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OPTIMAL TRANSFER TRAJECTORIES FROM EARTH PARKING ORBIT TO VARIOUS TERMINAL CONIC CONSTRAINTS AND MODIFICATIONS TO THE ROBOT COMPUTER PROGRAM

By Rodney Bradford
Program Development

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Terminal conditions were a circular orbit at synchronous altitude, 35 862 km, an elliptical orbit with apogee at synchronous altitude (in-and-out-of-parking-orbit-plane), and an injection burn into a typical 1973 Mars mission hyperbolic orbit. The vehicles used to perform these transfers were the S-IVB stage and the Command Service Module. Also included is a typical ascent trajectory profile utilizing a two-stage Saturn IB launch vehicle. Detailed orbital and trajectory profile parameters are presented in tabular form.

Modifications made to the ROBOT-Apollo and AAP Preliminary Mission Profile Optimization computer program are also presented.

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TECHNICAL MEMORANDUM X-53873

OPTIMAL TRANSFER TRAJECTORIES FROM EARTH PARKING ORBIT TO VARIOUS TERMINAL CONIC CONSTRAINTS AND MODIFICATIONS TO THE ROBOT COMPUTER PROGRAM

SUMMARY

Reference optimal (minimum fuel consumption) transfer trajectories were computed by the minimum Hamiltonian-steepest ascent method for departure from a circular parking orbit about the earth to various terminal conic constraints (V, γ, r), (V, γ, r, i), (C_3, C_1), (C_3, C_1, i), and (C_3, α, δ).

Terminal conditions were a circular orbit at synchronous altitude, 35 862 km, an elliptical orbit with apogee at synchronous altitude (in-and-out-of-parking-orbit-plane), and an injection burn into a typical 1973 Mars mission hyperbolic orbit. The vehicles used to perform these transfers were the S-IVB stage and the Command Service Module. Also included is a typical ascent trajectory profile utilizing a two-stage Saturn IB launch vehicle. Detailed orbital and trajectory profile parameters are presented in tabular form.

Modifications made to the ROBOT-Apollo and AAP Preliminary Mission Profile Optimization computer program are also presented.

INTRODUCTION

Reference optimal (minimum fuel consumption) transfer trajectories were computed for the transfer of an S-IVB stage and a Command Service Module (CSM) from a 185.2-km altitude, 37-deg inclined, circular parking orbit about the earth to various terminal conic constraints. The selection of the terminal constraints was based on the criteria of obtaining a reference cross-section of optimally performed orbital operations. The optimization method employed was the minimum Hamiltonian-steepest ascent method as described in Reference 1.

The terminal conic constraints were defined as (V, γ, r), (V, γ, r, i), (C_3, C_1), (C_3, C_1, i), and (C_3, α, δ)[1]. A physical interpretation of these constraints is presented in Figure 1. As shown in this figure the quantities V, γ and r are used to specify a circular orbit, whereas the quantities C_3 and C_1 are used to specify the shape of an elliptical orbit. This distinction was made to facilitate the calculation of the transfer trajectories by the computer program employed. The terminal condition for the constraint (V, γ, r) was an in-parking-orbit-plane circular orbit at synchronous altitude, 35 862 km. The terminal condition for the constraint (V, γ, r, i) was an out-of-parking-orbit-plane circular orbit at synchronous altitude with inclination equal to 50 deg. The terminal conditions for the constraints (C_3, C_1) and (C_3, C_1, i) corresponded to an elliptical orbit with perigee radius equal to r_E (earth radius) + 210 km and apogee radius equal to r_E + 35 862 km. The constraint (C_3, C_1) corresponded to an orbital inclination of 37 deg while the constraint (C_3, C_1, i) corresponded to an inclination of 50 deg.

The terminal constraint (C_3, α, δ) corresponded to the terminal conditions on a hyperbolic orbit for a typical 1973 Mars mission. For this constraint the date and time of departure were specified along with the right ascension and declination of the outgoing hyperbolic asymptote as measured in an inertial ephermeris coordinate system. The optimization method and computer program employed, as described in Reference 1, were referenced to an inertial plumbline coordinate system. Thus, this terminal constraint necessitated a coordinate transformation to an inertial ephemeris system in the computer program and modification of the input variables. Also, additional orbital parameters were computed, a new output format was designed, and a summary print table option incorporated. All modifications made to the computer program are documented in the appendices.

The detailed ascent trajectory profile presented is for a two-stage Saturn IB launched from Cape Kennedy at an azimuth of 115 deg. The S-IB and S-IVB stages are fueled to capacity and burned to depletion. The CSM propulsion system is then ignited and burned until injected into a 185.2-km altitude, 37-deg inclined, circular parking orbit. At this point of parking orbit injection, an initial state vector was obtained which was used as a departure point to the various terminal constraints.

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1. Symbols are defined in Appendices A and B.

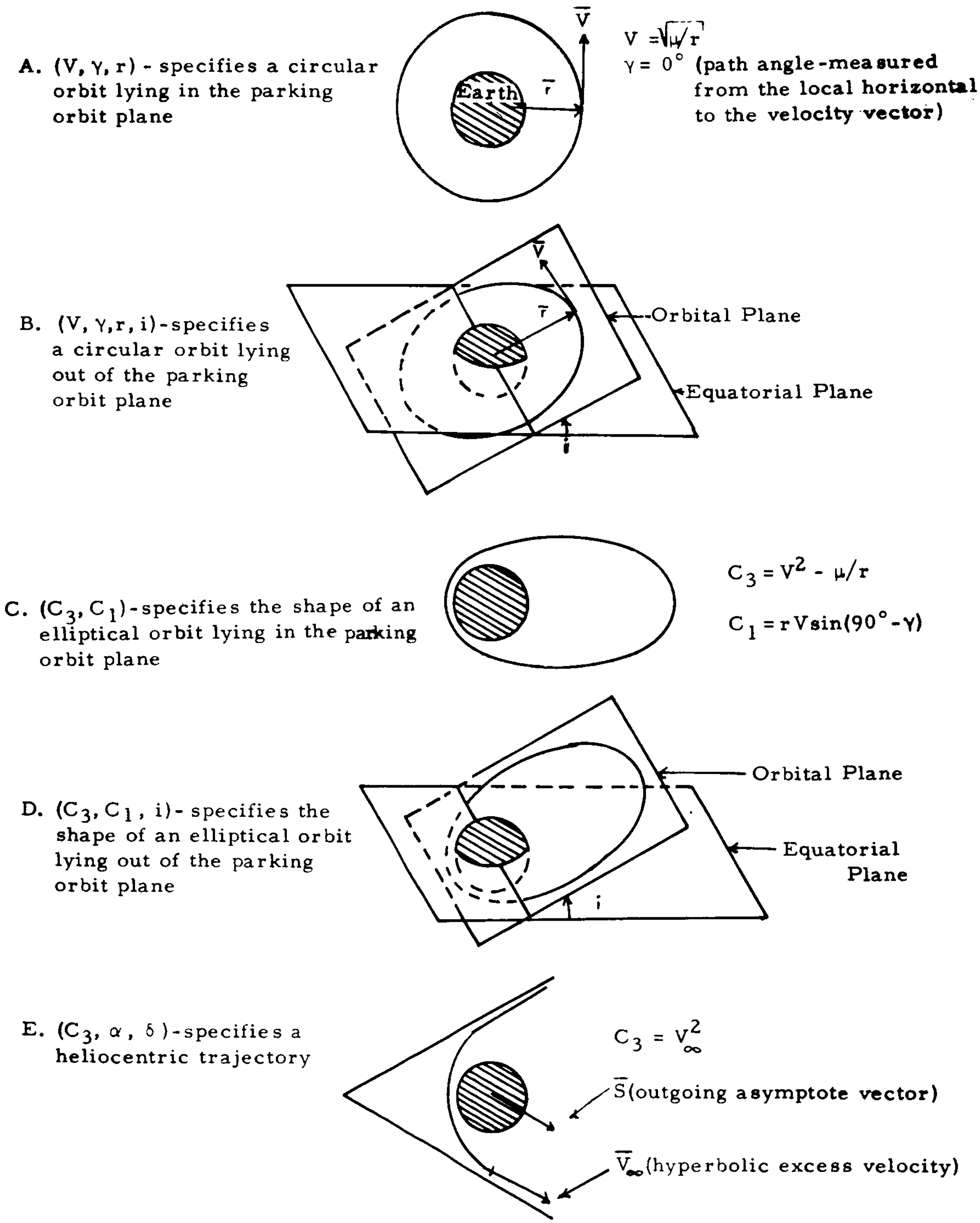


Figure 1. Terminal conic injection constraints.

COMPUTER PROGRAM MODIFICATIONS

Various modifications were made to the computer program [Ref. 1] which was used to compute the optimal transfer trajectories. These changes which were made in the program to make it more compatible for orbital operations computations, consisted of the design of a new output format and labeling code, coordinate system transformation, input variable alteration, and the computation and output of additional orbital parameters.

Appendix A gives a description and example of the output format for each print time interval, a definition of the output symbols, and a description of the optional summary print tables incorporated and the variables which must be specified for them. Appendix B gives the equations necessary for the transformation from the inertial plumbline (Fig. 2) to the inertial ephemeris coordinate system (Fig. 3) and equations defining the various orbital parameters included in the output format which were not previously computed in the program. The orbital geometry and notation are also shown in Figure 3.

Appendix C contains a description of the additional input variables necessary and listings of the input data required for computation of the transfer trajectories presented. Appendix D contains a UNIVAC 1108 FORTRAN listing of the subroutine titled APRTN which was modified to perform the coordinate system transformation and the computation of the various additional orbital parameters. The output of these parameters and quantities computed in the original program, in the new output format, is also accomplished by this subroutine. The subroutine, entitled TRASH, encompasses the optional summary print tables. A UNIVAC 1108 FORTRAN listing of the TRASH subroutine is presented in Appendix E.

TYPICAL ASCENT TRAJECTORY PROFILES

A typical three-stage Saturn V ascent trajectory and circular orbit injection profile is presented in Figure 4. As shown, trajectory arc 1 corresponds to the S-IC stage burn; arc 2 to the S-II stage burn; arc 3 to the first S-IVB stage burn to a 185.2-km parking orbit altitude; arc 4 to the parking orbit coast; arc 5 to the second S-IVB stage burn at perigee of the Hohmann transfer ellipse; arc 6 to the transfer coast; and arc 7 to the third S-IVB stage burn at apogee of the transfer ellipse. Detailed tabulations of Saturn V ascent trajectories for various launch azimuths can be found in Reference 2.

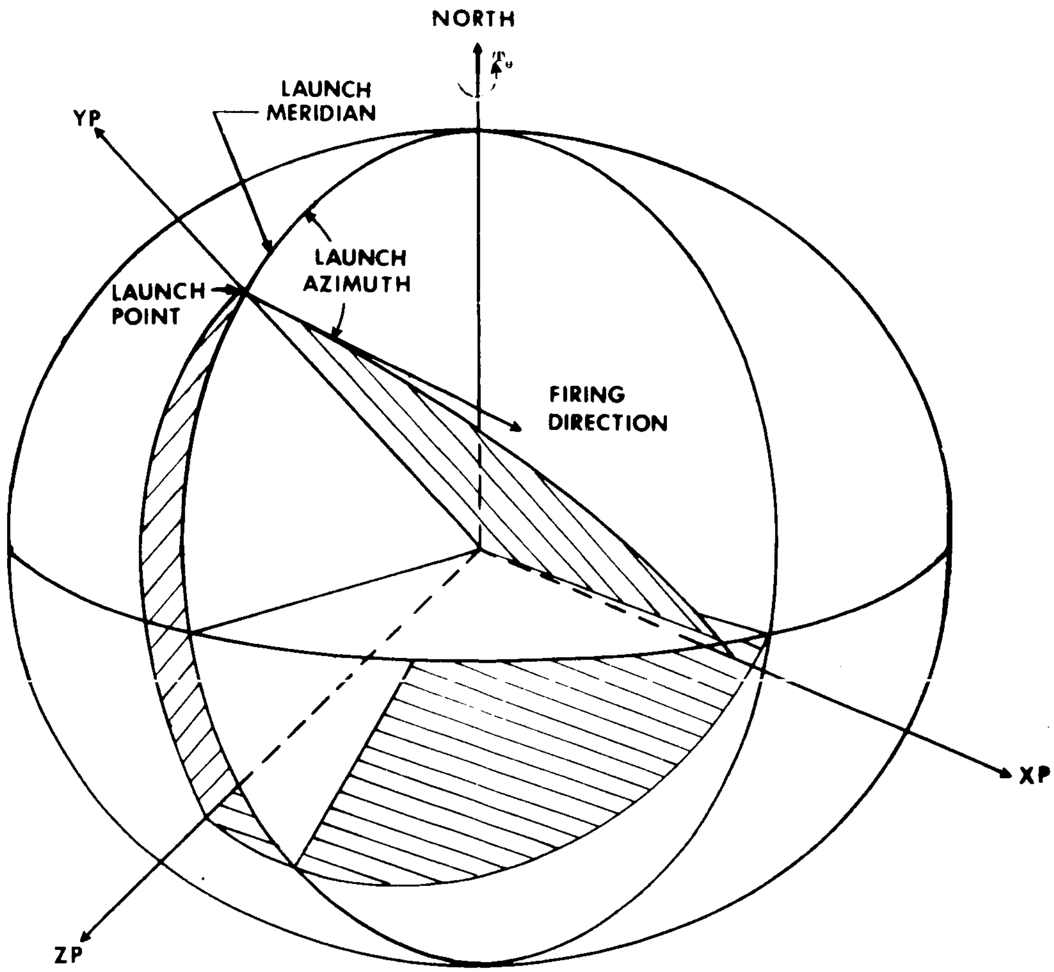
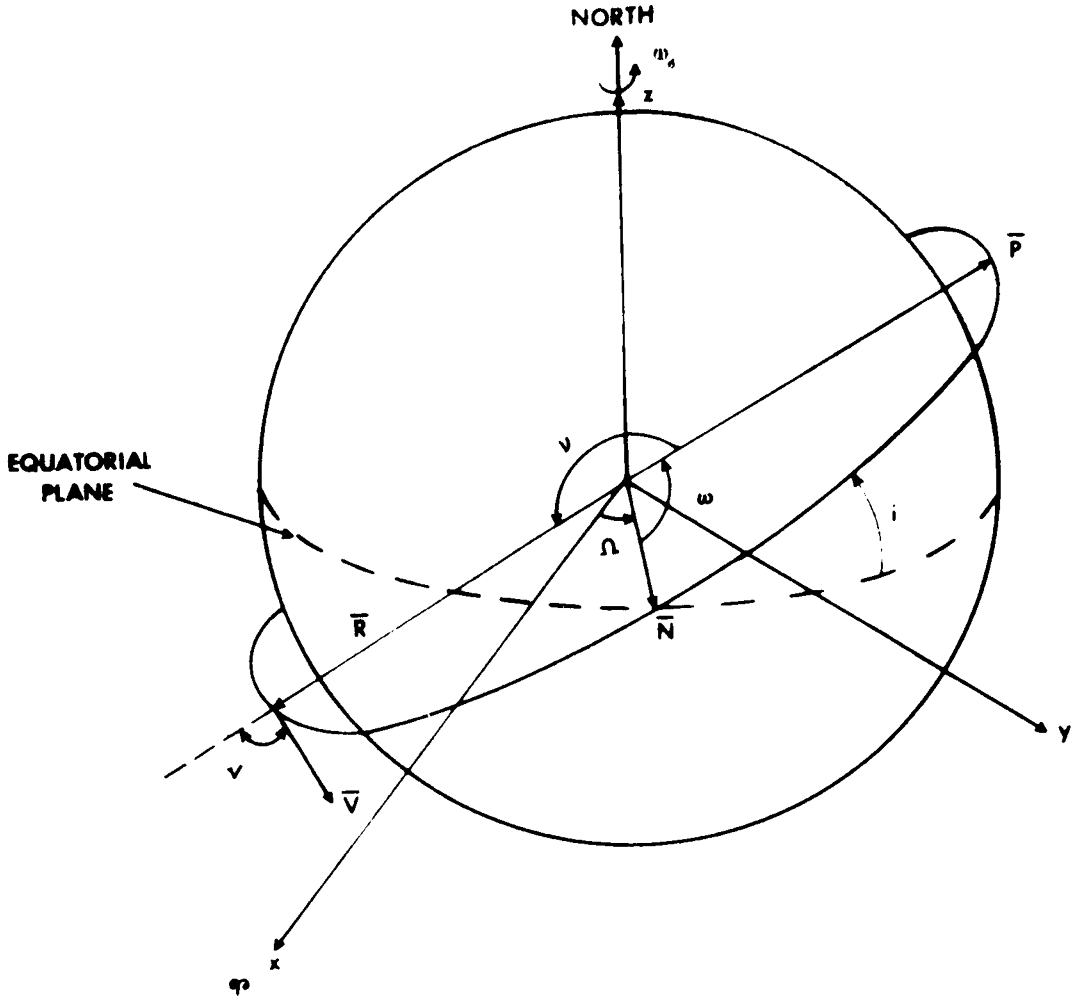


