\phi_R$
$|\Delta\phi_E| > .05$
YES
4-18
TO PAGE D-18
NO
$|\Delta\theta_E| > .02$
NO
YES
LAST PASS NODE CORRECTION
$\Delta T_{LO} = \Delta\theta_E/\omega_\oplus$, $\bar{X}_{TR1} = \bar{X}_{TS}$, $T = TSTI$, $\bar{X}_T = \bar{X}_{TS}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TS}$
$TULO = TULO + \Delta T_{LO}$, $\Delta T_{LOT} = TULOSS - TULO$, $TUTP = TUTP - \Delta T_{LO}$, $TULOSS = TULO$
SPACE STATION ORBIT INTEGRATION (ONLY) FROM T = TSTI TO T = TSTI + ΔT_{LO}
(IF $\Delta T_{LO} < 0$ INTEGRATE BACKWARDS)
$X_{TR2} = X_T$ @ $T = TSTI + \Delta T_{LO}$
$\Delta\phi_{LOC} = \cos^{-1} [\bar{X}_{TR1} \cdot \bar{X}_{TR2}/(|\bar{X}_{TR1}||\bar{X}_{TR2}|)$
$\Delta\phi_{LOC} = [\Delta T_{LO}/|\Delta T_{LO}|] \Delta\phi_{LOC}$
$\Delta TT1 = [\Delta\phi_{LOC} - (\Delta\phi_{LOC} \Delta\dot{\phi}_{CU}/\Delta\dot{\phi}_2) - \Delta T_{LO} \Delta\dot{\phi}_{CU}]/\Delta\dot{\phi}_2$,
$TTEST2 = TTEST2 + \Delta TT1$
4-19
TO PAGE D-18
4-16
FROM PG. D-18
THIS IS THE SOLUTION RECYCLE AND PRINT OUT ISOLATED TIMELINE AND TARGETING PARAMETERS
ISOLAS = 0
NO
4-21
TO PAGE D-20
YES
ACCUMULATED VALUE* OF LAUNCH TIME CORRECTION
$\bar{X}_T = \bar{X}_{TS}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TS}$,
$\bar{X}_P = \bar{X}_{PS}$, $\dot{\bar{X}}_P = \dot{\bar{X}}_{PS}$,
T = TSTI
$^*\Delta T_{LOT}$ = TULO - TULOS
ISOLAS = ISOLAS + 1
4-15
TO PG. D-11
MAJOR ISOLATION LOOP


4-21
FROM PAGE D-19
$\bar{X}_T = \bar{X}_{TLO}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TLO}$
SPACE STATION
INTEGRATION FROM
T = TULO TO T =
TULO + ΔT_{LOT}
$\Delta\theta_E = \omega \cdot \Delta T_{LO}$
KINS = 0
JINS = 1
4-19
TO PAGE D-18
FROM PG. D-18
4-20
KINS = 0
YES
NO
$\bar{X}_T = \bar{X}_{TS1}$, $\dot{\bar{X}}_T = \dot{\bar{X}}_{TS1}$
SPACE STATION ORBIT
INTEGRATION FROM
T = TULOS TO T =
TULOS + ΔT_{LO}
KINS = 1
STOP
READ
ANOTHER
CASE
4-19
TO PAGE D-18

D.3 SUBROUTINES



TRUE

$N_{EC} = \dot{\bar{X}} \times \bar{X}$, $\bar{N}_{CEC} = \bar{e} \times \bar{N}_{EC}$

$COS(TA) = \bar{e} \cdot \bar{X}/\{|\bar{e}||\bar{X}|\}$

$SIN(TA) = \bar{N}_{CEC} \cdot \bar{X}/\{|\bar{N}_{CEC}||\bar{X}|\}$

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

RETURN

RANGA

$\bar{A}_M = \bar{X} \times \dot{\bar{X}}$, $\overline{DN} = \bar{A}_M \times \hat{\Omega}$, $\bar{D}_{CH} = \bar{A}_M \times \overline{DN}$

$SIN\ \phi = \bar{D}_{CH} \cdot \bar{X}/\{|D_{CH}||X|\}$

$COS\ \phi = \overline{DN} \cdot \bar{X}/\{|\overline{DN}||\bar{X}|\}$

$\phi = TAN^{-1}(SIN\ \phi/COS\ \phi)$

RETURN

Appendix E

PROGRAM LISTING

```
      PROGRAM TARG
      DIMENSION XP(3), XDP(3), XT(3), XDT(3), XTR1(3), XTR2(3), TEMP1(3)
     1, TEMP2(3), TEMP3(3), TEMP4(3), TEMP5(3), XOMEGA(3), AAA(3,3), BBB
     2(3,3), CCC(3,3), DDD(3,3), XPS(3), XDPS(3), XTS(3), XDTS(3), EV(3)
     3, AM(3), XTS1(3), 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(
     17)
      DIMENSION XTLO(3), XDTLO(3)
      CF=1852.
      GM=.3986032E15
      RE=6378166.
      GM2=.7972064E15
      OMEGA=.729211585E-04
      PI2=6.2831852
      PI=3.1415926
      ZERO=0.0
      ONE=1.
      TWO=2.0
      CNV=57.29577951
      WATOL=.1/CNV
      KPASS=0
      JPASS=0
      READ 1750, ISURF,ILIG
      READ 1760, A,B,C,D,E,F,G,H,Q,S
      READ 2100, T,TN,TS,TTOL,HAP,HPER
      READ 2100, AN,EN,XENCN,THNN,ALFAN,PHIN
      READ 2100, AS,ES,XENCS,THNS,ALFAS,PHIS
      READ 2100, PHI,XLAMAL,BSVD,A1,B1,C1,TOLE,TY,DLHD,DLHB,SFNO1,SFNO2,
     1SFNO3,SLM
      JINS=0
      DT18=5.0
      DT=200.
      DT12=20.0
      SSFNO3=SFNO3
      JLIGHT=0
      DTS=DT
      PHIO=PHI
      AZO=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
```

PROGRAM TARG

```
      ALFAN=ALFAN/CNV
      PHIN=PHIN/CNV
      XENCS=XENCS/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
      XENCT=XENCN
      THNT=THNN
      ALFAT=ALFAN
      PHII=PHIN
      GO TO 90
   80 T=TS
      AT=AS
      ET=ES
      XENCT=XENCS
      THNT=THNS
      ALFAT=ALFAS
      PHII=PHIS
   90 IF (JPASS-1) 100,140,140
  100 IF (THNT-PI/2.) 110,110,120
  110 AZL=PI-ARSIN(COS(XENCT)/COS(PHI))
      AZO=AZL*CNV
      AZ=AZL
      GO TO 130
  120 AZL=ARSIN(COS(XENCT)/COS(PHI))
      AZ=AZL
      AZO=AZL*CNV
  130 PRINT 1800
      PHIIO=PHII*CNV
      ALFATO=ALFAT*CNV
      XENCTO=XENCT*CNV
      THNTO=THNT*CNV
      PRINT 1790, T,AT,ET,XENCTO,THNTO,ALFATO,PHIIO
      PRINT 1810, AZO
  140 PHIT=PHII-ALFAT
```

```
      CALL MAROT (AAA,AZ-PI/2.,1,1)
      CALL MAROT (BBB,PHI,3,+1)
      CALL MAMUL (CCC,BBB,AAA)
      CALL MAROT (AAA,THNT,2,-1)
      CALL MAROT (BBB,XENCT,1,-1)
      CALL MAMUL (DDD,BBB,AAA)
      CALL MAMUL (AAA,DDD,CCC)
      CALL MAROT (BBB,PHIT,2,-1)
      CALL MAMUL (CCC,BBB,AAA)
      CALL FATT (DDD,CCC)
      XOMEGA(1)=SIN(PHI)
      XOMEGA(2)=-COS(PHI)*SIN(AZ)
      XOMEGA(3)=COS(PHI)*COS(AZ)
      IF (KPASS-1) 150,160,150
  150 RO=AT*(ONE-ET*ET)/(ONE+ET*COS(PHII))
      VO=SQRT(GM*(TWO/RO-ONE/AT))
      GAMMO=ARTAN(ET*SIN(PHII),ONE+ET*COS(PHII),1)
  160 CONTINUE
      TEMP1(1)=RO
      TEMP1(2)=ZERO
      TEMP1(3)=ZERO
      TEMP2(1)=VO*SIN(GAMMO)
      TEMP2(2)=ZERO
      TEMP2(3)=VO*COS(GAMMO)
      CALL FATMU (XT,DDD,TEMP1)
      CALL FATMU (XDT,DDD,TEMP2)
      DTT3=100.0
      MPASSI=0
      IF (JPASS-1) 170,370,170
  170 CALL RANGA (XT,XDT,XOMEGA,PHIT)
      CALL VCROSS (TEMP1,XT,XDT)
      CALL VCROSS (TEMP2,TEMP1,XOMEGA)
      RRT=VMAG(XT)
      PSI=ARSIN(VDOT(XT,XOMEGA)/RRT)
      PSIO=PSI*CNV
      TEMP5(1)=COS(PHI)
      TEMP5(2)=SIN(PHI)*SIN(AZ)
      TEMP5(3)=-SIN(PHI)*COS(AZ)
      THNT=ARCOS(VDOT(TEMP5,TEMP2)/VMAG(TEMP2))
      CALL VUNIT (TEMP4,TEMP1)
      DUM1=VDOT(XOMEGA,TEMP4)
      DUM=DUM1*DUM1
      XENC=ARTAN(SQRT(ONE-DUM),DUM1,1)
      AT=RRT*GM/(TWO*GM-VDOT(XDT,XDT)*RRT)
      XENCO=XENC*CNV
      PHITO=PHIT*CNV
      THNTO=THNT*CNV
      PRINT 1700, PSIO
      IF (MPASSI-1) 180,300,180
  180 IF (THNT-PI/TWO) 200,190,190
```

PROGRAM TARG

```
190 NORTH=1
    GO TO 210
200 NORTH=0
    SOUTHERNLY LAUNCH COEFFICIENTS
210 IF (NORTH-1) 220,230,230
220 PSIDO=POLY(B,XENCO,6)
    PSID=PSIDO/CNV
    DUM=COS(XENC)/COS(PSID)
    AA=SQRT(ONE-DUM*DUM)
    PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
    PHILS=PI2-PHILS
    DPHRR=PHILS-PHIT
    GO TO 240
    NORTHERNLY LAUNCH COEFFICIENTS
230 PSIDO=POLY(A,XENCO,6)
    PSID=PSIDO/CNV
    DUM=COS(XENC)/COS(PSID)
    AA=SQRT(ONE-DUM*DUM)
    PHILS=ARTAN((SIN(PSID)/COS(PSID)),AA,-1)
    PHILS=PI+PHILS
    DPHRR=PHILS-PHIT
240 CONTINUE
    DPHRRO=DPHRR*CNV
    PRINT 1710, PSIDO
    IF (PHIT-PI) 290,290,250
250 IF (DPHRR) 290,290,260
260 PHID=SQRT(GM/(AT*AT*AT))
    TGR=DPHRR/PHID
    IF (TGR-100.0) 270,270,290
270 DTT3=10.0
    IF (TGR-20.0) 280,280,290
280 DTT3=TGR
    MPASSI=1
290 TF=T+DTT3
    CALL RKG (PHIO,AZO,XT,XDT,T,TF)
    T=TF
    TULOD=0.0
    PRINT 2210
    CALL PRINT (TF,XT,XDT,AZ,PHI,TULOD)
    GO TO 170
300 PRINT 1840
    PRINT 1820, PSIO
    PRINT 1830, PSIDO
    XIDO=XENCO
    PRINT 1850, XENCO
    IF (ISURF-1) 310,330,310
    THIS IS WHERE THE STEADY STATE SHOULD BE PROGRAMED IN THE FUTURE
310 DO 320 I=1,3
    XP(I)=0.0
320 XDP(I)=0.0
```

T I D Y *

PROGRAM TARG PAGE 28

```
      PRINT 1860
      GO TO 400
 330  IF (NORTH-1) 350,340,350
 340  AZN=POLY(C,XIDO,6)
      AZO=AZN
      THNNP=POLY(D,XIDO,6)
      T1N=POLY(E,XIDO,6)
      PHIPN=POLY(Q,XIDO,6)
      PHII=PHIPN/CNV
      ALFAT=0.0
      THNT=THNNP/CNV
      AZ=AZN/CNV
      T1=T1N
      GO TO 360
 350  AZS=POLY(F,XIDO,6)
      AZO=AZS
      THNSP=POLY(G,XIDO,6)
      T1S=POLY(H,XIDO,6)
      PHIPS=POLY(S,XIDO,6)
      PHII=PHIPS/CNV
      ALFAT=0.0
      THNT=THNSP/CNV
      AZ=AZS/CNV
      T1=T1S
 360  XENCT=XIDO/CNV
      PRINT 1870, AZO
      KPASS=1
      JPASS=1
      RO=HPER*CF+RE
      RA=HAP*CF+RE
      ET=(RA-RO)/(RA+RO)
      AT=(RA+RO)/TWO
      VO=SQRT(GM*(ONE+ET)/RO)
      GAMMO=0.0
      GO TO 140
 370  IF (KPASS-1) 410,380,380
 380  DO 390 I=1,3
      XP(I)=XT(I)
 390  XDP(I)=XDT(I)
 400  KPASS=0
      PRINT 1880, XP,XDP
      PUNCH 2350, XP,XDP
      JPASS=1
      GO TO 60
 410  TF=T+T1
      DO 420 I=1,3
      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
      XTS1(I)=XT(I)
      XDTS1(I)=XDT(I)
      XPS1(I)=XP(I)
  430 XDPS1(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)
      PDPA1=SQRT(GM/(AP*AP*AP))
      PDTA1=SQRT(GM/(AT*AT*AT))
      DLPD1=PDPA1-PDTA1
      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-EP)/(ONE+EP))
      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)
      TAUP1=PI2*SQRT(AP*AP*AP/GM)
      T2=T1+TAUP1/TWO
      DRT=RAT-RPT
      GAMAPO=GAMAP*CNV
      HAT=(RAT-RE)/CF
      PHDOTP=PDPA1*CNV
      HPT=(RPT-RE)/CF
      PHDOTT=PDTA1*CNV
      HAP=(RAP-RE)/CF
      DLPD10=DLPD1*CNV
      HPP=(RPP-RE)/CF
      GAMATO=GAMAT*CNV
      DLMR10=DLMR1*CNV
      PRINT 2110
      PRINT 2120, RRP,VVP,GAMAPO,EP,AP,HAP,HPP,PHDOTP
      PRINT 2130
      PRINT 2140, RRT,VVT,GAMATO,ET,AT,HAT,HPT,PHDOTT
      PRINT 2150
      PRINT 2160, DLPD10,DLMR10,T2
```

```
      RCP=RAP
      VCP=SQRT(GM/RCP)
      DUM=SQRT(RCP*RCP*RCP/GM)
      TAUCP=PI2*DUM
      PDOTCP=ONE/DUM
      DLPD2=PDOTCP-PDTA1
      DLMR2=SFNO1*DLPD2*TAUCP
      DELV2=VCP-VAP
      T3=T2+SFNO1*TAUCP
      PDOTCO=PDOTCP*CNV$DLMR20=DLMR2*CNV
      PRINT 2170
      PRINT 2180, RCP,VCP,TAUCP,PDOTCO,DLPD2,DLMR20,DELV2,T3
      IF (ILIG-1) 450,460,450
450   XN=ZERO
      GO TO 470
460   XN=ONE
470   CONTINUE
      RPP3=RCP
      RAP3=RPT-DLHD+DLHB
      AP3=(RPP3+RAP3)/TWO
      DUM=SQRT(AP3*AP3*AP3/GM)
      TAUP3=PI2*DUM
      PDPA3=ONE/DUM
      DLPD3=PDPA3-PDTA1
      DLMR3=SFNO2*DLPD3*TAUP3
      T4=T3+SFNO2*TAUP3
      VPP3=SQRT(GM2*RAP3/(RPP3*(RAP3+RPP3)))
      DELV3=VPP3-VCP
      PRINT 2190
      PDPA30=PDPA3*CNV$DLPD30=DLPD3*CNV
      DLMR30=DLMR3*CNV
      DLMR30=DLMR3*CNV
      PRINT 2200, TAUP3,PDPA30,DLPD30,DELV3,T4,DLMR30
C     CIRCULARIZATION AT CDH ALTITUDE
      RAP3=RAT-DLHD+DLHB
      AP3=(RPP3+RAP3)/TWO
      EP3=(RAP3-RPP3)/(RAP3+RPP3)
      RPP4=RPT-DLHD
      RAP4=RAT-DLHD
      AP4=(RPP4+RAP4)/TWO
      EP4=(RAP4-RPP4)/(RAP4+RPP4)
      P3=AP3*(ONE-EP3*EP3)
      P4=AP4*(ONE-EP4*EP4)
      TH4=ARCOS((P3-P4)/(EP3*P4-EP4*P3))
      R4=P4/(ONE+EP4*COS(TH4))
      V4=SQRT((GM2*AP3/R4-GM)/AP3)
      GAMA4=ARTAN(R4*EP3*SIN(TH4),P3,-1)
      VT4=SQRT((GM2*AP4/R4-GM)/AP4)
      GAMT4=ARTAN(R4*EP4*SIN(TH4),P4,-1)
      DELV4=SQRT(VT4*VT4+V4*V4-TWO*VT4*V4*COS(GAMT4-GAMA4))
```