Figure 2. Inertial Cartesian plumbline coordinate system.

A typical two-stage Saturn IB ascent trajectory and elliptical target orbit injection profile is presented in Figure 5. As shown, trajectory arc 1 corresponds to the S-IB stage burn; arc 2 to the S-IVB stage burn; arc 3 to the first Command Service Module burn to a 185.2-km parking orbit injection; arc 4 to the parking orbit coast; and arc 5 to the second CSM burn to injection. A typical Saturn IB ascent trajectory profile for a launch azimuth of 115 deg is presented in Table 1. A detailed tabulation of this trajectory is presented in Table 2. The last entries in this table give the position and velocity of the CSM at parking orbit injection. These values of position and velocity were used as the initial "state" for transfer to the various terminal conic constraints.



ω = Argument of Perigee

Ω = Right Ascension of Ascending Node

i = Orbit Inclination

ν = True Anomaly

v = Flight Path Angle (Measured from Local Vertical)

N̄ = Node Vector

P̄ = Perigee Vector

R̄ = Radius Vector

V̄ = Velocity Vector

Figure 3. Geocentric ephemeris coordinate system and orbital geometry and notation.

1. S-IC Burn
2. S-II Burn
3. First S-IVB Burn to 185.2-km Circular Orbit Altitude
4. Parking Orbit Coast
5. Second S-IVB Burn (Perigee Burn for Transfer Ellipse)
6. Transfer Coast
7. Third S-IVB Burn (Apogee Burn for Target Orbit Injection)

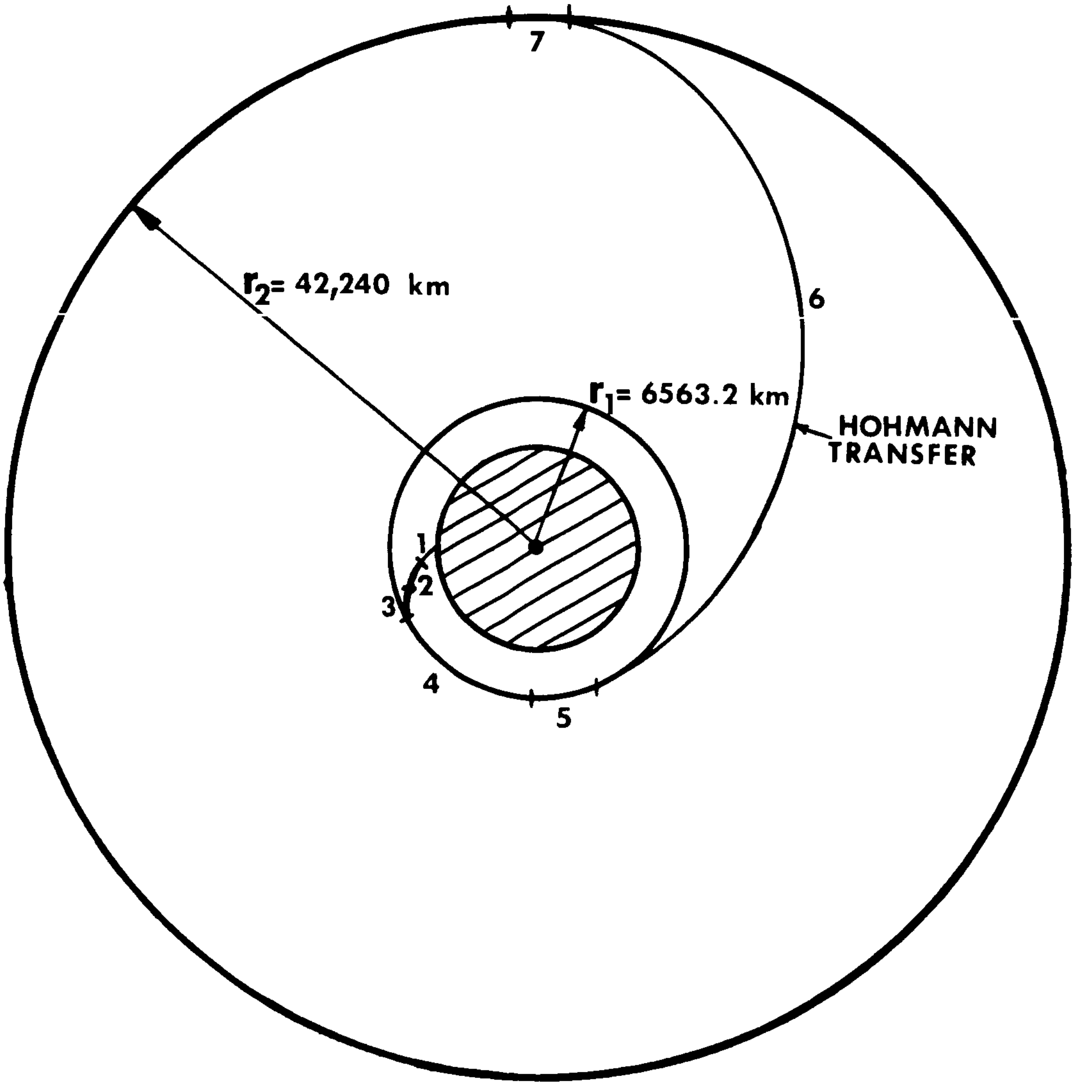


Figure 4. Typical Saturn V ascent and circular target orbit injection profile.

1. S-IB Burn

2. S-IVB Burn

3. First CSM Burn to 185.2-km Circular Orbit Altitude

4. Parking Orbit Coast

5. Second CSM Burn (Injection Burn for Elliptical Target Orbit)

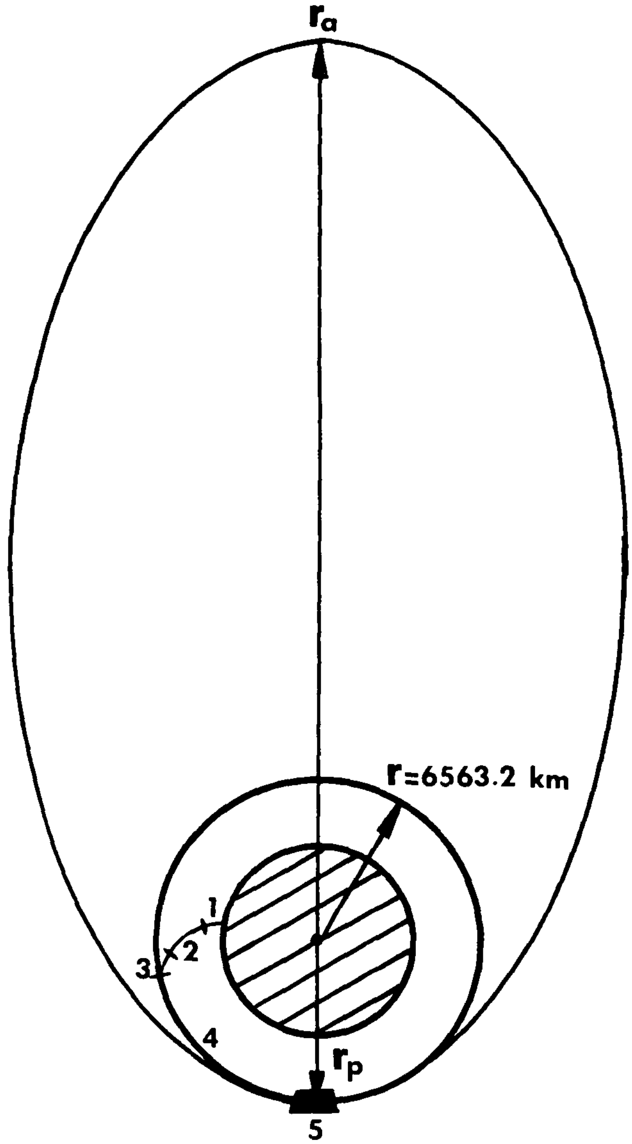


Figure 5. Typical Saturn IB ascent and elliptical target orbit injection profile.

OPTIMAL TRANSFER TO SYNCHRONOUS ALTITUDE CIRCULAR ORBITS

The optimal[2] transfer from the initial state in the parking orbit to the in-parking-orbit-plane synchronous altitude circular orbit corresponding to the terminal conic constraint (V, γ, r) ($V = 3.072$ km/sec, $\gamma = 0$ deg, $r = 42\ 240$ km) required no coast in the parking orbit from the injection point. This condition resulted from the fact that any point in the parking orbit was an optimum departure point for this in-plane target orbit case. Therefore, the S-IVB burn at perigee of the transfer ellipse was specified to occur immediately after parking orbit injection. The optimum burn and transfer time computed is shown in the timing analysis of Table 3. The remaining vehicle mass after satisfaction of the terminal constraint was 50 156.3 kg as compared to an initial vehicle mass of 128 986.8 kg. A detailed tabulation of this trajectory is presented in Table 4.

The optimal transfer to the out-of-parking-orbit-plane terminal conic constraint (V, γ, r, i) ($V = 3.072$ km/sec, $\gamma = 0$ deg, $r = 42\ 240$ km, $i = 50$ deg) required a plane change of approximately 13 deg. For a minimum velocity impulse to perform this plane change, the perigee point of the transfer ellipse is located at one of the nodal points of the parking orbit where only a portion of the total plane change is performed. Therefore, this transfer required a coast in the parking orbit of 268.4 sec.

The parking orbit injection point was located at a latitude (geocentric latitude) of 15.8 deg and a longitude of -55.6 deg. The perigee burn of 263.8 sec duration began at a latitude and longitude of 5.19 deg and -41.6 deg, respectively, and ended at a latitude and longitude of -7.18 deg and -26.44 deg, respectively. Thus, the midpoint of the perigee burn occurred approximately at the equator, adding enough velocity increment to perform a plane change maneuver of 1.16 deg (Δi_1) and modify the S-IVB orbit to that of an ellipse with apogee radius equal to 42 240 km (Hohmann transfer ellipse). The transfer time along this conic was 5.240 hr. With the plane change of 1.16 deg performed at perigee, the plane change required at apogee (Δi_2) was 11.9 deg. These amounts were computed to be the optimum perigee/apogee plane change ratio. The length of the apogee burn was 101.2 sec. A complete timing analysis for

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2. "Optimal" in the following discussion will refer to minimum fuel consumption.

this transfer is presented in Table 5. The velocity vector diagrams for both the perigee and apogee burns are shown in Figure 6. A detailed transfer trajectory tabulation is presented in Table 6.

OPTIMAL TRANSFER TO ELLIPTICAL ORBITS WITH APOGEE AT SYNCHRONOUS ALTITUDE

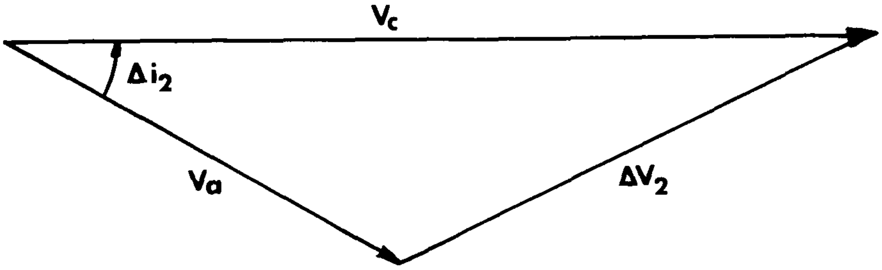
The terminal conic constraint (C_3, C_1) (C_3 = -16.33 km^2/sec^2, C_1 = 67.40 km^2/sec) specified an in-parking-orbit-plane elliptical orbit with perigee altitude equal to 210 km and apogee altitude equal to 35 862 km. A typical elliptical orbit injection profile was shown in Figure 4. Again, because of the in-plane target orbit, no particular point in the parking orbit was an optimum point of departure, and thus the parking orbit injection point was chosen as the departure point. A single burn of the S-IVB stage was required to optimally satisfy the terminal constraint giving an injected mass of 71 361.9 kg as tabulated in the timing analysis of this transfer given in Table 7. Presented in Table 8 is a tabulation of this transfer trajectory.