PROGRAM TARG

```
      TH40=TH4*CNV
      GAMA40=GAMA4*CNV
      GAMT40=GAMT4*CNV
      PRINT 2210
      PRINT 2220, EP3,RPP4,RAP4,AP4,EP4,TH40,R4,V4,GAMA40,VT4,GAMT40,DEL
     1V4
      DUM=SQRT(AP4*AP4*AP4/GM)
      TAUP4=PI2*DUM
      PDPA4=ONE/DUM
      PDPA40=PDPA4*CNV
      DPDCU=PDPA4-PDTA1
      DPPHO=SLM*DELTH
      DPHR=DPPHO/CNV
      PRINT 2230, DPPHO
      DELVR=0.0
      DLPMR4=DPDCU*TAUP4*(SFNO3+XN)+DPHR
      TTPI=T4+TAUP4*(SFNO3+XN)+DPHR/DPDCU
      DPDCUO=DPDCU*CNV
      DVIT=DELV2+DELV3+DELV4+DELVR
      DLMR40=DLPMR4*CNV
      DPMRT1=DLMR1+DLMR2+DLMR3+DLPMR4
      DMRTO=DPMRT1*CNV
      PDPA40=PDPA4*CNV
      DPDCUO=DPDCU*CNV
      PRINT 2240
      PRINT 2250
      PRINT 2260, TAUP4,PDPA40,DPDCUO,DLMR40,TTPI,DMRTO,DVIT
      CALL RANGA (XP,XDP,XOMEGA,PHIP1)
      CALL RANGA (XT,XDT,XOMEGA,PHIT1)
      ISOLAS=0
      ICOR=0
      PHIP10=PHIP1*CNV
      PHIT10=PHIT1*CNV
      PRINT 2270, PHIP10,PHIT10
      IF (PHIT1-PI) 480,490,490
  480 PHIT1=PHIT1+PI2
      DPA1=PHIT1-PHIP1
      GO TO 500
  490 DPA1=PHIT1-PHIP1
  500 IF (DPA1-DPMRT1) 510,520,520
  510 DPA1=DPA1+PI2
      GO TO 530
  520 DPA1=DPA1
  530 DT1=SFNO3*TAUP4+TAUP1/TWO+TAUP3*SFNO2
      DPH1=DLMR1+DLMR3+DPDCU*TAUP4*SFNO3
      DPA10=DPA1*CNV
      PRINT 1910, DPA10
      DPH2=DPA1-DPH1-DPHR
      DT2=DPH2/DLPD2
      TTEST1=T1+TAUP1/TWO-200.
```

```
      TTEST2=T1+TAUP1/TWO+DT2
      TSBST=T1+DT1+DT2
      PRINT 1920, SFNO1,SFNO2,SFNO3
      PRINT 2320
      CALL PRINT (T1,XT,XDT,AZ,PHI,TULO)
      CALL RKG (PHIO,AZO,XT,XDT,T1,TSBST)
      PRINT 2320
      CALL PRINT (TSBST,XT,XDT,AZ,PHI,TULO)
      PRINT 2280
      DPH1O=DPH1*CNV
      DPH2O=DPH2*CNV
      PRINT 2290, DPH1O,DPH2O,DT2,TSBST,DT1,T1,TTEST1,TTEST2
      IF (ILIG-1) 630,540,630
      TULO=SHUTTLE LIFT-OFF TIME IN SECONDS UNIVERSAL TIME
      TY  =NUMBER OF DAYS PAST JAN.1 OF LAUNCH YEAR
      LAMDA,L  = LONGITUDE OF LAUNCH SITE
      A1,B1,C1    INPUT CONSTANTS
      OMEGA      = EARTHS# ROTATION
  540 T=TSBST
  550 DUM=PI*XLAMAL-OMEGA*TULO
      PHSV=DUM
      CALL MAROT (AAA,DUM,2,-1)
      DUM=A1*COS(B1+C1*TY)
      ALSV=DUM
      CALL MAROT (BBB,DUM,3,-1)
      CALL MAMUL (CCC,BBB,AAA)
      CALL MAROT (AAA,AZ-PI/TWO,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 FATMU (TEMP2,BBB,TEMP1)
      JFLAG=0
  560 CALL VCROSS (TEMP3,XT,XDT)
      BSD=VMAG(TEMP3)/VDOT(XT,XT)
      CALL VUNIT (TEMP4,TEMP3)
      CALL VCROSS (TEMP5,TEMP4,TEMP2)
      CALL VUNIT (TEMP5,TEMP5)
      CALL VCROSS (TEMP2,TEMP5,TEMP4)
      BSVPT=ARTAN(VDOT(XT,TEMP5),VDOT(XT,TEMP2),1)
      IF (JLIGHT-1) 570,1450,570
  570 IF ((BSVPT-BSVD)-.0001) 580,580,610
  580 IF (JFLAG-1) 590,620,590
  590 CHECK=BSVPT+BSD*DT
      IF (CHECK-BSVD) 610,600,600
  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
    XLAMDO=XLAMAL*CNV
    PRINT 2310, AO,BO,CO,TY,XLAMDO,PHSVO,ALSVO,BSVPTO
    TUTP=T
    DT3=T-TSBST
    DPH1=DPH1+DPDCU*DT3
    DPH2=DPA1-DPH1-DPHR
    DT2=DPH2/DLPD2
    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,T1,TTEST1)
    CALL RKG (PHIO,AZO,XP,XDP,T1,TTEST1)
    PRINT 2320
    CALL PRINT (TTEST1,XT,XDT,AZ,PHI,TULO)
    PRINT 2330
    CALL PRINT (TTEST1,XP,XDP,AZ,PHI,TULO)
    T=TTEST1
660 CALL ECCV (GM,XP,XDP,TEMP3)
    CALL TRUE (XP,XDP,TEMP3,PTA)
    EP=VMAG(TEMP3)
    RPM=VMAG(XP)
    AP=RPM*GM/(GM2-VDOT(XDP,XDP)*RPM)
    CALL TIME (AP,EP,PTA,PI,GM,PI,TGP2)
    IF (TGP2-30.0) 670,670,680
670 DT12=ONE
    IF (TGP2-TWO) 690,690,680
680 T12=T+DT12
    CALL RKG (PHIO,AZO,XT,XDT,T,T12)
    CALL RKG (PHIO,AZO,XP,XDP,T,T12)
    T=T12
    GO TO 660
690 RAP=VMAG(XP)
    PRINT 2320
    CALL PRINT (T12,XT,XDT,AZ,PHI,TULO)
    PRINT 2330
    CALL PRINT (T12,XP,XDP,AZ,PHI,TULO)
```