The analogous out-of-plane terminal conic constraint to the above was (C_3, C_1, i) (C_3 = -16.33 km^2/sec^2, C_1 = 67.40 km^2/sec, i = 50 deg). The optimum coast time in parking orbit was computed to be 216.9 sec, corresponding to a position of 7.26 deg latitude and -44.2 deg longitude, as shown in the timing analysis of Table 9. At this position the single S-IVB stage burn of 316.7 sec duration commenced. The burn ended at the position of -7.14 deg latitude and -29.6 deg longitude, after the energy and momentum constraints were satisfied and the plane change of approximately 13 deg was performed. A final mass of 59 771.5 kg remained at injection. The tabulation of this transfer maneuver is presented in Table 10.

OPTIMAL TRANSFER TO 1973 MARS MISSION HYPERBOLIC ORBIT

The terminal conditions for the injection burn into a typical 1973 Mars mission trajectory were on a specified hyperbolic orbit. The necessary terminal conic constraint consisted of an energy level, C_3, right ascension, α, and declination, δ, of the outgoing hyperbolic asymptote (C_3 = +18.0 km^2/sec^2, α = 15.55 deg, δ = 31.59 deg) along with a specified launch date

APOGEE INJECTION VELOCITY DIAGRAM



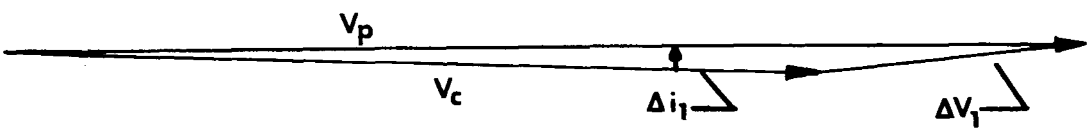
Δi_2 = 11.90 deg

V_a = 1.593 km/sec

V_c = 3.072 km/sec

ΔV_2 = 1.479 km/sec

PERIGEE INJECTION VELOCITY DIAGRAM



Δi_1 = 1.160 deg

V_p = 10.25 km/sec

V_c = 7.793 km/sec

ΔV_1 = 2.464 km/sec

Figure 6. Circular target orbit velocity increment diagram.

(August 6, 1973) and time (14 hr, 38 min, 15.85 sec Greenwich Mean Time). The hyperbolic injection geometry is illustrated in Figure 7. The right ascension and declination of the outgoing asymptote were referenced to an inertial, geocentric ephemeris coordinate system (Fig. 2) while the equations of motion in the computer program of Reference 1 were referenced to an inertial plumbline coordinate system. Thus a coordinate transformation was performed. The mechanics of this transformation are given in Appendix B.

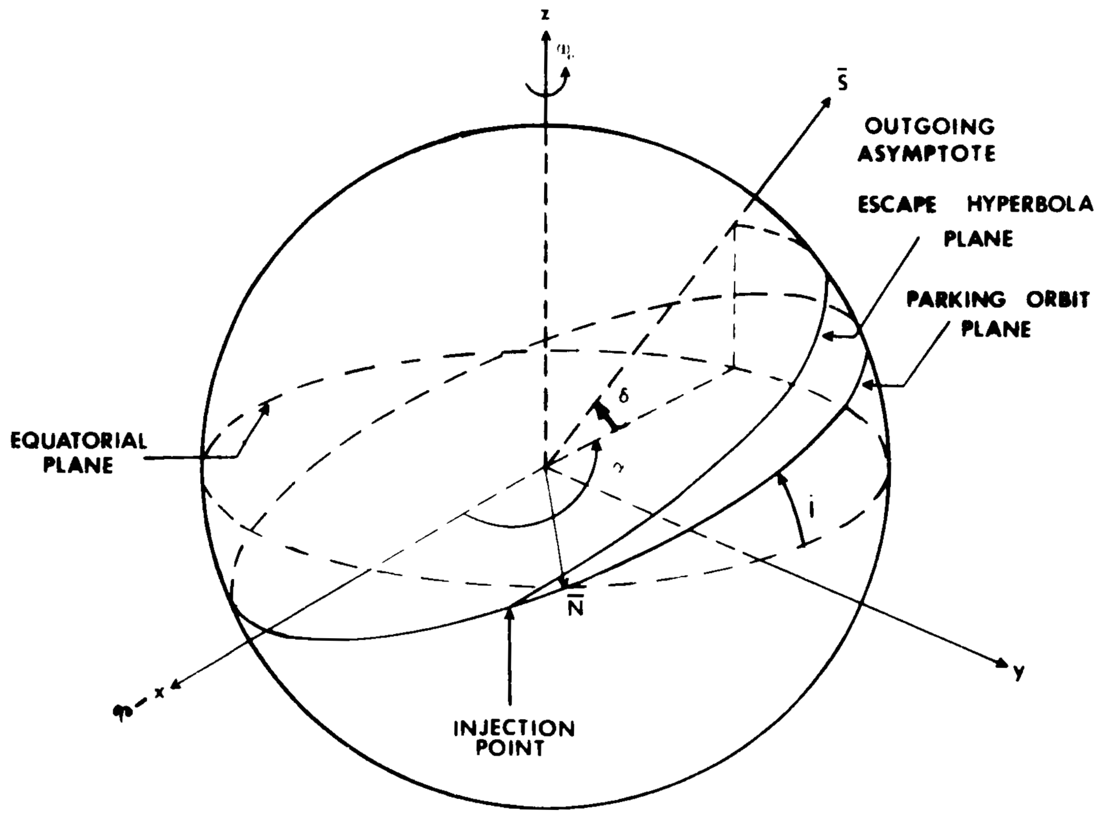


Figure 7. Hyperbolic injection geometry.

As tabulated in the timing analysis of Table 11 the optimum parking orbit coast time computed for the transfer was 1587.6 sec, which positioned the spacecraft at -36.3 deg latitude and 39.1 deg longitude. From this position a burn of 455.1-sec duration of the CSM propulsion system was required to insert the vehicle into the specified hyperbolic orbit. The vehicle mass injected into this orbit was 4817.3 kg compared with an initial vehicle mass of 18 029.7 kg. A detailed trajectory tabulation is presented in Table 12.

CONCLUSIONS

The transfer trajectories presented above provide somewhat of a reference cross-section of optimally performed orbital operations. Profiles and detailed trajectories were presented for the optimal transfer of (a) an S-IVB stage vehicle from a parking orbit about the earth to circular orbits at synchronous altitude and elliptical orbits with apogee at synchronous altitude (in-and-out-of-parking-orbit-plane), (b) a Command Service Module from an earth parking orbit to a typical 1973 Mars mission hyperbolic orbit. The parking orbit about the earth was a 100-nautical-mile, 37-deg-inclined circular orbit. An example of the utilization of these type transfer trajectories might be in the support of high-energy missions by the ILRV (Integral Launch and Reentry Vehicle). For instance, some of these proposed missions could involve the delivery of propulsive stages and payloads into low earth orbit for subsequent transfer to synchronous orbit.

The input data listings presented should serve as examples for similar runs to be made on the ROBOT computer program. Also, the vehicle roll and pitch programs tabulated in the trajectory tables should be of future use as initial estimates for similar runs. The modifications made to the ROBOT computer program (ephemeris coordinate system transformation, computation of additional orbital parameters, new output format, and inclusion of optional, publishable, summary print tables) make it much more compatible for orbital operations computations.

TABLE 1. SATURN IB ASCENT TRAJECTORY PROFILE FOR A 115-DEGREE LAUNCH AZIMUTH

Thrust Event	Time (sec)	Weight (kg)	Weight (lb)	Altitude (km)	Velocity[a] (km/sec)	Lat[b] (deg)	Long.[c] (deg)
Lift-off	000.00	564 621	1 244 777	000.00	0.409	28.361	-80.561
Jettison weight (launch escape system)	70.00	499	1 100				
S-IB cutoff	133.61	191 031	421 151	52.69	2.221	28.140	-80.041
a. S-IB propellant consumed		373 590	823 626				
b. S-IB jettison weight		49 764	109 711				
S-IVB ignition	139.11	141 267	311 440	57.71	2.199	28.105	-79.959
S-IVB cutoff	566.47	36 941	81 440	178.97	7.082	21.458	-67.117
a. S-IVB propellant consumed		104 326	230 000				
b. S-IVB jettison weight		14 133	31 157				
CSM first ignition	566.47	22 808	50 283	178.97	7.082	21.458	-67.117
CSM first cutoff[d]	731.32	18 030	39 749	185.22	7.792	15.756	-58.264
CSM propellant consumed		4 778	10 534				

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

[d] Parking orbit insertion (185.2-km altitude circular orbit).

TABLE 2. SATURN IB ASCENT TRAJECTORY FOR A 115-DEGREE LAUNCH AZIMUTH

	TIME	INERTIAL VELØCITY		RELATIVE VELØCITY		THETA S	THETA R
	SEC	M/SEC	FT/SEC	M/SEC	FT/SEC	DEG	DEG
LIFT-ØFF	0.000	408.968	1341.758	0.000	0.000	0.000	90.000
	5.000	409.280	1342.783	16.321	53.546	2.285	89.822
	10.000	410.356	1346.313	34.367	112.754	4.804	89.810
	15.000	413.537	1356.749	54.069	177.393	7.511	88.732
	20.000	420.178	1378.538	75.463	247.583	10.324	86.252
	25.000	430.679	1412.990	99.450	326.281	13.262	83.458
	30.000	445.132	1460.407	125.784	412.678	16.191	80.665
	35.000	463.732	1521.430	154.824	507.954	19.060	77.995
	40.000	486.637	1596.579	186.827	612.949	21.819	75.494
	45.000	514.132	1686.786	221.976	728.274	24.412	73.184
	45.328	516.111	1693.276	224.404	736.234	24.575	73.039
	50.000	546.208	1792.023	260.604	855.001	26.824	71.048
	55.000	587.451	1927.332	302.794	993.417	28.451	67.561
	60.000	632.305	2074.492	346.086	1135.452	29.483	64.054
	65.000	683.478	2242.383	394.497	1294.280	30.180	60.573
10 KMS.	65.654	690.714	2266.123	401.311	1316.637	30.251	60.122
	70.000	742.136	2434.828	449.674	1475.309	30.610	57.179
DRØP WT 1	70.000	742.136	2434.828	449.674	1475.309	30.610	57.179
Q MAXIMUM	72.766	778.102	2552.826	483.513	1586.329	30.747	55.358
	75.000	808.904	2653.884	512.521	1681.500	30.805	53.927
14 KMS.	76.067	824.211	2704.104	526.951	1728.842	30.818	53.255
	80.000	883.836	2899.724	583.267	1913.606	30.783	50.853
	85.000	967.157	3173.068	662.309	2172.930	30.580	47.980
	90.000	1059.144	3474.882	750.060	2460.828	30.232	45.315
	95.000	1159.984	3805.723	846.803	2778.225	29.773	42.660
	100.000	1269.876	4166.261	952.799	3125.979	29.233	40.608
	105.000	1389.059	4557.280	1068.325	3505.003	28.639	38.549
	110.000	1518.025	4980.397	1193.899	3916.991	28.016	36.672
	115.000	1657.429	5437.758	1330.184	4364.120	27.381	34.963
	120.000	1808.131	5932.189	1478.040	4849.212	26.752	33.412
	125.000	1971.223	6467.267	1638.550	5375.819	26.139	32.005
	130.000	2148.133	7047.681	1813.130	5948.591	25.553	30.734
ENG CUTØFF	130.606	2170.585	7121.340	1835.316	6021.379	25.484	30.588
ENG DECAY	130.606	2170.585	7121.340	1835.316	6021.379	25.484	30.588

TABLE 2. (Continued)

	TIME SEC	INERTIAL VELØCITY M/SEC	INERTIAL VELØCITY FT/SEC	RELATIVE VELØCITY M/SEC	RELATIVE VELØCITY FT/SEC	THETA S DEG	THETA R DEG
BEGIN DECAY	133.606	2221.047	7286.901	1884.050	6181.266	24.999	29.881
SEPARATIØN	133.606	2221.047	7286.901	1884.050	6181.266	24.999	29.881
END CØAST	139.106	2198.753	7213.755	1857.882	6095.415	23.844	28.582
END ATMØS	139.106	2198.753	7213.755	1857.882	6095.415	23.844	28.582
IGNITIØN	139.106	2198.753	7213.755	1857.882	6095.414	23.844	28.582
END BUILDUP	139.461	2198.636	7213.374	1857.548	6094.317	23.778	28.505
	149.000	2231.124	7319.962	1885.178	6184.966	22.291	26.674
	159.000	2268.557	7442.771	1917.978	6292.578	20.783	24.814
	169.000	2309.409	7576.802	1954.655	6412.910	19.329	23.021
	179.000	2353.649	7721.947	1995.156	6545.787	17.933	21.299
	189.000	2401.247	7878.107	2039.426	6691.031	16.596	19.651
	199.000	2452.174	8045.191	2087.412	6848.465	15.318	18.080
	209.000	2506.408	8223.124	2139.063	7017.922	14.101	16.587
	219.000	2563.932	8411.849	2194.331	7199.249	12.945	15.173
	229.000	2624.733	8611.329	2253.178	7392.316	11.848	13.838
	239.000	2688.810	8821.555	2315.572	7597.021	10.812	12.581
	249.000	2756.166	9042.541	2381.490	7813.287	9.834	11.401
	259.000	2826.816	9274.331	2450.920	8041.075	8.915	10.296
	269.000	2900.783	9517.004	2523.861	8280.383	8.052	9.265
	279.000	2978.100	9770.668	2600.324	8531.247	7.245	8.305
	289.000	3058.812	10035.472	2680.334	8793.745	6.492	7.413
	299.000	3142.976	10311.602	2763.927	9068.002	5.791	6.589
	309.000	3230.662	10599.283	2851.137	9354.188	5.141	5.828
	319.000	3321.952	10898.793	2942.091	9652.528	4.541	5.129
	329.000	3416.944	11210.447	3036.812	9963.293	3.988	4.488
	339.000	3515.751	11534.615	3135.420	10286.810	3.481	3.904
	349.000	3618.500	11871.718	3238.033	10623.467	3.019	3.374
	359.000	3725.338	12222.238	3344.758	10973.713	2.600	2.896
	369.000	3836.432	12586.720	3455.842	11338.063	2.222	2.467
	379.000	3951.969	12965.777	3571.375	11717.108	1.884	2.085
	389.000	4072.158	13360.099	3691.590	12111.516	1.585	1.749
	399.000	4197.238	13770.466	3816.720	12522.047	1.323	1.455
	409.000	4327.473	14197.747	3947.024	12949.555	1.098	1.204
	419.000	4463.161	14642.917	4082.796	13395.000	0.907	0.992

TABLE 2. (Continued)

	TIME	INERTIAL VELOCITY		RELATIVE VELOCITY		THETA S	THETA R
	SEC	M/SEC	FT/SEC	M/SEC	FT/SEC	DEG	DEG
	429.000	4604.636	15107.073	4224.365	13859.466	0.751	0.818
	439.000	4752.273	15591.446	4372.104	14344.174	0.627	0.682
	449.000	4906.495	16097.424	4526.434	14850.504	0.535	0.580
	459.000	5067.781	16626.576	4687.829	15380.016	0.475	0.513
	469.000	5236.673	17180.636	4856.831	15934.484	0.445	0.479
	479.000	5413.789	17761.776	5034.055	16515.928	0.444	0.477
	489.000	5599.837	18372.159	5220.207	17125.664	0.472	0.507
THRUST SHIFT	495.642	5743.536	18860.027	5366.963	17614.773	0.513	0.549
	499.000	5786.776	18985.434	5407.242	17740.295	0.507	0.543
	509.000	5953.442	19532.290	5575.989	18287.367	0.498	0.532
	519.000	6127.788	20104.290	5748.414	18859.627	0.513	0.547
	529.000	6310.442	20703.551	5931.144	19459.134	0.551	0.586
	539.000	6502.119	21332.411	6122.890	20088.223	0.612	0.650
	549.000	6703.650	21993.603	6324.484	20749.621	0.696	0.738
	559.000	6915.996	22690.276	6536.885	21446.474	0.802	0.849
ENG CUTOFF	566.455	7082.210	23235.598	6703.124	21991.911	0.896	0.947
SEPARATION	566.455	7082.210	23235.598	6703.124	21991.911	0.896	0.947
IGNITION	566.455	7082.210	23235.598	6703.124	21991.911	0.896	0.947
	576.000	7117.964	23352.899	6738.869	22109.216	0.815	0.861
	586.000	7155.140	23478.150	6777.083	22234.490	0.734	0.775
	596.000	7195.018	23605.702	6815.963	22362.084	0.657	0.693
	606.000	7234.601	23735.567	6855.563	22492.006	0.584	0.616
	616.000	7274.892	23867.756	6895.878	22624.271	0.514	0.543
	626.000	7315.897	24002.288	6936.929	22758.888	0.449	0.474
	636.000	7357.620	24139.173	6978.642	22895.873	0.388	0.409
	646.000	7400.065	24278.427	7021.141	23035.239	0.331	0.349
	656.000	7443.237	24420.066	7064.350	23177.000	0.278	0.293
	666.000	7487.142	24564.113	7108.294	23321.175	0.229	0.241
	676.000	7531.785	24710.581	7152.979	23467.781	0.183	0.193
	686.000	7577.173	24859.492	7198.412	23616.836	0.142	0.149
	696.000	7623.312	25010.870	7244.597	23768.363	0.104	0.110
	706.000	7670.213	25164.740	7291.543	23922.384	0.071	0.074
	716.000	7717.879	25321.126	7339.257	24078.924	0.041	0.043
	726.000	7766.322	25480.059	7387.747	24238.015	0.015	0.016

TABLE 2. (Continued)

	TIME SEC	INERTIAL VELØCITY M/SEC	INERTIAL VELØCITY FT/SEC	RELATIVE VELØCITY M/SEC	RELATIVE VELØCITY FT/SEC	THETA S[a] DEG	THETA R[b] DEG
ENG CUTØFF	731.322	7792.402	25565.625	7413.852	24323.660	-0.004	-0.004

a. THETA S is the flight path angle as measured from the local horizontal to the inertial velocity vector.

b. THETA R is the flight path angle as measured from the local horizontal to the relative velocity vector.

TABLE 2. (Continued)

	TIME SEC	MACH	AZ.S DEG	LATITUDE DEG	LONGITUDE DEG	ALPHA DEG	CHIP DEG	CHIY DEG
LIFT-ØFF	0.000	0.0000	90.000	28.361	-80.561	0.000	90.000	0.000
	5.000	0.0471	90.007	28.361	-80.561	0.000	90.000	0.000
	10.000	0.0993	90.013	28.361	-80.561	0.000	90.000	0.000
	15.000	0.1566	90.093	28.361	-80.561	0.770	87.937	0.000
	20.000	0.2194	90.321	28.361	-80.561	0.371	85.873	0.000
	25.000	0.2905	90.697	28.361	-80.561	0.518	83.810	0.000
	30.000	0.3696	91.208	28.360	-80.560	1.232	81.746	0.000
	35.000	0.4580	91.842	28.360	-80.559	1.849	79.683	0.000
	40.000	0.5572	92.583	28.359	-80.557	56.994	77.620	0.000
	45.000	0.6688	93.343	28.358	-80.554	52.245	75.556	-2.500
	45.328	0.6766	93.391	28.358	-80.554	51.938	75.421	-2.664
	50.000	0.7955	94.183	28.356	-80.551	48.164	73.493	0.000
	55.000	0.9401	95.421	28.355	-80.546	0.000	67.330	-0.178
	60.000	1.0978	96.698	28.352	-80.540	0.000	63.801	-0.091
	65.000	1.2841	98.023	28.349	-80.532	0.000	60.295	-0.018
10 KMS.	65.654	1.3111	98.199	28.348	-80.531	0.000	59.841	-0.009
	70.000	1.5067	99.372	28.345	-80.522	0.000	56.875	0.045
DRØP WT 1	70.000	1.5067	99.372	28.345	-80.522	0.000	56.875	0.045
Q MAXIMUM	72.768	1.6455	100.118	28.342	-80.516	0.000	55.039	0.076
	75.000	1.7638	100.712	28.339	-80.510	0.000	53.594	0.100
14 KMS.	76.067	1.8219	100.994	28.338	-80.507	0.000	52.916	0.111
	80.000	2.0402	102.008	28.333	-80.494	0.000	50.489	0.148
	85.000	2.3048	103.237	28.325	-80.476	0.000	47.581	0.192
	90.000	2.5698	104.383	28.316	-80.453	0.000	44.878	0.231
	95.000	2.8572	105.444	28.305	-80.427	0.000	42.380	0.267
	100.000	3.1752	106.414	28.292	-80.396	0.000	40.082	0.300
	105.000	3.5146	107.297	28.277	-80.361	0.000	37.972	0.331
	110.000	3.8624	108.099	28.259	-80.320	0.000	36.038	0.360
	115.000	4.2231	108.828	28.239	-80.273	0.000	34.267	0.388
	120.000	4.5994	109.492	28.217	-80.220	0.000	32.647	0.414
	125.000	5.0065	110.100	28.191	-80.160	0.000	31.166	0.438
	130.000	5.4591	110.658	28.162	-80.093	0.000	29.812	0.462
ENG CUTØFF	130.606	5.5638	110.723	28.159	-80.085	0.000	29.656	0.465
END DECAY	130.606	5.5638	110.723	28.159	-80.085	0.000	29.656	0.465

TABLE 2. (Continued)

	TIME SEC	MACH	AZ.S DEG	LATITUDE DEG	LØNGITUDE DEG	ALPHA DEG	CHIP DEG	CHIY DEG
BEGIN DECAY	133.606	5.7630	110.895	28.140	-80.041	0.000	28.896	0.479
SEPARATIØN	133.606	5.7630	110.895	28.140	-80.041	0.000	28.896	0.479
END CØAST	139.106	5.8187	110.945	28.105	-79.959	0.000	27.498	0.503
END ATMØS	139.106	5.8187	110.945	28.105	-79.959	0.000	27.498	0.503
IGNITIØN	139.106	5.8187	110.945	28.105	-79.959	0.000	38.769	0.000
END BUILDUP	139.461	5.8177	110.951	28.102	-79.954	0.000	38.740	0.000
	149.000	5.9042	111.166	28.040	-79.811	0.000	37.958	0.000
	159.000	6.0069	111.391	27.973	-79.656	0.000	37.129	0.000
	169.000	6.1218	111.613	27.903	-79.497	0.000	36.291	0.000
	179.000	6.2486	111.835	27.830	-79.333	0.000	35.443	0.000
	189.000	6.3873	112.055	27.755	-79.164	0.000	34.587	0.000
	199.000	6.5376	112.274	27.677	-78.989	0.000	33.720	0.000
	209.000	6.6993	112.492	27.596	-78.810	0.000	32.844	0.000
	219.000	6.8724	112.709	27.513	-78.625	0.000	31.958	0.000
	229.000	7.0567	112.926	27.426	-78.435	0.000	31.060	0.000
	239.000	7.2522	113.142	27.336	-78.238	0.000	30.151	0.000
	249.000	7.4586	113.357	27.243	-78.036	0.000	29.232	0.000
	259.000	7.6761	113.573	27.146	-77.828	0.000	28.301	0.000
	269.000	7.9045	113.788	27.046	-77.613	0.000	27.359	0.000
	279.000	8.1440	114.003	26.942	-77.392	0.000	26.405	0.000
	289.000	8.3946	114.218	26.835	-77.164	0.000	25.439	0.000
	299.000	8.6564	114.433	26.723	-76.930	0.000	24.461	0.000
	309.000	8.9296	114.648	26.608	-76.688	0.000	23.470	0.000
	319.000	9.2144	114.864	26.488	-76.439	0.000	22.465	0.000
	329.000	9.5110	115.081	26.363	-76.182	0.000	21.448	0.000
	339.000	9.8198	115.298	26.234	-75.918	0.000	20.417	0.000
	349.000	10.1412	115.516	26.100	-75.646	0.000	19.374	0.000
	359.000	10.4756	115.735	25.961	-75.365	0.000	18.316	0.000
	369.000	10.8234	115.955	25.817	-75.076	0.000	17.245	0.000
	379.000	11.1852	116.176	25.667	-74.778	0.000	16.160	0.000
	389.000	11.5617	116.399	25.512	-74.470	0.000	15.060	0.000
	399.000	11.9536	116.622	25.350	-74.154	0.000	13.946	0.000
	409.000	12.3617	116.848	25.182	-73.827	0.000	12.817	0.000
	419.000	12.7869	117.074	25.008	-73.490	0.000	11.674	0.000

TABLE 2. (Continued)

	TIME	MACH	AZ.S	LATITUDE	LØNGITUDE	ALPHA	CHIP	CHIY
	SEC		DEG	DEG	DEG	DEG	DEG	DEG
	429.000	13.2303	117.303	24.827	-73.143	0.000	10.516	0.000
	439.000	13.6930	117.533	24.638	-72.784	0.000	9.344	0.000
	449.000	14.1764	117.765	24.442	-72.415	0.000	8.158	0.000
	459.000	14.6818	117.999	24.238	-72.033	0.000	6.957	0.000
	469.000	15.2111	118.236	24.025	-71.639	0.000	5.741	0.000
	479.000	15.7662	118.474	23.804	-71.233	0.000	4.511	0.000
	489.000	16.3492	118.715	23.574	-70.813	0.000	3.266	0.000
THRUST SHIFT	496.642	16.8152	118.901	23.391	-70.482	0.000	2.306	0.000
	499.000	16.9350	118.956	23.333	-70.379	0.000	2.008	0.000
	509.000	17.4572	119.192	23.084	-69.932	0.000	0.736	0.000
	519.000	18.0035	119.429	22.825	-69.474	0.000	-0.549	0.000
	529.000	18.5758	119.668	22.557	-69.003	0.000	-1.847	0.000
	539.000	19.1763	119.909	22.279	-68.519	0.000	-3.157	0.000
	549.000	19.8077	120.152	21.990	-68.021	0.000	-4.480	0.000
	559.000	20.4729	120.397	21.690	-67.509	0.000	-5.814	0.000
ENG CUTØFF	566.465	20.9936	120.581	21.458	-67.117	0.000	-6.817	0.000
SEPARATIØN	566.465	20.9936	120.581	21.458	-67.117	0.000	-6.817	0.000
IGNITIØN	566.465	20.9936	120.581	21.458	-67.117	0.000	-6.817	0.000
	576.000	21.1056	120.786	21.156	-66.610	0.000	-8.109	0.000
	586.000	21.2252	120.998	20.836	-66.079	0.000	-9.471	0.000
	596.000	21.3470	121.208	20.512	-65.547	0.000	-10.842	0.000
	606.000	21.4710	121.414	20.184	-65.014	0.000	-12.221	0.000
	616.000	21.5973	121.617	19.853	-64.481	0.000	-13.609	0.000
	626.000	21.7258	121.818	19.518	-63.947	0.000	-15.004	0.000
	636.000	21.8565	122.015	19.179	-63.412	0.000	-16.404	0.000
	646.000	21.9896	122.210	18.837	-62.877	0.000	-17.808	0.000
	656.000	22.1249	122.401	18.490	-62.340	0.000	-19.216	0.000
	666.000	22.2625	122.589	18.140	-61.803	0.000	-20.628	0.000
	676.000	22.4025	122.774	17.786	-61.264	0.000	-22.042	0.000
	686.000	22.5448	122.955	17.428	-60.725	0.000	-23.456	0.000
	696.000	22.6894	123.134	17.066	-60.184	0.000	-24.871	0.000
	706.000	22.8364	123.309	16.700	-59.642	0.000	-26.285	0.000
	716.000	22.9859	123.480	16.330	-59.099	0.000	-27.696	0.000
	726.000	23.1377	123.649	15.957	-58.554	0.000	-29.989	0.000
ENG CUTØFF	731.322	23.2195	123.737	15.756	-58.264	0.000	-31.807	0.000

TABLE 2. (Continued)