PROGRAM TARG

```
      TSTI=T
      VC=SQRT(GM/RAP)
      CALL VCROSS (TEMP1,XDP,XP)
      CALL VCROSS (TEMP2,XP,TEMP1)
      CALL VUNIT (TEMP2,TEMP2)
      DO 700 I=1,3
  700 TEMP3(I)=VC*TEMP2(I)
      DO 710 I=1,3
  710 TEMP1(I)=TEMP3(I)-XDP(I)
      V01=VMAG(TEMP1)
      PRINT 1990
      PRINT 2000
      PRINT 2330
      CALL PRINT (TSTI,XP,XDP,AZ,PHI,TULO)
      CALL VCROSS (AM,XP,TEMP3)
      CALL ECCV (GM,XP,TEMP3,EV)
      PRINT 2010, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2),
     1TEMP1(3)
      DO 720 I=1,3
  720 XDP(I)=TEMP3(I)
      DO 730 I=1,3
      XPS(I)=XP(I)
      XDPS(I)=XDP(I)
      XTS(I)=XT(I)
  730 XDTS(I)=XDT(I)
  740 CALL RKG (PHI0,AZ0,XT,XDT,TSTI,TTEST2)
      CALL RKG (PHI0,AZ0,XP,XDP,TSTI,TTEST2)
      PRINT 2330
      CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
      PRINT 2320
      CALL PRINT (TTEST2,XT,XDT,AZ,PHI,TULO)
      T=TTEST2
      CALL ECCV (GM,XT,XDT,TEMP3)
      RTM=VMAG(XT)
      AT=RTM*GM/(GM2-VDOT(XDT,XDT)*RTM)
      ET=VMAG(TEMP3)
      RPP=VMAG(XP)
      RATD=AT*(ONE+ET)-DLHD
      RPTD=AT*(ONE-ET)-DLHD
      ETD=(RATD-RPTD)/(RATD+RPTD)
      DO 750 I=1,3
  750 TEMP2(I)=-XP(I)
      RPP=VMAG(XP)
      CTTAPA=VDOT(TEMP3,TEMP2)/(ET*RPP)
      RAP=TWO*RATD*RPTD/((RATD+RPTD)+(RATD-RPTD)*CTTAPA)+DLHB
      EP=(RAP-RPP)/(RAP+RPP)
      VPP=SQRT((GM/RPP)*(ONE+EP))
      PRINT 2330
      CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
      PRINT 1930
```

PROGRAM TARG

```
      CALL VCROSS (TEMP1,XDP,XP)
      CALL VCROSS (TEMP3,XP,TEMP1)
      CALL VUNIT (TEMP3,TEMP3)
      DO 760 I=1,3
  760 TEMP2(I)=VPP*TEMP3(I)
      DO 770 I=1,3
  770 TEMP1(I)=TEMP2(I)-XDP(I)
      VG2=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),
     1TEMP1(3)
  790 CONTINUE
      DO 800 I=1,3
  800 XDP(I)=TEMP2(I)
      PRINT 1940
      PRINT 2330
      CALL PRINT (TTEST2,XP,XDP,AZ,PHI,TULO)
      AP=(RPP+RAP)/TWO
      TAUP2=PI2*SQRT(AP*AP*AP/GM)
      TTEST3=T+(TAUP2*SFNO2)-250.
      JPAS=0
      KPAS=0
      CALL RKG (PHIO,AZO,XT,XDT,TTEST2,TTEST3)
      CALL RKG (PHIO,AZO,XP,XDP,TTEST2,TTEST3)
      PRINT 2320
      CALL PRINT (TTEST3,XT,XDT,AZ,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)
      PP=AP*(ONE-EP*EP)
      DRTEST=RAP-VMAG(XT)+DLHD-100.
      CALL TRUE (XP,XDP,TEMP1,PTA)
      IF (ET-TOLE) 820,940,940
  820 IF (DRTEST) 830,830,900
  830 IF (PTA-PI) 840,870,870
  840 CALL TIME (AP,EP,PTA,PI,GM,PI,TG3)
```

PROGRAM TARG

```
      PRINT 1720, TG3
      IF (TG3-10.) 860,850,850
  850 T18=T+DT22
      CALL RKG (PHIO,AZO,XP,XDP,T,T18)
      CALL RKG (PHIO,AZO,XT,XDT,T,T18)
      T=T18
      IF (JPAS-1) 810,870,810
  860 DT22=TG3
      JPAS=1
      GO TO 850
  870 RCP=VMAG(XP)
      PRINT 1730
      VCP=SQRT(GM/RCP)
      CALL VCROSS (TEMP1,XDP,XP)
      CALL VCROSS (TEMP4,XP,TEMP1)
      CALL VUNIT (TEMP4,TEMP4)
      DO 880 I=1,3
  880 TEMP2(I)=VCP*TEMP4(I)
      DO 890 I=I,3
  890 TEMP3(I)=TEMP2(I)-XDP(I)
      VG3=VMAG(TEMP3)
      GO TO 1140
  900 RS=VMAG(XT)-DLHD
      PTASI=-ARCOS((PP-RS)/(EP*RS))+PI2
      PRINT 1900
      CALL ECCV (GM,XP,XDP,TEMP1)
      CALL TRUE (XP,XDP,TEMP1,PTA)
      PHTST=PTASI-PTA
      IF (PHTST) 870,910,910
  910 CALL TIME (AP,EP,PTA,PTASI,GM,PI,TG3)
      PRINT 1740, TG3
      IF (TG3-10.) 930,920,920
  920 T18=T+DT22
      CALL RKG (PHIO,AZO,XT,XDT,T,T18)
      CALL RKG (PHIO,AZO,XP,XDP,T,T18)
      T=T18
      IF (KPAS-1) 810,870,810
  930 DT22=TG3
      KPAS=1
      GO TO 920
  940 RMT=VMAG(XT)
      AT=RMT*GM/(GM2-VDOT(XDT,XDT)*RMT)
      RATD=AT*(ONE+ET)-DLHD
      RPTD=AT*(ONE-ET)-DLHD
      ATD=(RATD+RPTD)/TWO
      ETD=(RATD-RPTD)/(RATD+RPTD)
      PTD=ATD*(ONE-ETD*ETD)
      DO 950 I=1,3
  950 TEMP2(I)=-TEMP1(I)
      CTAPA=VDOT(TEMP2,TEMP4)/(ET*EP)
```

```
      RTD=PTD/(ONE+ETD*CTAPA)
      DRTEST=RAP-RTD-100.0
      IPASSI=0
      IF (DRTEST) 1020,960,960
  960 CALL VCROSS (TEMP2,XP,XDP)
      CALL VCROSS (TEMP3,TEMP2,XOMEGA)
      CALL VCROSS (TEMP5,TEMP3,TEMP2)
      SINAP=VDOT(TEMP1,TEMP5)/(EP*VMAG(TEMP5))
      COSAP=VDOT(TEMP1,TEMP3)/(EP*VMAG(TEMP3))
      ALFAP=ARTAN(SINAP,COSAP,1)
      CALL VCROSS (TEMP2,XT,XDT)
      CALL VCROSS (TEMP3,TEMP2,XOMEGA)
      CALL VCROSS (TEMP5,TEMP3,TEMP2)
      SINAT=VDOT(TEMP4,TEMP5)/(ET*VMAG(TEMP5))
      COSAT=VDOT(TEMP4,TEMP3)/(ET*VMAG(TEMP3))
      ALFAT=ARTAN(SINAT,COSAT,1)
      DELAL=ALFAT-ALFAP
      D=ETD*PP*COS(DELAL)-PTD*EP
      E=-ETD*PP*SIN(DELAL)
      F=PTD-PP
      A=-(E*E+D*D)
      B=TWO*F*E
      C=D*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,XDP,T,T18)
      CALL RKG (PHIO,AZO,XT,XDT,T,T18)
      T=T18
      IF (IPASSI-1) 810,1040,810
 1020 IF (PTA-PI) 1030,1030,1040
 1030 PTASI=PI
      GO TO 990
 1040 RPM=VMAG(XP)
      PRINT 2320
      CALL PRINT (T18,XT,XDT,AZ,PHI,TULO)
      PRINT 2330
      CALL PRINT (T18,XP,XDP,AZ,PHI,TULO)
      CALL ECCV (GM,XT,XDT,TEMP1)
      RTM=VMAG(XT)
      AT=RTM*GM/(GM2-VDOT(XDT,XDT)*RTM)
```

```
      ET=VMAG(TEMP1)
      RAT=AT*(ONE+ET)
      RPT=AT*(ONE-ET)
      CALL VCROSS (TEMP2,XDP,XP)
      CALL VCROSS (TEMP3,TEMP1,TEMP2)
      CTTAPP=VDOT(TEMP1,XP)/(RPM*ET)
      STTAPP=VDOT(TEMP3,XP)/(VMAG(TEMP3)*RPM)
      PT=AT*(ONE-ET*ET)
      RRT=PT/(ONE+ET*CTTAPP)
      DELR1=RRT-RPM
      B=RPM-RAT-RPT
      IF (DELR1) 1050,1050,1060
 1050 B=-B
 1060 C=RAT*RPT+RPM/TWO*(CTTAPP*(RPT-RAT)-(RAT+RPT))
      DLH1=ABS((-B+SQRT(B*B-4.*C))/TWO)
      DLH2=ABS((-B-SQRT(B*B-4.*C))/TWO)
      DELR=ABS(DELR1)
      DRT1=ABS(DELR-DLH1)
      DRT2=ABS(DELR-DLH2)
      IF (DRT1-DRT2) 1070,1070,1080
 1070 DLHDP=DLH1
      GO TO 1090
 1080 DLHDP=DLH2
 1090 IF (DELR1) 1100,1100,1110
 1100 DLHDP=-DLHDP
 1110 RPP=RPT-DLHDP
      RAP=RAT-DLHDP
      EP=(RAP-RPP)/(RAP+RPP)
      AP=(RAP+RPP)/TWO
      PP=AP*(ONE-EP*EP)
      VP=SQRT(GM/PP)*SQRT(ONE+EP*EP+TWO*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)
      VG3=VMAG(TEMP1)
 1140 IF (ISOLAS-1) 1160,1150,1150
 1150 PRINT 2030
      PRINT 2000
      PRINT 2330
      CALL PRINT (T18,XP,XDP,AZ,PHI,TULO)
      CALL VCROSS (AM,XP,TEMP2)
      CALL ECCV (GM,XP,TEMP2,EV)
      PRINT 2010, AM(1),AM(2),AM(3),EV(1),EV(2),EV(3),TEMP1(1),TEMP1(2),
     1TEMP1(3)
```