	TIME SEC	ALTITUDE M	ALTITUDE FT	INCLINATIØN DEG	DYN. PRESSURE KG/(M)SQ	DYN. PRESSURE LB/(FT)SQ
LIFT-ØFF	0.000	0.00	0.0	28.361	0.000	0.000
	5.000	39.85	130.8	28.361	16.017	3.281
	10.000	165.89	544.3	28.361	70.227	14.384
	15.000	386.33	1267.5	28.361	170.385	34.898
	20.000	709.12	2326.5	28.362	322.120	65.975
	25.000	1143.46	3751.5	28.368	536.862	109.958
	30.000	1700.10	5577.8	28.384	813.549	166.628
	35.000	2388.11	7835.0	28.415	1150.992	235.742
	40.000	3217.70	10556.8	28.467	1540.873	315.596
	45.000	4199.84	13779.0	28.538	1966.849	402.842
	45.328	4269.94	14009.0	28.543	1995.621	408.735
	50.000	5345.81	17538.8	28.638	2408.282	493.255
	55.000	6661.18	21854.3	28.826	2835.241	580.703
	60.000	8138.31	26700.5	29.068	3168.091	648.876
	65.000	9773.87	32066.5	29.371	3439.909	704.549
10 KMS.	65.654	9999.95	32808.3	29.415	3469.736	710.658
	70.000	11575.92	37978.9	29.731	3619.534	741.339
DRØP WT 1	70.000	11575.92	37978.8	29.731	3619.534	741.339
Q MAXIMUM	72.768	12648.67	41498.3	29.952	3651.228	747.830
	75.000	13554.00	44468.5	30.139	3628.524	743.180
14 KMS.	76.067	14000.00	45931.8	30.230	3600.654	737.472
	80.000	15717.70	51567.3	30.577	3397.811	695.927
	85.000	18075.63	59303.3	31.032	2921.488	598.368
	90.000	20635.34	67701.3	31.438	2395.426	490.622
	95.000	23404.45	76786.3	31.935	1914.428	392.106
	100.000	26390.19	86582.0	32.365	1495.828	306.370
	105.000	29599.66	97111.8	32.771	1135.741	232.618
	110.000	33040.40	108400.3	33.151	834.455	170.910
	115.000	36721.54	120477.5	33.505	597.361	122.349
	120.000	40653.84	133378.8	33.833	418.566	85.729
	125.000	44850.25	147146.5	34.137	289.275	59.248
	130.000	49327.16	161834.5	34.419	199.072	40.773
ENG CUTØFF	130.606	49889.44	163679.3	34.452	190.807	39.080
ENG DECAY	130.606	49889.44	163679.3	34.452	190.807	39.080

TABLE 2. (Continued)

	TIME	ALTITUDE		INCLINATIØN	DYN. PRESSURE	
	SEC	M	FT	DEG	KG/(M)SQ	LB/(FT)SQ
BEGIN DECAY	133.606	52692.30	172375.0	34.532	144.266	29.548
SEPARATIØN	133.606	52692.30	172375.0	34.532	144.266	29.548
END CØAST	139.106	57706.64	189326.3	34.533	77.010	15.773
END ATMØS	139.106	57706.64	189326.3	34.533	77.010	15.773
IGNITIØN	139.106	57706.64	189326.3	34.533	77.010	15.773
END BUILDUP	139.461	58021.50	190359.3	34.534	76.982	15.767
	149.000	65265.81	217407.5	34.606	79.290	16.240
	159.000	74500.28	244423.5	34.681	82.073	16.810
	169.000	82324.65	270094.0	34.754	85.242	17.459
	179.000	89747.14	294446.0	34.826	88.811	18.190
	189.000	96776.13	317507.0	34.896	92.796	19.006
	199.000	103419.78	339303.8	34.965	97.214	19.911
	209.000	109686.55	359864.0	35.033	102.084	20.908
	219.000	115585.11	379216.3	35.100	107.428	22.003
	229.000	121124.17	397389.0	35.165	113.267	23.199
	239.000	126312.40	414410.8	35.229	119.627	24.501
	249.000	131158.79	430311.0	35.292	126.534	25.916
	259.000	135672.73	445120.5	35.354	134.020	27.449
	269.000	139863.57	458870.0	35.415	142.116	29.108
	279.000	143740.94	471591.0	35.474	150.857	30.898
	289.000	147314.72	483316.0	35.533	160.284	32.829
	299.000	150595.13	494078.5	35.590	170.437	34.908
	309.000	153592.66	503913.0	35.646	181.365	37.146
	319.000	156318.43	512855.8	35.702	193.118	39.554
	329.000	158783.58	520943.5	35.756	205.753	42.142
	339.000	160999.78	528214.5	35.809	219.332	44.923
	349.000	162979.30	534709.0	35.862	233.923	47.911
	359.000	164734.95	540469.0	35.913	249.602	51.123
	369.000	166279.83	545537.5	35.963	266.452	54.574
	379.000	167628.11	549961.0	36.013	284.565	58.284
	389.000	168794.35	553787.3	36.061	304.045	62.273
	399.000	169794.10	557067.3	36.109	325.006	66.567
	409.000	170643.50	559854.0	36.156	347.577	71.189
	419.000	171360.01	562204.8	36.202	371.900	76.171

TABLE 2. (Continued)

	TIME SEC	ALTITUDE M	ALTITUDE FT	INCLINATIØN DEG	DYN. PRESSURE KG/(M)SQ	DYN. PRESSURE LB/(FT)SQ
	429.000	171961.61	564178.5	36.247	398.139	81.545
	439.000	172468.11	565840.3	36.292	426.474	87.349
	449.000	172900.16	567257.8	36.335	457.113	93.624
	459.000	173280.09	568504.3	36.378	490.292	100.420
	469.000	173631.76	569658.0	36.420	526.280	107.791
	479.000	173980.91	570803.5	36.462	565.389	115.801
	489.000	174355.43	572032.3	36.503	607.976	124.523
THRUST SHIFT	496.642	174677.37	573088.5	36.534	643.125	131.722
	499.000	174782.68	573434.0	36.541	652.323	133.606
	509.000	175227.99	574895.0	36.574	693.176	141.974
	519.000	175689.69	576409.8	36.605	737.237	150.998
	529.000	176193.65	578063.3	36.637	784.853	160.751
	539.000	176768.61	579949.5	36.668	836.420	171.312
	549.000	177444.88	582168.3	36.699	892.404	182.779
	559.000	178255.88	584829.0	36.729	953.351	195.262
ENG CUTØFF	566.465	178970.10	587172.3	36.752	1002.460	205.320
SEPARATIØN	566.465	178970.10	587172.3	36.752	1002.460	205.320
IGNITIØN	566.465	178970.10	587172.3	36.752	1002.460	205.320
	576.000	179904.24	590237.0	36.757	1013.183	207.516
	586.000	180788.23	593137.3	36.762	1024.657	209.875
	596.000	181573.28	595729.3	36.768	1036.491	212.290
	606.000	182278.55	598026.8	36.773	1048.570	214.764
	616.000	182893.49	600044.3	36.779	1060.939	217.297
	626.000	183426.89	601794.3	36.784	1073.602	219.891
	636.000	183885.25	603291.5	36.789	1086.565	222.546
	646.000	184267.07	604550.8	36.794	1099.833	225.263
	656.000	184582.15	605584.5	36.800	1113.411	228.045
	666.000	184833.39	606406.8	36.805	1127.307	230.891
	676.000	185024.88	607037.0	36.810	1141.524	233.803
	686.000	185161.35	607484.8	36.815	1156.071	236.782
	696.000	185247.15	607766.3	36.820	1170.954	239.830
	706.000	185287.23	607897.8	36.825	1186.179	242.949
	716.000	185286.01	607893.8	36.829	1201.754	246.139
	726.000	185248.52	607770.8	36.834	1217.686	249.402
ENG CUTØFF	731.322	185220.63	607679.3	36.836	1226.307	251.167

TABLE 2. (Continued)

	TIME SEC	MASS KGS	WEIGHT LBS	THRUST N	THRUST LBS	LØNGIT. ACCELERATIØN M/(SEC)SQ	LØNGIT. ACCELERATIØN FT/(SEC)SQ
LIFT-ØFF	0.000	554621.2	1244775.7	7295083.4	1640000.0	12.83	42.10
	5.000	550500.3	1213645.3	7298997.9	1640880.0	13.24	43.42
	10.000	536379.3	1182514.0	7311284.7	1643642.2	13.57	44.51
	15.000	522258.4	1151382.6	7332436.7	1648397.3	13.90	45.59
	20.000	508137.4	1120251.2	7362634.[illegible]	1655186.1	14.32	46.97
	25.000	494016.5	1039119.9	7401836.[illegible]	1663999.0	14.74	48.36
	30.000	479895.5	1057938.5	7449721.[illegible]	1674764.0	15.19	49.83
	35.000	465774.6	1026857.2	7505375.[illegible]	1687275.6	15.68	51.43
	40.000	451653.6	995725.8	7567548.[illegible]	1701252.[illegible]	16.20	53.14
	45.000	437532.7	964594.5	7634655.[illegible]	1716339.5	16.76	54.97
	45.328	436605.1	962549.5	7639194.[illegible]	1717359.[illegible]	16.80	55.10
	50.000	423411.7	933463.1	7704839.[illegible]	1732116.6	17.35	56.93
	55.000	409290.8	902331.7	7775739.[illegible]	1748055.8	17.62	57.82
	60.000	395169.8	871200.4	7844499.4	1763513.6	17.77	58.31
	65.000	381048.9	840069.0	7908870.7	1777984.9	18.82	61.76
10 KMS.	65.654	379201.3	835995.9	7916881.[illegible]	1779785.8	18.97	62.25
	70.000	366928.0	808937.7	7967288.4	1791117.2	19.98	65.55
DRØP WT 1	70.000	366429.0	807837.7	7967288.4	1791117.2	20.01	65.64
Q MAXIMUM	72.768	358611.0	790602.0	7996412.[illegible]	1797665.1	20.66	67.79
	75.000	352308.1	776706.3	8017973.[illegible]	1802512.2	21.23	69.64
14 KMS.	76.067	349293.6	770060.5	8027640.[illegible]	1804685.3	21.49	70.51
	80.000	338187.1	745575.0	8059474.[illegible]	1811842.0	22.51	73.87
	85.000	324066.2	714443.6	8091039.[illegible]	1818937.9	23.90	78.40
	90.000	309945.2	683312.2	8113305.[illegible]	1823943.8	25.35	83.17
	95.000	295824.3	652180.9	8126567.1	1827374.6	26.87	88.15
	100.000	281703.3	621049.5	8136759.	1829266.0	28.45	93.34
	105.000	267582.4	589918.2	8145447.[illegible]	1831169.3	30.13	98.84
	110.000	253461.4	558786.8	8149718.[illegible]	1832129.7	31.94	104.79
	115.000	239340.5	527655.4	8152381.4	1832728.3	33.92	111.28
	120.000	225219.5	496524.1	8154007.[illegible]	1833093.9	36.11	118.47
	125.000	211098.6	465392.7	8154986.1	1833313.8	38.56	126.52
	130.000	196977.6	434261.4	8155571.4	1833445.4	41.35	135.67
ENG CUTØFF	130.606	195267.0	430490.1	8155623.[illegible]	1833457.2	41.72	136.87
END DECAY	130.606	195267.0	430490.1	4077812.[illegible]	916728.6	20.85	68.41

TABLE 2. (Continued)

	TIME	MASS	WEIGHT	THRUST		LONGIT. ACCELERATION	
	SEC	KGS	LBS	N	LBS	M/(SEC)SQ	FT/(SEC)SQ
BEGIN DECAY	133.606	191030.7	421150.7	0.0	0.0	-0.01	-0.02
SEPARATIØN	133.606	141266.7	311439.7	0.0	0.0	-0.01	-0.03
END CØAST	139.106	141266.7	311439.7	0.0	0.0	-0.05	-0.16
END ATMØS	139.106	141266.7	311439.7	0.0	0.0	-0.05	-0.16
IGNITIØN	139.106	141266.7	311439.7	-0.0	-0.0	-0.00	-0.01
END BUILDUP	139.461	141230.6	311360.1	1050385.3	236136.0	7.43	24.37
	149.000	138824.3	306055.2	1050385.3	236136.0	7.56	24.79
	159.000	136301.7	300493.8	1050385.3	236136.0	7.70	25.26
	169.000	133779.1	294932.4	1050385.3	236136.0	7.84	25.73
	179.000	131256.5	289371.1	1050385.3	236136.0	7.99	26.23
	189.000	128733.9	283809.7	1050385.3	236136.0	8.15	26.74
	199.000	126211.3	278248.3	1050385.3	236136.0	8.31	27.27
	209.000	123688.7	272686.9	1050385.3	236136.0	8.48	27.83
	219.000	121166.1	267125.6	1050385.3	236136.0	8.66	28.41
	229.000	118643.5	261564.2	1050385.3	236136.0	8.84	29.01
	239.000	116120.9	256002.8	1050385.3	236136.0	9.03	29.64
	249.000	113598.3	250441.4	1050385.3	236136.0	9.23	30.30
	259.000	111075.7	244880.1	1050385.3	236136.0	9.44	30.99
	269.000	108553.1	239318.7	1050385.3	236136.0	9.66	31.70
	279.000	106030.5	233757.3	1050385.3	236136.0	9.89	32.46
	289.000	103507.9	228195.9	1050385.3	236136.0	10.13	33.25
	299.000	100985.3	222634.6	1050385.3	236136.0	10.39	34.08
	309.000	98462.7	217073.2	1050385.3	236136.0	10.65	34.95
	319.000	95940.1	211511.8	1050385.3	236136.0	10.93	35.87
	329.000	93417.5	205950.4	1050385.3	236136.0	11.23	36.83
	339.000	90894.9	200389.1	1050385.3	236136.0	11.54	37.85
	349.000	88372.3	194827.7	1050385.3	236136.0	11.87	38.93
	359.000	85849.8	189266.3	1050385.3	236136.0	12.22	40.08
	369.000	83327.2	183704.9	1050385.3	236136.0	12.58	41.29
	379.000	80804.6	178143.6	1050385.3	236136.0	12.98	42.57
	389.000	78282.0	172582.2	1050385.3	236136.0	13.39	43.94
	399.000	75759.4	167020.8	1050385.3	236136.0	13.84	45.40
	409.000	73236.8	161459.4	1050385.3	236136.0	14.31	46.96
	419.000	70714.2	155898.1	1050385.3	236136.0	14.82	48.63

TABLE 2. (Continued)