PROGRAM TARG

```
1160 CONTINUE
     DO 1170 I=1,3
1170 XDP(I)=TEMP2(I)
     ICOR=ICOR+1
     T=T18
     PRINT 2040
     PRINT 2320
     CALL PRINT (T18,XT,XDT,AZ,PHI,TULO)
     PRINT 2330
     CALL PRINT (T18,XP,XDP,AZ,PHI,TULO)
     CALL RKG (PHIO,AZO,XT,XDT,T,TUTP)
     CALL RKG (PHIO,AZO,XP,XDP,T,TUTP)
     PRINT 2050
     PRINT 2320
     CALL PRINT (TUTP,XT,XDT,AZ,PHI,TULO)
     PRINT 2330
     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)=XDTS1(I)
     XP(I)=XPS1(I)
1190 XDP(I)=XDPS1(I)
     PRINT 1950
     TULO=TULOS
     DT=DTS
     GO TO 440
1200 CALL VCROSS (TEMP1,XP,XDP)
     CALL VCROSS (TEMP2,XT,XDT)
     CALL VCROSS (TEMP5,TEMP1,TEMP2)
     WATP=ARCOS(VDOT(TEMP1,TEMP2)/(VMAG(TEMP1)*VMAG(TEMR2)))
     CALL RANGA (XP,XDP,XOMEGA,PHIP)
     CALL RANGA (XT,XDT,XOMEGA,PHIT)
     CALL VCROSS (TEMP1,XT,TEMP5)
     CALL VCROSS (TEMP2,TEMP5,TEMP1)
     SINPNT=VDOT(TEMP2,XT)/(VMAG(TEMP2)*VMAG(XT))
     COSPNT=VDOT(TEMP5,XT)/(VMAG(TEMP5)*VMAG(XT))
     PHINT=ARTAN(SINPNT,COSPNT,1)
     CALL VCROSS (TEMP1,XP,TEMP5)
     CALL VCROSS (TEMP2,TEMP5,TEMP1)
     SINPNP=VDOT(TEMP2,XP)/(VMAG(TEMP2)*VMAG(XP))
     COSPNP=VDOT(TEMP5,XP)/(VMAG(TEMP5)*VMAG(XP))
     PHINP=ARTAN(SINPNP,COSPNP,1)
     TEMP1(1)=COS(PHI)
     TEMP1(2)=SIN(PHI)*SIN(AZ)
     TEMP1(3)=-SIN(PHI)*COS(AZ)
     CALL VCROSS (TEMP2,XT,XDT)
     CALL VCROSS (TEMP3,TEMP2,XOMEGA)
     THNT=ARCOS(VDOT(TEMP1,TEMP3)/(VMAG(TEMP1)*VMAG(TEMP3)))
```

```
      CALL VCROSS (TEMP2,XP,XDP)
      CALL VCROSS (TEMP3,TEMP2,XOMEGA)
      THNP=ARCOS(VDOT(TEMP1,TEMP3)/(VMAG(TEMP1)*VMAG(TEMP3)))
      DTHE=THNT-THNP
      DTHEO=DTHE*CNV
      PRINT 2060, DTHEO
      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 (PHINP-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 DELPHO=DELPH*CNV
      WATPO=WATP*CNV
      PHIPO=PHIP*CNV
      PHITO=PHIT*CNV
```

PROGRAM TARG

```
      PHINTO=PHINT*CNV
      PHINPO=PHINP*CNV
      PRINT 1970, WATPO,PHIPO,PHITO,PHINTO,PHINPO
      PRINT 2070, DELPHO
      IF (ILIG-1) 1460,1430,1460
1430  IF (ISOLAS-1) 1460,1440,1460
1440  JLIGHT=1
      GO TO 550
1450  BSVPAO=BSVPT*CNV
      PRINT 1960, BSVPAO
      GO TO 1650
1460  CONTINUE
      PRINT 2080, ICOR
      IF (ICOR-2) 1470,1530,1560
1470  IF (ABS(DTHE)-.02/CNV) 1530,1480,1480
1480  DLTLO=DTHE/OMEGA
      TULO=TULO+DLTLO
      T=TSTI
      PRINT 1980, DLTLO
      TUTP=TUTP-DLTLO
      DO 1490 I=1,3
      XTR1(I)=XTS(I)
      XT(I)=XTS(I)
1490  XDT(I)=XDTS(I)
      DPHEE=DELPH-DPHR
      TDTLO=T+DLTLO
      CALL RKG (PHIO,AZO,XT,XDT,TSTI,TDTLO)
      PRINT 2320
      CALL PRINT (TDTLO,XT,XDT,AZ,PHI,TULO)
      DO 1500 I=1,3
1500  XTR2(I)=XT(I)
      DLPLOC=ARCOS(VDOT(XTR1,XTR2)/(VMAG(XTR1)*VMAG(XTR2)))
      DLPLOC=(DLTLO/ABS(DLTLO))*DLPLOC
      DLTT1=(DLPLOC-((DLPLOC*DPDCU)/DLPD2)-DLTLO*DPDCU)/DLPD2
      DLTT2=DPHEE/(DLPD2-DPDCU)
      DLTTT2=DLTT1+DLTT2
      TTEST2=TTEST2+DLTTT2
1510  CALL RANGA (XT,XDT,XOMEGA,PHITT)
      CALL VCROSS (TEMP1,XT,XDT)
      CALL VCROSS (TEMP2,TEMP1,XOMEGA)
      CALL VUNIT (TEMP4,TEMP1)
      DUM1=VDOT(XOMEGA,TEMP4)
      DUM=DUM1*DUM1
      XINT=ARTAN(SQRT(ONE-DUM),DUM1,1)
      TEMP1(1)=COS(PHI)
      TEMP1(2)=SIN(PHI)*SIN(AZ)
      TEMP1(3)=-SIN(PHI)*COS(AZ)
      THTNT=ARCOS(VDOT(TEMP1,TEMP2)/(VMAG(TEMP2)))
      THTNE=THTNT-DTHE
      CALL MAROT (AAA,AZ-PI/2.,1,1)
```

```
      CALL MAROT (BBB,PHI,3,1)
      CALL MAMUL (CCC,BBB,AAA)
      CALL MAROT (AAA,THTNE,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 FATT (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 FATMU (XT,DDD,TEMP1)
      TEMP1(1)=VVT*SIN(GAMMA)
      TEMP1(2)=ZERO
      TEMP1(3)=VVT*COS(GAMMA)
      CALL FATMU (XDT,DDD,TEMP1)
      T=TSTI
      DO 1520 I=1,3
      XDP(I)=XDPS(I)
      XTS(I)=XT(I)
      XDTS(I)=XDT(I)
 1520 XP(I)=XPS(I)
      TU=T+TULO
      IF (JINS) 1670,740,1670
 1530 DPHEE=DELPH-DPHR
      IF (ABS(DPHEE)-.05/CNV) 1580,1580,1540
 1540 DTTT2=DPHEE/(DLPD2-DPDCU)
      T=TSTI
      DO 1550 I=1,3
      XP(I)=XPS(I)
      XDP(I)=XDPS(I)
      XT(I)=XTS(I)
 1550 XDT(I)=XDTS(I)
      TU=TSTI+TULO
      TTEST2=TTEST2+DTTT2
      GO TO 740
 1560 DPHEE=DELPH-DPHR
      IF (ABS(DPHEE)-.05/CNV) 1570,1570,1540
 1570 IF (ABS(DTHE)-.02/CNV) 1580,1610,1610
 1580 PRINT 2090
      IF (ISOLAS-1) 1590,1650,1650
 1590 ISOLAS=1
      DTULOT=TULO-TULOS
      PRINT 1980, DTULOT
      T=TSTI
      DO 1600 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
      XTR1(I)=XTS(I)
      XT(I)=XTS(I)
 1620 XDT(I)=XDTS(I)
      TULO=TULO+DLTLO
      T=TSTI
      PRINT 1980, DLTLO
      TUTP=TUTP-DLTLO
      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,TSTI,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
      DLTT1=(DLPLOC-((DLPLOC*DPDCU)/DLPD2)-DLTLO*DPDCU)/DLPD2
      TTEST2=TTEST2+DLTT1
      GO TO 1510
C
C
 1650 TIMLAU=TULOS+DTULOT
      TIMIN=TULOS+DTULOT+T1
      CALL RKG (PHIO,AZO,XTLO,XDTLO,TULOS,TIMLAU)
      DO 1660 I=1,3
      XT(I)=XTLO(I)
 1660 XDT(I)=XDTLO(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,XDTS1,TULOS+T1,TIMIN)
      KINS=1
```

```
      PRINT 2370
      PRINT 2360, XT,XDT
      CALL PRINT (0.0,XT,XDT,AZ,PHI,TIMLAU)
      DO 1700 I=1,3
      XT(I)=XTS1(I)
 1700 XDT(I)=XDTS1(I)
      GO TO 1510
 1710 PRINT 2380, TIMLAU
C
 1720 FORMAT (1E16.8//)
 1730 FORMAT (32H CIRCULARIZE W/O C D H EQUATIONS//)
 1740 FORMAT (1E16.8//)
 1750 FORMAT (2I2)
 1760 FORMAT (5E15.8/2E15.8)
 1770 FORMAT (17H NORTHERLY LAUNCH//)
 1780 FORMAT (17H SOUTHERLY LAUNCH//)
 1790 FORMAT (7H   TIMEE15.8,7H      ATE15.8,7H      ETE15.8,7H XENCTOE15.
     18/7H  THNTOE15.8,7H ALFATOE15.8,7H  PHIIOE15.8//)
 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 INSTANTANEIOUS 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
     1.8//)
 1860 FORMAT (61H INSERTION CONDITIONS DETERMINED FROM STEADY STATE TRAJ
     1ECTORY//)
 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
     2 ZDPE15.8//)
 1890 FORMAT (59H STATE VECTOR OF SPACE STATION AT TIME OF ORBITER INSER
     1TION/7H      XTE15.8,7H      YTE15.8,7H      ZTE15.8/7H     XDTE15.8,7
     2H     YDTE15.8,7H     ZDTE15.8///)
 1900 FORMAT (39H INTERSECTION ASSUMMING 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 (72H1SFNO3 HAS BEEN BUMPED BY .5 BECAUSE THE TIME OF TPI OC
     1CURRED BEFORE CDH///)
 1960 FORMAT (33H THE SOLAR VECTOR ANGLE ACHIEVED=E15.8//)
 1970 FORMAT (7H  WATPOE15.8,7H  PHIPOE15.8,7H  PHITOE15.8,7H PHINTOE15.
     18,7H  PHINPE15.8//)
 1980 FORMAT (50H THE LAUNCH TIME SHOULD BE ADJUSTED BY DELTA TULO=E15.8
     1)
 1990 FORMAT (62H1TARGETING VALUES FOR THE COV 100 NM CIRCULARZATION AT
     1 APOGEE//)
 2000 FORMAT (29H POSITION VECTOR FOR IGNITION//)
 2010 FORMAT (37H TARGETING VALUES FOR DESIRED ELLIPSE/24H ANGULAR MOMEN
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```
     1TUM VECTOR/7H  AM(1)E15.8,7H  AM(2)E15.8,7H  AM(3)E15.8/20H ECCENT   A1051
     2RICITY VECTOR/7H  EV(1)E15.8,7H  EV(2)E15.8,7H  EV(3)E15.8/29H VEL   A1052
     3OCITY TO BE GAINED VECTOR/7H  VG(1)E15.8,7H  VG(2)E15.8,7H  VG(3)E   A1053
     415.8//)                                                              A1054
 2020 FORMAT (42H1TARGETING VALUES FOR THE COV PERIGEE BURN//)             A1055
 2030 FORMAT (46H1 TARGETING VALUES FOR THE CDH MANUVER FOR COV/)          A1056
 2040 FORMAT (26H1CDH HAS BEEN ACCOMPLISHED////)                           A1057
 2050 FORMAT (23H1UNIVERSAL TIME FOR TPI////)                              A1058
 2060 FORMAT (6H DTHEOE15.8///)                                            A1059
 2070 FORMAT (7H DELPHOE15.8//)                                            A1060
 2080 FORMAT (32H1BEGIN NEXT ISOLATION LOOP ICOR=1I2)                      A1061
 2090 FORMAT (21H1THIS IS THE SOLUTION///)                                 A1062
 2100 FORMAT (6E13.8)                                                      A1063
 2110 FORMAT (42H PAPAMETERS FOR 50X100 N.M. PHASING ORBIT///)             A1064
 2120 FORMAT (7H    RRPE15.8,7H    VVPE15.8,7H GAMMAPE15.8,7H    EPE15.    A1065
     18/7H    APE15.8,7H    HAPE15.8,7H    HPPE15.8,7H PHDOTPE15.8//)      A1066
 2130 FORMAT (32H PARAMETERS FOR THE TARGET ORBIT///)                      A1067
 2140 FORMAT (7H    RRTE15.8,7H    VVTE15.8,7H GAMATOE15.8,7H    ETE15.    A1068
     18/7H    ATE15.8,7H    HATE15.8,7H    HPTE15.8,7H PHDOTTE15.8//)      A1069
 2150 FORMAT (74H CATCH UP RATE AND ANGLE FOR THE HALF ORBIT OF THE 50X1   A1070
     100 NM PHASING ORBIT///)                                              A1071
 2160 FORMAT (23H ORBITAL CATCH UP RATE=E15.8//19H ANGLE OF CATCH UPEE15   A1072
     1.8//32H TIME AT APOGEE OF 50X100 ORBIT=E15.8)                        A1073
 2170 FORMAT (51H FIRST MANUVER TO CIRCULARIZE 80X100 AT ITS APOGEE//)     A1074
 2180 FORMAT (7H    RCPE15.8,7H    VCPE15.8,7H  TAUCPE15.8,7H PDOTCOE15.   A1075
     18/7H  DLPD2E15.8,7H DLMR2OE15.8,7H  DELV2E15.8,7H     T3E15.8///)    A1076
 2190 FORMAT (66H SECOND BURN TRANSFER OUT OF 100 NM CIRCULAR TOWARDS      A1077
     1 COELLIPTIC///)                                                      A1078
 2200 FORMAT (16H ORBITAL PERIOD=E15.8/19H MEAN ORBITAL RATE=E15.8/15H C   A1079
     1ATCH UP RATE=E15.8/21H IMPULSE REQUIREMENT=E15.8/18H TIME INTO FLI   A1080
     2GHT=E15.8/7H  DPHR3E15.8///)                                         A1081
 2210 FORMAT (45H COELLIPIC ORBIT PLACING VEHICLE IN CDH ORBIT///)         A1082
 2220 FORMAT (7H    EP3E15.8,7H   RPP4E15.8,7H   RAP4E15.8,7H    AP4E15.   A1083
     18/7H    EP4E15.8,7H   TH4OE15.8,7H    R4E15.8,7H    V4E15.8/7H G     A1084
     2AMA4OE15.8,7H    VT4E15.8,7H GAMT4OE15.8,7H  DELV4E15.8////)         A1085
 2230 FORMAT (50H THE TPI IGNITION ANGLE IN RELATION TO THE TAAGET=E15.8   A1086
     1)                                                                    A1087
 2240 FORMAT (61H THIS SECTION DETERMINES THE CATCH UP RATE IN THE CDH     A1088
     1 ORBIT/)                                                             A1089
 2250 FORMAT (77H IT ALSO SUMS UP THE DELTA VELOCITY AND CATCH UP ANGLE    A1090
     1 FOR THE TOTAL MISSION/)                                             A1091
 2260 FORMAT (7H  TAUP4E15.8,7H PDPA4OE15.8,7H DPDCUOE15.8,7H DLMR4OE15.   A1092
     18/7H   TTPIE15.8,7H  DMRTOE15.8,7H   DVITE15.8///)                   A1093
 2270 FORMAT (24H RANGE ANGLE OF PURSUIT=E15.8//23H RANGE ANGLE OF TARGE   A1094
     1T=E15.8///)                                                          A1095
 2280 FORMAT (29H COMPUTATIONS FOR SECTION 4-8//)                          A1096
 2290 FORMAT (7H  DPH1OE15.8,7H  DPH2OE15.8,7H    DT2E15.8,7H  TSBSTE15.   A1097
     18/7H    DT1E15.8,7H    T1E15.8,7H TTEST1E15.8,7H TTEST2E15.8///)     A1098
 2300 FORMAT (50H COMPUTATIONS FOR LIGHTING CONDITIONS SECTION 4-10//)     A1099
 2310 FORMAT (7H    AOE15.8,7H    BOE15.8,7H    COE15.8,7H    TYE15.       A1100
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     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
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```
      SUBROUTINE RK713 (T0,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(I) IS 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=T0
      DT=TF-T0
      M=0
      DO 10 I=1,N
   10 X(I)=XI(I)
   20 CALL DEQ (X,T,TE,AB,TI)
      DO 30 I=1,N
   30 F(1,I)=TE(I)
      DO 70 K=2,13
      DO 40 I=1,N
   40 XDUM(I)=X(I)
      NN=K-1
      DO 50 I=1,N
      DO 50 J=1,NN
   50 XDUM(I)=XDUM(I)+DT*BETA(K,J)*F(J,I)
      TDUM=T+ALPH(K)*DT
      CALL DEQ (XDUM,TDUM,TE,AB,TI)
      DO 60 I=1,N
   60 F(K,I)=TE(I)
   70 CONTINUE
      DO 80 I=1,N
   80 XDUM(I)=X(I)
      DO 90 I=1,N
      DO 90 L=1,13
   90 X(I)=X(I)+DT*CH(L)*F(L,I)
      EPS=1.
      DO 120 I=1,N
      IF ALL THE VARIABLES BEING INTEGRATED HAVE MAGNITUDES WHOSE
      ABSOLUTE VALUES ARE ALWAYS MUCH LESS THAN 1., THEN A VALJE
      OF EPS LESS THAN ONE MAY NEED TO BE USED TO ACHIEVE AN ACCURACY
      AS SPECIFIED BY TOL.
      IF (ABS(XDUM(I))-EPS) 100,110,110
  100 A=EPS
      GO TO 120
```

```
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(1))
    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)-ABS(TF-T)) 170,170,160
160 DT=TF-T
170 CONTINUE
    GO TO 200
180 DO 190 I=1,N
190 X(I)=XDUM(I)
200 IF (M-KT) 210,220,220
210 IF (T-TF) 20,230,20
220 TF=T
230 RETURN
    END
```