	TIME SEC	MASS KGS	WEIGHT LBS	THRUST N	THRUST LBS	LONGIT. ACCELERATION M/(SEC)SQ	LONGIT. ACCELERATION FT/(SEC)SQ
	429.000	68191.6	150336.7	1050385.3	236136.0	15.37	50.43
	439.000	65669.0	144775.3	1050385.3	236136.0	15.96	52.36
	449.000	63146.4	139213.9	1050385.3	236136.0	16.60	54.45
	459.000	60623.8	133652.6	1050385.3	236136.0	17.28	56.71
	469.000	58101.2	128091.2	1050385.3	236136.0	18.03	59.16
	479.000	55578.6	122529.8	1050385.3	236136.0	18.85	61.84
	489.000	53056.0	116968.4	1050385.3	236136.0	19.74	64.77
THRUST SHIFT	496.642	51128.2	112718.3	854663.5	192136.0	16.66	54.66
	499.000	50649.1	111662.1	854663.5	192136.0	16.82	55.17
	509.000	48617.1	107182.3	854663.5	192136.0	17.52	57.47
	519.000	46585.1	102702.6	854663.5	192136.0	18.28	59.97
	529.000	44553.1	98222.9	854663.5	192136.0	19.11	62.69
	539.000	42521.2	93743.1	854663.5	192136.0	20.02	65.67
	549.000	40489.2	89263.4	854663.5	192136.0	21.02	68.95
	559.000	38457.2	84783.6	854663.5	192136.0	22.12	72.58
ENG CUTOFF	566.465	36940.4	81439.7	854663.5	192136.0	23.03	75.55
SEPARATION	566.465	22807.8	50282.7	-0.0	-0.0	-0.15	-0.48
IGNITION	566.465	22807.8	50282.7	88964.4	20000.0	3.90	12.79
	576.000	22531.5	49673.4	88964.4	20000.0	3.95	12.94
	586.000	22241.6	49034.4	88964.4	20000.0	4.00	13.11
	596.000	21951.8	48395.5	88964.4	20000.0	4.05	13.28
	606.000	21662.0	47756.5	88964.4	20000.0	4.10	13.46
	616.000	21372.1	47117.5	88964.4	20000.0	4.16	13.65
	626.000	21082.3	46478.5	88964.4	20000.0	4.22	13.83
	636.000	20792.5	45839.5	88964.4	20000.0	4.28	14.03
	646.000	20502.6	45200.6	88964.4	20000.0	4.34	14.22
	656.000	20212.8	44561.6	88964.4	20000.0	4.40	14.43
	666.000	19923.0	43922.6	88964.4	20000.0	4.46	14.64
	676.000	19633.1	43283.6	88964.4	20000.0	4.53	14.85
	686.000	19343.3	42644.7	88964.4	20000.0	4.60	15.08
	696.000	19053.5	42005.7	88964.4	20000.0	4.67	15.31
	706.000	18763.6	41366.7	88964.4	20000.0	4.74	15.54
	716.000	18473.8	40727.7	88964.4	20000.0	4.81	15.79
	726.000	18183.9	40088.7	88964.4	20000.0	4.89	16.04
ENG CUTOFF	731.322	18029.7	39748.7	88964.4	20000.0	0.93	16.17

TABLE 2. (Continued)

	TIME	XXX		YYY		ZZZ	
	SEC	M	FT	M	FT	M	FT
LIFT-ØFF	0.000	0.0	0.0	0.0	0.0	0.0	0.0
	5.000	1853.2	6080.2	39.7	130.2	-864.2	-2835.2
	10.000	3706.4	12160.1	164.7	540.5	-1728.3	-5670.4
	15.000	5561.5	18246.5	383.5	1258.1	-2592.4	-8505.4
	20.000	7429.1	24373.8	703.9	2309.5	-3456.5	-11340.2
	25.000	9322.3	30585.0	1135.2	3724.6	-4320.5	-14174.9
	30.000	11254.6	36924.5	1683.3	5539.0	-5184.6	-17009.7
	35.000	13239.5	43436.7	2371.7	7781.3	-6048.6	-19844.6
	40.000	15291.1	50167.6	3196.1	10485.7	-6912.8	-22679.9
	45.000	17423.5	57163.8	4171.9	13687.3	-7778.1	-25518.8
	45.328	17566.8	57633.9	4241.6	13915.8	-7835.1	-25705.8
	50.000	19651.6	64473.8	5310.5	17422.8	-8645.3	-28363.8
	55.000	22008.3	72205.6	6617.2	21710.0	-9515.9	-31220.2
	60.000	24533.3	80489.6	8084.2	26523.1	-10386.7	-34077.0
	65.000	27255.1	89419.6	9707.9	31849.9	-11257.4	-36933.6
10 KMS.	65.654	27627.5	90641.5	9932.2	32585.9	-11371.3	-37307.4
	70.000	30209.4	99112.3	11495.8	37715.7	-12127.7	-39788.9
DRØP WT 1	70.000	30209.4	99112.3	11495.8	37715.7	-12127.7	-39788.9
Q MAXIMUM	72.768	31959.2	104853.2	12559.5	41205.6	-12609.2	-41368.9
	75.000	33435.4	109696.2	13456.9	44149.8	-12997.3	-42642.2
14 KMS.	76.067	34163.3	112084.3	13898.8	45599.7	-13182.8	-43250.7
	80.000	36975.1	121309.5	15600.4	51182.4	-13865.9	-45491.7
	85.000	40871.7	134093.4	17933.8	58838.1	-14723.0	-48336.5
	90.000	45169.7	148194.5	20464.2	67139.8	-15598.3	-51175.4
	95.000	49915.1	163763.6	23197.5	76108.4	-16461.0	-54006.0
	100.000	55154.9	180954.5	26140.5	85762.9	-17320.9	-56827.0
	105.000	60936.9	199924.4	29297.7	96121.1	-18177.2	-59636.5
	110.000	67310.6	220835.2	32675.3	107202.3	-19029.4	-62432.5
	115.000	74327.6	243856.9	36275.7	119028.0	-19876.8	-65212.7
	120.000	82042.9	269169.6	40119.3	131624.9	-20718.8	-67975.0
	125.000	90515.6	296967.1	44203.6	145024.8	-21554.5	-70716.9
	130.000	99810.4	327462.0	48545.1	159268.7	-22383.0	-73435.1
ENG CUTØFF	130.606	100995.6	331350.3	49089.2	161053.8	-22482.9	-73762.7
ENG DECAY	130.606	100995.6	331350.3	49089.2	161053.8	-22482.9	-73762.7

TABLE 2. (Continued)

	TIME	XXX		YYY		ZZZ	
	SEC	M	FT	M	FT	M	FT
BEGIN DECAY	133.606	136980.0	350984.1	51796.9	169937.3	-22976.3	-75381.7
SEPARATIØN	133.606	136980.0	350984.1	51796.9	169937.3	-22976.3	-75381.7
END CØAST	139.106	118099.0	387464.0	56619.9	185760.7	-23878.9	-78342.8
END ATMØS	139.106	118099.0	387464.0	56619.9	185760.7	-23878.9	-78342.8
IGNITIØN	139.106	118099.0	387464.0	56619.9	185760.7	-23878.9	-78342.8
END BUILDUP	139.461	118817.6	389821.6	56921.6	186750.8	-23937.2	-78534.0
	149.000	138362.7	453946.0	64781.2	212536.8	-25499.7	-83660.4
	159.000	159415.2	523015.9	72535.8	237978.2	-27134.0	-89022.4
	169.000	181058.0	594022.2	79796.1	261798.2	-28764.4	-94371.3
	179.000	203306.2	667015.2	86564.2	284003.2	-30390.5	-99706.3
	189.000	226175.9	742047.0	92841.7	304598.7	-32012.1	-105026.7
	199.000	249683.5	819171.6	98629.9	323588.9	-33629.1	-110331.8
	209.000	273846.1	898445.4	103929.7	340976.8	-35241.2	-115620.9
	219.000	298681.6	979926.6	108741.7	356764.1	-36848.2	-120893.2
	229.000	324208.4	1063676.0	113056.0	370951.5	-38449.9	-126148.0
	239.000	350445.9	1149756.8	116902.4	383537.9	-40046.1	-131384.7
	249.000	377414.0	1238235.0	120250.0	394521.0	-41636.4	-136602.5
	259.000	405133.8	1329179.0	123107.[illegible]	403897.0	-43220.9	-141800.7
	269.000	433626.9	1422660.4	125474.1	411660.5	-44799.1	-146978.7
	279.000	462916.2	1518753.9	127346.7	417804.2	-46370.9	-152135.6
	289.000	493025.4	1617537.5	128722.9	422319.2	-47936.2	-157271.0
	299.000	523975.5	1719092.7	129599.4	425194.8	-49494.6	-162384.0
	309.000	555804.3	1823505.0	129972.2	426418.0	-51046.1	-167473.9
	319.000	588527.3	1930863.8	129836.8	425973.8	-52590.2	-172540.2
	329.000	622177.0	2041263.1	129187.9	423844.7	-54127.0	-177582.0
	339.000	656783.4	2154801.3	128019.4	420011.0	-55656.1	-182598.8
	349.000	692378.2	2271582.1	126324.4	414450.0	-57177.4	-187589.9
	359.000	728994.6	2391714.8	124095.1	407136.2	-58690.6	-192554.5
	369.000	766667.8	2515314.2	121323.0	398041.2	-60195.6	-197492.1
	379.000	805434.6	2642502.0	117998.1	387132.9	-61692.1	-202401.9
	389.000	845334.4	2773406.7	114109.7	374375.7	-63180.0	-207283.3
	399.000	886408.5	2908164.5	109645.7	359730.0	-64658.9	-212135.6
	409.000	928701.3	3046920.2	104592.6	343151.7	-66128.9	-216958.2
	419.000	972259.4	3189827.4	98935.6	324591.9	-67589.5	-221750.4

TABLE 2. (Continued)

	TIME	XXX		YYY		ZZZ	
	SEC	M	FT	M	FT	M	FT
	429.000	1017132.9	3337050.2	92658.2	303996.7	-69040.7	-226511.6
	439.000	1063375.3	3488764.1	85742.0	281305.9	-70482.3	-231241.1
	449.000	1111043.8	3645156.8	78167.0	256453.3	-71914.0	-235938.3
	459.000	1160199.9	3806430.1	69910.6	229365.4	-73335.6	-240602.5
	469.000	1210909.9	3972801.6	60948.1	199960.8	-74747.1	-245233.1
	479.000	1263245.6	4144506.7	51251.8	168149.0	-76148.0	-249829.5
	489.000	1317284.9	4321800.8	40791.1	133829.2	-77538.4	-254391.1
THRUST SHIFT	496.642	1359783.3	4461231.4	32260.5	105841.6	-78593.7	-257853.3
	499.000	1373101.7	4504926.9	29531.4	96887.9	-78918.0	-258917.2
	509.000	1430518.3	4693301.4	17426.2	57172.6	-80286.5	-263407.3
	519.000	1489488.5	4886773.3	4435.9	14553.6	-81643.9	-267860.7
	529.000	1550080.7	5085566.8	-9477.5	-31094.1	-82990.0	-272276.8
	539.000	1612369.0	5289924.4	-24355.9	-79907.8	-84324.5	-276655.1
	549.000	1676434.2	5500112.1	-40246.0	-132040.7	-85647.3	-280995.0
	559.000	1742364.9	5716420.2	-57199.5	-187662.3	-86958.2	-285296.0
ENG CUTØFF	566.465	1792853.5	5882065.3	-70582.0	-231568.2	-87928.9	-288480.7
SEPARATIØN	566.465	1792853.5	5882065.3	-70582.0	-231568.2	-87928.9	-288480.7
IGNITIØN	566.465	1792853.5	5882065.3	-70582.0	-231568.2	-87928.9	-288480.7
	576.000	1858125.0	6096210.6	-88514.9	-290403.2	-89159.0	-292516.5
	586.000	1926701.0	6321197.5	-108245.5	-355136.6	-90437.0	-296709.4
	596.000	1995398.4	6546582.6	-128929.3	-422996.2	-91702.5	-300861.4
	606.000	2064211.0	6772345.8	-150572.9	-494005.7	-92955.4	-304971.7
	616.000	2133132.6	6998466.5	-173184.0	-568189.0	-94195.4	-309040.1
	626.000	2202156.6	7224923.4	-196770.0	-645570.9	-95422.5	-313065.8
	636.000	2271276.5	7451694.6	-221338.6	-726176.7	-96636.4	-317048.5
	646.000	2340485.3	7678757.6	-246897.8	-810032.3	-97837.0	-320987.5
	656.000	2409776.0	7906089.4	-273455.7	-897164.3	-99024.2	-324882.4
	666.000	2479141.4	8133666.0	-301020.4	-987599.8	-100197.7	-328732.7
	676.000	2548573.9	8361463.0	-329600.5	-1081366.4	-101357.5	-332537.9
	686.000	2618065.9	8589455.1	-359204.5	-1178492.4	-102503.5	-336297.5
	696.000	2687609.5	8817616.6	-389841.2	-1279006.5	-103635.3	-340010.9
	706.000	2757196.6	9045920.8	-421519.5	-1382938.0	-104753.0	-343677.9
	716.000	2826818.8	9274340.1	-454248.5	-1490316.5	-105856.4	-347297.8
	726.000	2896467.7	9502846.9	-488037.4	-1601172.4	-106945.2	-350870.1

TABLE 2. (Continued)

	TIME	XXX[a]		YYY[a]		ZZZ[a]	
	SEC	M	FT	M	FT	M	FT
ENG CUTØFF	731.322	2933546.5	9624496.4	-506451.3	-1661585.6	-107518.8	-352751.9

a. These quantities represent position coordinates in a topocentric plumbline coordinate system defined in Reference 2. Transformation from this coordinate system to the geocentric inertial plumbline coordinate system (XP, YP, ZP) shown in Figure 2 is accomplished as follows:

$$XP = XXX + XP(0)$$
$$YP = YYY + YP(0)$$
$$ZP = ZZZ + ZP(0)$$

where XP(0), YP(0), ZP(0) are the coordinates of the origin of the XP, YP, ZP system at the center of the earth as defined by

$$XP(0) = R(\theta) \sin K \sin \beta_0$$
$$YP(0) = R(\theta) \cos \beta_0$$
$$ZP(0) = -R(\theta) \cos K \sin \beta_0$$

where β_0 is the difference between the geodetic and geocentric latitude of the launch site,

$K = \frac{3\pi}{2} - \sigma_L$ (launch azimuth), and $R(\theta)$ is the radius of the earth (considered to be an ellipsoid) computed as a function of the geocentric colatitude (θ) of the launch site by $R(\theta) = (1-f)\, R_e / \sqrt{(1-f)^2 \sin^2\theta + \cos^2\theta}$ where the flattening, f, is 1/298.3 and R_e is the equatorial radius of the earth.