SUBROUTINE RKG (PHIL,AZ,XI,DXI,TI,TF)

```
      SUBROUTINE RKG (PHIL,AZ,XI,DXI,TI,TF)
      DIMENSION X(6), DX(6), ALPH(13), BETA(13,12), CH(13), AB(3), XI(3)
     1, DXI(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
      RAZ=AZ*RCONV
      AB(1)=SIN(RPHIL)
      AC3=COS(RPHIL)
      AB(2)=-AC3*SIN(RAZ)
      AB(3)=AC3*COS(RAZ)
      DO 30 I=1,13
      DO 20 J=1,12
   20 BETA(I,J)=0.
      ALPH(I)=0.
   30 CH(I)=0.
      CH(6)=34./105.
      CH(7)=9./35.
      CH(8)=CH(7)
      CH(9)=9./280.
      CH(10)=CH(9)
      CH(12)=41./840.
      CH(13)=CH(12)
      ALPH(2)=2./27.
      ALPH(3)=1./9.
      ALPH(4)=1./6.
      ALPH(5)=5./12.
      ALPH(6)=.5
      ALPH(7)=5./6.
      ALPH(8)=1./6.
      ALPH(9)=2./3.
      ALPH(10)=1./3.
      ALPH(11)=1.
      ALPH(13)=1.
      BETA(2,1)=2./27.
      BETA(3,1)=1./36.
      BETA(4,1)=1./24.
      BETA(5,1)=5./12.
      BETA(6,1)=.05
      BETA(7,1)=-25./108.
      BETA(8,1)=31./300.
      BETA(9,1)=2.
      BETA(10,1)=-91./108.
      BETA(11,1)=2383./4100.
      BETA(12,1)=3./205.
      BETA(13,1)=-1777./4100.
      BETA(3,2)=1./12.
```

```
      SUBROUTINE 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)=-289./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)=18./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
      T0=TI
      CALL RK713 (T0,TF,TOL,X,X,6,2000,M,BETA,ALPH,CH,TI,AB)
      CALL DEQ (X,TF,DX,AB,TI)
      DO 40 I=1,3
      XI(I)=X(I)
   40 DXI(I)=X(I+3)
```

SUBROUTINE RKG (PHIL,AZ,XI,DXI,TI,TF)

```
      RETURN                                                           D 101
      END                                                              D 102
```

```
      SUBROUTINE CONIC (R,V,AZ,PHI,AA,AP,ENC,THTN,TH,E,P,A,ALFAD,RA,RP,C
     13,PHII)
      DIMENSION W(3), R(3), RU(3), H(3), V(3), HU(3), THNV(3), THNU(3),
     1QU(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,R,V)
      CALL VUNIT (HU,H)
      CALL VCROSS (THNV,H,W)
      CALL VUNIT (THNU,THNV)
      CALL VCROSS (QU,HU,RU)
      CALL VCROSS (PU,THNU,HU)
      GM=3.986031979E14
      RM=SQRT(VDOT(R,R))
      P=VDOT(H,H)/GM
      RD=VDOT(V,RU)
      A=GM*RM/(2.*GM-RM*VDOT(V,V))
      TEST=(1.-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=(RD/E)*SQRT(P/GM)
      DO 40 I=1,3
   40 XI(I)=RU(I)*COSTH-QU(I)*SINTH
      ALFAD=ARTAN(VDOT(XI,PU),VDOT(XI,THNU),1)
      TH=ARTAN(SINTH,COSTH,1)
      CALL VCROSS (CU,HU,THNU)
      PHII=ARTAN(VDOT(CU,RU),VDOT(THNU,RU),1)
      T(1)=COS(PHI)
      T(2)=SIN(AZ)*SIN(PHI)
      T(3)=-COS(AZ)*SIN(PHI)
      CALL VCROSS (SU,W,T)
      THTN=ARTAN(VDOT(THNU,SU),VDOT(THNU,T),1)
      CALL VCROSS (B,W,THNU)
      ENC=ARTAN(VDOT(HU,B),VDOT(HU,W),-1)
      RE=6378166.
      CNV=1852.
      C3=-GM/A
      RA=A*(1.+E)
      RP=A*(1.-E)
      AA=(RA-RE)/CNV
      AP=(RP-RE)/CNV
      RETURN
      END
```

```
      SUBROUTINE GMAT (PHI,AZI,THTN,ENC,G,PI)
      DIMENSION AA(3,3), B(3,3), C(3,3), D(3,3), TE(3,3), G(3,3)
      CALL MAROT (AA,AZI-PI/2.,1,1)
      CALL MAROT (B,PHI,3,1)
      CALL MAROT (C,THTN,2,-1)
      CALL MAROT (D,ENC,1,-1)
      CALL MAMUL (G,B,AA)
      CALL MAMUL (TE,C,G)
      CALL MAMUL (G,D,TE)
      RETURN
      END
```

```
      SUBROUTINE MAROT (A,ANGLE,K,L)
      DIMENSION A(3,3), C(3,3)
      SANG=SIN(ANGLE)
      CANG=COS(ANGLE)
      DO 10 I=1,3
      DO 10 J=1,3
   10 A(I,J)=0.
      M=(-3*K**2+11*K-4)/2
      N=(3*K**2-13*K+16)/2
      A(K,K)=1.0
      A(M,M)=CANG
      A(N,N)=CANG
      A(M,N)=SANG
      A(N,M)=-SANG
      IF (L) 20,20,50
   20 DO 30 I=1,3
      DO 30 J=1,3
   30 C(I,J)=A(J,I)
      DO 40 I=1,3
      DO 40 J=1,3
   40 A(I,J)=C(I,J)
   50 RETURN
      END
```

FUNCTION ARTAN (SANG,CANG,ISW)

```
      FUNCTION ARTAN (SANG,CANG,ISW)
C     THIS SUBROUTINE USE THE SINE AND COSINE OF THE FUNCTION
C
C     AND PLACES THE ANGLE IN THE PROPER QUADRANT.
C
C     IF ISW=1  THE ANGLE IS PUT BETWEEN 0 AND 2 PI
C     IF ISW=-1 THE ANGLE IS PUT BETWEEN - PI AND + PI
C
      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
      GO TO 14
    9 ARTAN=0.
      GO TO 14
   10 IF (CANG) 11,12,13
   11 ARTAN=PI+ATAN(SANG/CANG)
      GO TO 14
   12 ARTAN=PI/2.
      GO TO 14
   13 ARTAN=ATAN(SANG/CANG)
   14 RETURN
                         ( B L A N K   C A R D )
      END
```

```
      FUNCTION POLY (C,X,N)
C     C IS THE COEFFICIENT ARRAY
C     X IS THE INDEPENDENT VARIABLE
C     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
```

3200 FORTRAN (3.0)/RTS / /

```
      SUBROUTINE ECCV(GM,XP,XDP,TEMP1)
      DIMENSION XP(3),XDP(3),TEMP1(3),TEMP2(3),TEMP3(3)
      CALL VCROSS (TEMP1,XP,XDP)
      CALL VUNIT (TEMP2,XP)
      CALL VCROSS (TEMP3,TEMP1,XDP)
      DO 360 I=1,3
  360 TEMP1(I)=-(TEMP2(I)+TEMP3(I)/GM)
      RETURN
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR ECCV

```
      SUBROUTINE DEQ (X,T,DX,AB,TI)
      DIMENSION X(6), DX(6), AB(3), XDUM(6), ACCO(3)
      GM=3.9860319E14
      AA=.6378166E+07
      FJ=1.62345E-03
      FH=-5.75E-06
      FD=7.875E-06
      DO 20 I=1,3
   20 DX(I)=X(I+3)
      R2=X(1)*X(1)+X(2)*X(2)+X(3)*X(3)
      R=SQRT(R2)
      RI=1./R
      R2I=1./R2
      B=AA*AA*R2I
      BB=AA*RI
      A=(AB(1)*X(1)+AB(2)*X(2)+AB(3)*X(3))*RI
      A2=A*A
      A4=A2*A2
      GR=B*(FJ*(1.-5.*A2)+3.*FD*(1./7.-2.*A2+3.*A4)*B+FH*BB*A*(3.-7.*A2)
     1)
      GP=B*(2.*FJ*A+4.*FD*A*(3./7.-A2)*B+3.*FH*BB*(A2-1./5.))
      DO 30 I=1,3
   30 DX(I+3)=-GM*R2I*((1.+GR)*X(I)*RI+GP*AB(I))
      RETURN
      END
```

SUBROUTINE FATT (BBB,AAA)

```
      SUBROUTINE FATT (BBB,AAA)
      DIMENSION BBB(3,3), AAA(3,3)
      DO 10 L=1,3
      DO 10 M=1,3
   10 BBB(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)

```
      SUBROUTINE FATMU (EEE,AAA,DDD)
      DIMENSION EEE(3), AAA(3,3), DDD(3)
      DO 10 L=1,3
   10 EEE(L)=0.
      DO 20 I=1,3
      DO 20 J=1,3
   20 EEE(I)=EEE(I)+AAA(I,J)*DDD(J)
      RETURN
      END
```

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

```
      SUBROUTINE PRINT (T,RI,VI,AZ,PH,TULO)
      DIMENSION RI(3), VI(3)
      TULOI=TULO+T
      TT=T
      ICOR=0
   10 HR=TT/3600.
      IHR=HR
      XMIN=(TT-IHR*3600.)/60.
      MIN=XMIN
      SEC=TT-IHR*3600.-MIN*60.
      IF (ICOR-1) 20,30,30
   20 PRINT 40, IHR,MIN,SEC
      TT=TULOI
      ICOR=1
      GO TO 10
   30 PRINT 50, IHR,MIN,SEC
      CNV=57.295779513
      CALL CONIC (RI,VI,AZ,PH,AA,AP,ENC,THN,TH,E,P,A,ALF,RA,RP,C3,PHII)
      ENC1=ENC*CNV
      THN1=THN*CNV
      TH1=TH*CNV
      ALF1=ALF*CNV
      PHII1=PHII*CNV
      PRINT 60, T,RI,VI,AA,AP,RA,RP,P,A,E,C3,ENC1,THN1,TH1,ALF1,PHII1
      RETURN


   40 FORMAT (2X,19H TIME FROM LIFT-OFF/5H HRS=,I2,3X,5H MIN=,I2,3X,5H S
     1EC=,E15.8//)
   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,E15.8,5
     1X,2HXD,E15.8,5X,2HYD,E15.8,5X,2HZD,E15.8/4X,3H AA,E15.8,4X,3H AP,E
     215.8,4X,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,3HENC,E15.8,4X,3HTHN,E15.8,5X,2HT
     4H,E15.8,2X,5HALFAD,E15.8/7H  PHIIOE15.8///)
      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
```

```
*TIDY*                                                        PAGE 34
                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 ELLPTICAL 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)=SQRT(1.-E**2)*SIN(TH(I))/(1.+E*COS(TH(I)))
      COSE(I)=(E+COS(TH(I)))/(1.+E*COS(TH(I)))
      ECA(I)=ARTAN(SINE(I),COSE(I),1)
   10 XM(I)=ECA(I)-E*SIN(ECA(I))
      XMTR=XM(2)
      ET1=ECA(1)
      ET2=ECA(2)
      T=SQRT(A**3/GM)
      TFA=T*XM(1)
      TFB=T*XM(2)
      IF (TFB-TFA) 20,30,30
   20 TFB=TFB+2.*PI*T
   30 TF=TFB-TFA
      RETURN
      END
```


C.3

3200 FORTRAN (3.0)/RTS / /

```
SUBROUTINE RANGA(XT,XDT,XOMEGA,PHIT)
DIMENSION TEMP1(3),TEMP2(3),TEMP3(3),XOMEGA(3),XT(3),XDT(3)
CALL VCROSS (TEMP1,XT,XDT)
CALL VCROSS (TEMP2,TEMP1,XOMEGA)
CALL VCROSS (TEMP3,TEMP1,TEMP2)
RRT=VMAG(XT)
SINPHT=VDOT(TEMP3,XT)/(VMAG(TEMP3)*RRT)
COSPHT=VDOT(TEMP2,XT)/(VMAG(TEMP2)*RRT)
PHIT=ARTAN(SINPHT,COSPHT,1)
RETURN
END
```

FORTRAN DIAGNOSTIC RESULTS FOR RANGA

3200 FORTRAN (3.0)/RTS / /

```
      SUBROUTINE TRUE(XP,XDP,TEMP1,PTA)
      DIMENSION XP(3),XDP(3),TEMP1(3),TEMP2(3),TEMP3(3)
      EP=VMAG(TEMP1)
      RMP=VMAG(XP)
      CALL VCROSS (TEMP2,XDP,XP)                                A 549
      CALL VCROSS (TEMP3,TEMP1,TEMP2)                           A 550
      COSPTA=VDOT(TEMP1,XP)/(EP*RMP)                            A 551
      SINPTA=VDOT(TEMP3,XP)/(VMAG(TEMP3)*RMP)                   A 552
      PTA=ARTAN(SINPTA,COSPTA,1)                                A 553
      RETURN
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR TRUE