TABLE 2. (Continued)

	TIME	DXP		DYP		DZP	
	SEC	M/SEC	FT/SEC	M/SEC	FT/SEC	M/SEC	FT/SEC
LIFT-ØFF	0.000	370.651	1216.045	0.000	0.000	-172.837	-567.051
	5.000	370.643	1216.021	16.190	53.116	-172.834	-567.042
	10.000	370.622	1215.951	34.105	111.892	-172.825	-567.011
	15.000	371.844	1219.962	53.661	176.052	-172.815	-566.980
	20.000	375.529	1232.379	74.768	245.300	-172.808	-566.954
	25.000	382.094	1253.586	98.120	321.918	-172.805	-566.944
	30.000	391.257	1283.653	123.276	404.448	-172.810	-566.962
	35.000	403.179	1322.763	150.419	493.501	-172.825	-567.012
	40.000	417.926	1371.147	179.655	589.421	-172.853	-567.102
	45.000	435.542	1428.943	211.049	692.419	-173.475	-569.143
	45.328	436.802	1433.077	213.191	699.446	-173.562	-569.430
	50.000	456.196	1496.706	244.790	803.116	-174.088	-571.156
	55.000	487.406	1599.100	277.864	911.627	-174.143	-571.336
	60.000	523.555	1717.700	308.823	1013.198	-174.151	-571.361
	65.000	566.311	1857.97[illegible]	340.766	1117.999	-174.107	-571.218
10 KMS.	65.654	572.451	1878.119	345.074	1132.134	-174.097	-571.186
	70.000	616.627	2023.056	374.511	1228.709	-174.005	-570.881
DRØP WT 1	70.000	616.627	2023.056	374.511	1228.709	-174.005	-570.881
Q MAXIMUM	72.768	648.006	2126.003	394.059	1292.846	-173.919	-570.599
	75.000	675.162	2215.099	410.199	1345.799	-173.833	-570.318
14 KMS.	76.067	688.746	2259.665	418.032	1371.497	-173.787	-570.166
	80.000	742.164	2434.920	447.468	1468.071	-173.584	-569.501
	85.000	817.940	2683.531	486.160	1595.015	-173.248	-568.399
	90.000	902.796	2961.929	526.193	1726.356	-172.818	-566.987
	95.000	996.942	3270.806	567.440	1861.680	-172.284	-565.237
	100.000	1100.569	3610.791	609.814	2000.701	-171.640	-563.124
	105.000	1213.885	3982.561	653.276	2143.295	-170.878	-560.623
	110.000	1337.292	4387.440	697.965	2289.910	-169.969	-557.706
	115.000	1471.337	4827.220	744.103	2441.284	-168.963	-554.340
	120.000	1616.754	5304.312	792.017	2598.482	-167.788	-550.486
	125.000	1774.496	5821.838	842.127	2762.883	-166.451	-546.098
	130.000	1945.833	6383.967	894.990	2936.318	-164.933	-541.120
ENG CUTØFF	130.606	1957.586	6455.335	901.612	2958.045	-164.736	-540.474
ENG DECAY	130.606	1957.[illegible]	6455.335	901.612	2958.045	-164.736	-540.474

TABLE 2. (Continued)

	TIME	DXP		DYP		DZP	
	SEC	M/SEC	FT/SEC	M/SEC	FT/SEC	M/SEC	FT/SEC
BEGIN DECAY	133.606	2022.294	6634.824	903.561	2964.439	-164.180	-538.649
SEPARATIØN	133.606	2022.294	6634.824	903.561	2964.439	-164.180	-538.649
END CØAST	139.106	2021.035	6630.692	850.316	2789.750	-163.991	-538.028
END ATMØS	139.106	2021.035	6630.692	850.316	2789.750	-163.991	-538.028
IGNITIØN	139.106	2021.035	6630.692	850.316	2789.750	-163.991	-538.028
END BUILDUP	139.461	2022.002	6633.865	847.715	2781.218	-163.978	-537.986
	149.000	2076.237	6811.801	800.239	2625.457	-163.628	-536.836
	159.000	2134.512	7002.991	750.708	2452.953	-163.236	-535.559
	169.000	2194.290	7199.114	701.391	2301.153	-162.827	-534.208
	179.000	2255.623	7400.354	652.256	2139.947	-162.393	-532.784
	189.000	2316.584	7606.905	603.267	1979.222	-161.937	-531.288
	199.000	2383.221	7818.967	554.389	1818.361	-161.459	-529.720
	209.000	2449.504	8036.755	505.584	1658.741	-160.959	-528.080
	219.000	2517.302	8260.504	456.815	1498.736	-160.437	-526.369
	229.000	2587.887	8490.444	408.040	1338.714	-159.894	-524.587
	239.000	2659.940	8726.536	359.215	1178.526	-159.330	-522.735
	249.000	2734.039	8969.945	310.296	1018.032	-158.744	-520.812
	259.000	2810.274	9220.055	261.236	857.073	-158.136	-518.820
	269.000	2888.736	9477.480	211.984	695.486	-157.508	-516.758
	279.000	2969.524	9742.532	162.483	533.098	-156.858	-514.627
	289.000	3052.742	10015.559	112.691	369.723	-156.186	-512.428
	299.000	3138.504	10295.939	62.574	205.166	-155.496	-510.159
	309.000	3226.929	10587.039	11.955	39.217	-154.784	-507.822
	319.000	3318.148	10886.312	-39.123	-128.357	-154.051	-505.417
	329.000	3412.297	11195.200	-90.767	-297.791	-153.297	-502.944
	339.000	3509.526	11514.195	-143.036	-469.344	-152.523	-500.404
	349.000	3609.996	11843.819	-195.077	-643.236	-151.728	-497.796
	359.000	3713.881	12184.645	-249.919	-819.945	-150.913	-495.121
	369.000	3821.369	12537.296	-304.683	-999.616	-150.077	-492.380
	379.000	3932.664	12902.442	-360.475	-1182.659	-149.221	-489.571
	389.000	4047.991	13280.812	-417.411	-1369.457	-148.345	-486.597
	399.000	4167.595	13673.215	-475.622	-1560.440	-147.449	-483.757
	409.000	4291.744	14080.524	-535.248	-1756.062	-146.533	-480.751
	419.000	4420.732	14503.715	-596.439	-1956.820	-145.597	-477.680

TABLE 2. (Concluded)

	TIME SEC	DXP M/SEC	DXP FT/SEC	DYP M/SEC	DYP FT/SEC	DZP M/SEC	DZP FT/SEC
	429.000	4554.886	14943.852	-659.365	-2163.272	-144.641	-474.544
	439.000	4694.568	15402.127	-724.213	-2376.026	-143.666	-471.344
	449.000	4840.182	15879.862	-791.187	-2595.759	-142.671	-468.080
	459.000	4992.178	16378.536	-860.519	-2823.224	-141.657	-464.752
	469.000	5151.066	16899.822	-932.465	-3059.267	-140.623	-461.362
	479.000	5317.419	17445.601	-1007.319	-3304.852	-139.571	-457.909
	489.000	5491.892	18018.016	-1085.411	-3561.059	-138.499	-454.394
THRUST SHIFT	496.642	5631.160	18474.934	-1147.499	-3764.762	-137.668	-451.667
	499.000	5666.122	18589.641	-1167.453	-3830.228	-137.410	-450.819
	509.000	5818.243	19088.723	-1254.170	-4114.732	-136.301	-447.183
	519.000	5976.938	19609.375	-1344.517	-4411.146	-135.175	-443.487
	529.000	6142.751	20153.381	-1438.866	-4720.687	-134.031	-439.733
	539.000	6316.295	20722.754	-1537.631	-5044.722	-132.869	-435.921
	549.000	6498.287	21319.840	-1641.295	-5384.825	-131.689	-432.051
	559.000	6689.540	21947.311	-1750.435	-5742.898	-130.493	-428.125
ENG CUTØFF	565.465	6838.922	22437.408	-1835.772	-6022.873	-129.588	-425.158
SEPARATIØN	566.465	6838.922	22437.408	-1835.772	-6022.873	-129.588	-425.158
IGNITIØN	566.465	6838.922	22437.408	-1835.772	-6022.873	-129.588	-425.158
	576.000	6851.331	22478.121	-1925.662	-6317.789	-128.420	-421.325
	586.000	6863.770	22518.931	-2020.601	-6629.269	-127.178	-417.251
	596.000	6875.604	22557.757	-2116.245	-6943.061	-125.920	-413.124
	606.000	6886.817	22594.543	-2212.614	-7259.231	-124.646	-408.945
	616.000	6897.391	22629.237	-2309.726	-7577.842	-123.356	-404.712
	626.000	6907.309	22661.774	-2407.602	-7898.956	-122.050	-400.428
	636.000	6916.550	22692.093	-2506.259	-8222.633	-120.729	-396.092
	646.000	6925.096	22720.130	-2605.715	-8548.934	-119.392	-391.706
	656.000	6932.926	22745.820	-2705.989	-8877.917	-118.040	-387.269
	666.000	6940.020	22769.094	-2807.098	-9209.640	-116.672	-382.782
	676.000	6946.357	22789.884	-2909.059	-9544.158	-115.289	-378.246
	686.000	6951.915	22808.119	-3011.888	-9881.521	-113.892	-373.661
	696.000	6956.672	22823.729	-3115.600	-10221.785	-112.480	-369.029
	706.000	6960.608	22836.640	-3220.212	-10565.001	-111.053	-364.348
	716.000	6963.699	22846.785	-3325.738	-10911.214	-109.613	-359.621
	726.000	6965.925	22854.084	-3432.193	-11260.477	-108.158	-354.848
ENG CUTOFF	731.322	6966.323	22855.392	-3490.034	-11450.242	-197.378	-352.289

TABLE 3. OPTIMAL TRANSFER TRAJECTORY CHARACTERISTICS FOR THE TERMINAL CONIC CONSTRAINT (V, γ, r) — SYNCHRONOUS ALTITUDE CIRCULAR ORBIT IN THE PARKING ORBIT PLANE ($V = 3.072$ km/sec, $\gamma = 0$ deg, $r = 42\ 240$ km)

Thrust Event	Time (hr)	Weight (kg)	Weight (lb)	Altitude (km)	Velocity[a] (km/sec)	Lat[b] (deg)	Long.[c] (deg)
Parking orbit injection	0.028	128 897	284 169	185.3	7.792	15.762	-55.636
End parking orbit coast and ignition for perigee S-IVB burn (fixed coast time)	0.028	128 897	284 169	186.3	7.792	15.762	-55.636
S-IVB cutoff and begin transfer coast	0.101	71 440	157 499	247.3	10.198	-3.925	-39.880
End transfer coast and begin apogee S-IVB burn	5.388	71 440	157 499	35 863.5	1.595	-9.956	52.308
Apogee S-IVB burn cutoff (terminal constraint satisfied)	5.415	50 157	110 576	35 861.8	3.072	-9.780	52.150

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

TABLE 4. OPTIMAL TRANSFER TRAJECTORY FOR THE TERMINAL CONIC CONSTRAINT (V, γ, r)

a. PARKING ORBIT COAST

b. PERIGEE BURN

c. CONIC CONDITIONS AFTER PERIGEE BURN

d. TRANSFER COAST

e. APOGEE BURN

f. CONIC CONDITIONS AFTER APOGEE BURN

TABLE 4a.

BEGIN COAST WEIGHT= .12889675+06 KGS PARKING ORBIT COAST .28416870+06 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636

END COAST

BEGIN COAST WEIGHT= .12889675+06 KGS PARKING ORBIT COAST .28416870+06 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107

END COAST

TABLE 4b.

PERIGEE BURN

BEGIN BURN   WEIGHT= .12869675+06 KGS   .28416870+06 LBS

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
150.000	50.000	6563.729	8.162	124.535	.119	13.808	-52.866
160.000	60.000	6563.939	8.239	124.678	.178	13.401	-52.302
170.000	70.000	6564.247	8.318	124.817	.251	12.969	-51.733
180.000	80.000	6564.675	8.399	124.953	.338	12.572	-51.162
190.000	90.000	6565.244	8.481	125.085	.438	12.149	-50.586
200.000	100.000	6565.979	8.565	125.214	.552	11.721	-50.006
210.000	110.000	6566.905	8.650	125.339	.681	11.287	-49.422
220.000	120.000	6568.044	8.736	125.460	.823	10.848	-48.834
230.000	130.000	6569.423	8.824	125.577	.980	10.403	-48.242
240.000	140.000	6571.071	8.914	125.690	1.151	9.953	-47.645
250.000	150.000	6573.014	9.006	125.799	1.336	9.496	-47.044
260.000	160.000	6575.280	9.100	125.903	1.535	9.034	-46.438
270.000	170.000	6577.900	9.195	126.003	1.749	8.567	-45.827
280.000	180.000	6580.905	9.293	126.099	1.976	8.093	-45.211
290.000	190.000	6584.326	9.393	126.189	2.221	7.614	-44.591
300.000	200.000	6588.197	9.494	126.275	2.479	7.129	-43.965
310.000	210.000	6592.553	9.599	126.356	2.753	6.638	-43.334
320.000	220.000	6597.428	9.705	126.432	3.041	6.141	-42.697
330.000	230.000	6602.861	9.814	126.502	3.344	5.638	-42.055
340.000	240.000	6608.891	9.926	126.567	3.662	5.129	-41.407
350.000	250.000	6615.556	10.041	126.626	3.996	4.615	-40.753
360.000	260.000	6622.901	10.159	126.680	4.346	4.094	-40.094
363.227	263.227	6625.422	10.198	126.696	4.462	3.925	-39.880

END BURN

TABLE 4b. (Continued)

PERIGEE BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107
150.000	50.000	3292.009	5677.666	-96.564	7.068	-4.080	-.105
160.000	60.000	3362.784	5636.263	-97.614	7.087	-4.201	-.105
170.000	70.000	3433.755	5593.651	-98.664	7.107	-4.322	-.105
180.000	80.000	3504.921	5549.824	-99.708	7.126	-4.444	-.104
190.000	90.000	3576.281	5504.771	-100.748	7.146	-4.567	-.104
200.000	100.000	3647.834	5458.483	-101.783	7.165	-4.691	-.103
210.000	110.000	3719.580	5410.951	-102.814	7.184	-4.816	-.103
220.000	120.000	3791.518	5362.164	-103.840	7.203	-4.942	-.102
230.000	130.000	3863.650	5312.113	-104.862	7.223	-5.069	-.102
240.000	140.000	3935.975	5260.786	-105.879	7.242	-5.197	-.101
250.000	150.000	4008.496	5208.171	-106.891	7.262	-5.326	-.101
260.000	160.000	4081.213	5154.258	-107.899	7.282	-5.457	-.101
270.000	170.000	4154.128	5099.032	-108.902	7.302	-5.589	-.100
280.000	180.000	4227.246	5042.482	-109.899	7.322	-5.722	-.100
290.000	190.000	4300.569	4984.593	-110.892	7.343	-5.856	-.099
300.000	200.000	4374.101	4925.350	-111.880	7.364	-5.992	-.099
310.000	210.000	4447.847	4864.738	-112.863	7.385	-6.130	-.098
320.000	220.000	4521.812	4802.741	-113.842	7.406	-6.270	-.098
330.000	230.000	4596.004	4739.340	-114.815	7.431	-6.411	-.097
340.000	240.000	4670.430	4674.518	-115.783	7.455	-6.554	-.097
350.000	250.000	4745.098	4608.254	-116.747	7.479	-6.699	-.096
360.000	260.000	4820.018	4540.528	-117.705	7.505	-6.847	-.096
363.227	263.227	4844.247	4518.359	-118.013	7.513	-6.895	-.095

END BURN

TABLE 4b. (Continued)

BEGIN BURN WEIGHT= .12889675+06 KGS PERIGEE BURN .28416870+06 LBS

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA Q DEG
100.000	.000	128896.753	284168.700	61.739	-.744	-117.248	-70.445
100.000	.000	128896.753	284168.700	118.259	-.748	-117.248	-70.445
150.000	50.000	117982.863	260107.690	58.890	-.706	57.691	1.190
160.000	60.000	115800.086	255295.490	58.320	-.698	61.644	1.200
170.000	70.000	113617.308	250483.290	57.750	-.689	62.867	1.200
180.000	80.000	111434.530	245671.090	57.180	-.681	64.083	1.201
190.000	90.000	109251.752	240856.880	56.610	-.672	65.292	1.201
200.000	100.000	107068.974	236046.680	56.041	-.663	66.493	1.201
210.000	110.000	104886.197	231234.480	55.471	-.654	67.686	1.201
220.000	120.000	102703.418	226422.280	54.902	-.645	68.872	1.200
230.000	130.000	100520.641	221610.080	54.333	-.636	70.051	1.199
240.000	140.000	98337.663	216797.870	53.764	-.627	71.222	1.197
250.000	150.000	96155.065	211985.680	43.195	-.618	72.386	1.195
260.000	160.000	93972.307	207173.470	52.627	-.609	73.542	1.193
270.000	170.000	91789.529	202361.270	52.059	-.600	74.691	1.191
280.000	180.000	89606.752	197549.070	51.492	-.590	75.833	1.188
290.000	190.000	87423.573	192736.860	50.925	-.581	76.967	1.184
300.000	200.000	85241.196	187924.670	50.358	-.571	78.093	1.181
310.000	210.000	83058.418	183112.460	49.792	-.562	79.212	1.177
320.000	220.000	80875.640	178300.260	49.227	-.553	80.323	1.172
330.000	230.000	78692.862	173486.060	46.662	-.543	81.426	1.167
340.000	240.000	76510.084	168675.660	48.099	-.534	82.521	1.162
350.000	250.000	74327.306	163863.660	47.536	-.524	83.609	1.156
360.000	260.000	72144.528	159051.460	46.974	-.514	84.689	1.150
363.227	263.227	71440.244	157498.780	46.793	-.511	85.380	1.144

END BURN

TABLE 4b. (Concluded)

PERIGEE BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
100.000	.000	-.004	-.008	.000
100.000	.000	.002	-.012	.000
150.000	50.000	.002	-.012	.000
160.000	60.000	.002	-.012	.000
170.000	70.000	.002	-.012	.000
180.000	80.000	.002	-.012	.000
190.000	90.000	.002	-.012	.000
200.000	100.000	.002	-.012	.000
210.000	110.000	.002	-.013	.000
220.000	120.000	.002	-.013	.000
230.000	130.000	.002	-.013	.000
240.000	140.000	.002	-.013	.000
250.000	150.000	.002	-.013	.000
260.000	160.000	.002	-.013	.000
270.000	170.000	.002	-.013	.000
280.000	180.000	.002	-.013	.000
290.000	190.000	.002	-.014	.000
300.000	200.000	.002	-.014	.000
310.000	210.000	.002	-.014	.000
320.000	220.000	.002	-.014	.000
330.000	230.000	.002	-.014	.000
340.000	240.000	.002	-.014	.000
350.000	250.000	.003	-.015	.000
360.000	260.000	.003	-.015	.000
363.227	263.227	.003	-.015	.000

END BURN

TABLE 4c.

ORBITAL ELEMENTS

C1	=	67360.44	(KM)SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C3	=	-16.3288	(KM/SEC)SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.730535		ECCENTRICITY
SMA	=	24411.01	KM	SEMI MAJOR AXIS OF CONIC
RCA	=	6577.92	KM	RADIUS AT PERI-CENTER
RAPO	=	42244.09	KM	RADIUS AT APO-CENTER
INC	=	36.875574	DEG	INCLINATION
TANO	=	10.57453	DEG	TRUE ANOMALY
ARPG	=	162.67545	DEG	ARGUMENT OF PERI-CENTER
PERIOD	=	37956.67	SEC	PERIOD OF CONIC

TABLE 4d.

TRANSFER COAST

BEGIN COAST WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
363.227	.000	6625.422	10.198	126.696	4.462	3.925	-39.880
19397.546	19034.320	42241.630	1.595	54.309	-1.026	-9.956	52.308

END COAST

TRANSFER COAST

BEGIN COAST WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
363.227	.000	4844.247	4518.359	-118.013	7.513	-6.895	- .095
19397.546	19034.320	-25298.468	-33821.294	680.719	-1.260	.978	.017

END COAST

TABLE 4e.

APOGEE BURN

BEGIN BURN WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
19397.546	.000	42241.630	1.595	54.309	- 1.026	-9.956	52.308
19407.547	10.000	42241.358	1.724	54.300	- .892	-9.943	52.285
19417.000	19.454	42241.106	1.851	54.293	- .774	-9.930	52.264
19427.000	29.454	42240.874	1.989	54.285	- .659	-9.915	52.244
19437.000	39.454	42240.653	2.131	54.278	- .550	-9.898	52.225
19447.000	49.454	42240.462	2.279	54.270	- .448	-9.881	52.208
19457.000	59.454	42240.300	2.432	54.263	- .349	-9.862	52.193
19467.000	69.454	42240.170	2.591	54.255	- .254	-9.842	52.179
19477.000	79.454	42240.069	2.756	54.248	- .162	-9.821	52.167
19487.000	89.454	42240.008	2.928	54.240	- .072	-9.799	52.157
19495.054	97.507	42239.998	3.072	54.234	- .000	-9.780	52.150

END BURN

TABLE 4e. (Continued)

APOGEE BURN

BEGIN BURN WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
19397.546	.000	-25298.468	-33821.294	680.719	-1.260	.978	.017
19407.547	10.000	-25311.583	-33811.130	680.897	-1.364	1.055	.018
19417.000	19.454	-25324.956	-33800.805	681.077	-1.466	1.130	.020
19427.000	29.454	-25340.166	-33789.100	681.281	-1.577	1.212	.021
19437.000	39.454	-25356.505	-33776.564	681.498	-1.692	1.296	.022
19447.000	49.454	-25374.014	-33763.169	681.731	-1.811	1.384	.024
19457.000	59.454	-25392.734	-33748.883	681.978	-1.934	1.474	.025
19467.000	69.454	-25412.710	-33733.673	682.241	-2.062	1.568	.027
19477.000	79.454	-25433.992	-33717.503	682.520	-2.195	1.666	.029
19487.000	89.454	-25456.631	-33700.335	682.815	-2.334	1.768	.030
19495.054	97.507	-25475.890	-33685.755	683.066	-2.450	1.853	.032

END BURN

TABLE 4e. (Continued)

APOGEE BURN

BEGIN BURN WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA W DEG
19397.546	.000	71440.244	157498.780	-54.661	.588	85.544	1.142
19407.547	10.000	69257.465	152686.570	-54.633	.588	181.438	-64.475
19417.000	19.454	67193.951	148137.300	-54.607	.588	181.572	-67.955
19427.000	29.454	65011.173	143325.510	-54.579	.587	181.773	-71.524
19437.000	39.454	62828.396	138512.900	-54.551	.587	182.146	-75.602
19447.000	49.454	60645.618	133700.700	-54.523	.586	182.912	-79.986
19457.000	59.454	58462.840	128888.850	-54.495	.586	185.161	-84.653
19467.000	69.454	56280.062	124076.300	-54.467	.585	229.045	-89.396
19477.000	79.454	54097.284	119264.100	-54.439	.585	-5.242	-85.246
19487.000	89.454	51914.506	114451.900	-54.111	.585	-2.383	-79.997
19495.054	97.507	50156.613	110576.400	-54.389	.584	-1.496	-74.692

END BURN

TABLE 4e. (Concluded)

APOGEE BURN

BEGIN BURN WEIGHT = .71440244+05 KG .15749878+06 LB

TIME SEC	BURN TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
19397.546	.000	- .010	.008	000
19407.547	10.000	- .011	.008	.000
19417.000	19.454	- .011	.008	.000
19427.000	29.454	- .011	.008	.000
19437.000	39.454	- .012	.009	.000
19447.000	49.454	- .012	.009	.000
19457.000	59.454	- .013	.009	.000
19467.000	69.454	- .013	.010	.000
19477.000	79.454	- .014	.010	.000
19487.000	89.454	- .014	.010	.000
19495.054	97.507	- .015	.011	.000

END BURN

TABLE 4f.

CONIC CONDITIONS AFTER APOGEE BURN

ORBITAL ELEMENTS

C_1	=	129757.46 (KM) SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C_3	=	-9.4366 (KM/SEC) SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.000211	ECCENTRICITY
SMA	=	42239.99 KM	SEMI MAJOR AXIS OF CONIC
RCA	=	42231.07 KM	RADIUS AT PERICENTER
RAPO	=	42248.93 KM	RADIUS AT APOCENTER
INC	=	36.906335 DEG	INCLINATION
TANO	=	-93.013808 DEG	TRUE ANOMALY
ARPG	=	74.413136 DEG	ARGUMENT OF PERICENTER
PERIOD	=	86396.34 SEC	PERIOD OF CONIC

TABLE 5. OPTIMAL TRANSFER TRAJECTORY CHARACTERISTICS FOR THE TERMINAL CONIC CONSTRAINT (V, γ, r, i) — SYNCHRONOUS ALTITUDE CIRCULAR ORBIT INCLINED AT 50 DEG ($V = 3.072$ km/sec, $\gamma = 0$ deg, $r = 42\ 240$ km, $i = 50$ deg)

Thrust Event	Time (hr)	Weight		Altitude (km)	Velocity[a] (km/sec)	Latitude[b] (deg)	Longitude[c] (deg)
		(kg)	(lb)				
Parking orbit injection	0.028	128 897	284 169	185.3	7.792	15.762	-55.636
End parking orbit coast and ignition for perigee S-IVB burn	0.102	128 897	284 169	186.1	7.791	5.185	-41.600
S-IVB cutoff and begin transfer coast	0.176	71 324	157 243	248.2	10.197	-7.182	-26.442
End transfer coast and begin apogee S-IVB burn	5.415	71 324	157 243	35 862.1	1.595	0.692	66.360
Apogee S-IVB burn cutoff (terminal constraint satisfied)	5.443	49 243	108 562	35 861.8	3.071	0.915	66.156

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

TABLE 6. OPTIMAL TRANSFER TRAJECTORY FOR THE TERMINAL CONIC CONSTRAINT (V, γ, r, i)

a. PARKING ORBIT COAST

b. PERIGEE BURN

c. CONIC CONDITIONS AFTER PERIGEE BURN

d. TRANSFER COAST

e. APOGEE BURN

f. CONIC CONDITIONS AFTER APOGEE BURN

TABLE 6a.

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107
150.000	50.000	3284.067	5692.108	-96.447	6.747	-3.897	-.101
200.000	100.000	3615.427	5477.355	-101.312	6.504	-4.291	-.094
250.000	150.000	3934.051	5253.306	-105.821	6.238	-4.669	-.086
300.000	200.000	4238.816	5010.751	-109.956	5.949	-5.031	-.079
350.000	250.000	4528.651	4750.547	-113.704	5.641	-5.375	-.071
368.409	268.409	4631.399	4650.479	-114.984	5.522	-5.497	-.068

END COAST

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
150.000	50.000	6563.593	7.792	124.518	.025	13.853	-52.933
200.000	100.000	6563.764	7.792	125.156	.025	11.909	-50.279
250.000	150.000	6563.930	7.792	125.691	.024	9.938	-47.666
300.000	200.000	6564.090	7.792	126.125	.023	7.943	-45.086
350.000	250.000	6564.244	7.791	126.458	.022	5.930	-42.534
368.409	268.409	6564.300	7.791	126.556	.022	5.185	-41.600

END COAST

TABLE 6b.

PERIGEE BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
368.409	.000	6564.300	7.791	126.556	.022	5.185	-41.600
400.000	31.591	6564.386	8.020	126.832	.040	3.883	-39.979
410.000	41.591	6564.464	8.095	126.912	.074	3.461	-39.457
420.000	51.591	6564.600	8.172	126.987	.121	3.034	-38.931
430.000	61.591	6564.815	8.249	127.059	.182	2.602	-38.400
440.000	71.591	6565.131	8.328	127.127	.257	2.166	-37.864
450.000	81.591	6565.569	8.409	127.190	.345	1.725	-37.323
460.000	91.591	6566.152	8.491	127.249	.447	1.279	-36.778
470.000	101.591	6566.903	8.574	127.303	.564	.828	-36.227
480.000	111.591	6567.847	8.660	127.353	.694	.372	-35.671
490.000	121.591	6569.009	8.746	127.399	.838	-.089	-35.110
500.000	131.591	6570.416	8.835	127.439	.997	-.554	-34.543
510.000	141.591	6572.093	8.925	127.474	1.170	-1.025	-33.970
520.000	151.591	6574.069	9.016	127.505	1.357	-1.501	-33.391
530.000	161.591	6576.374	9.110	127.530	1.559	-1.982	-32.807
540.000	171.591	6579.036	9.206	127.549	1.775	-2.467	-32.216
550.000	181.591	6582.086	9.303	127.563	2.006	-2.958	-31.618
560.000	191.591	6585.559	9.403	127.571	2.251	-3.454	-31.014
570.000	201.591	6589.485	9.505	127.573	2.512	-3.955	-30.404
580.000	211.591	6593.901	9.609	127.570	2.787	-4.461	-29.786
590.000	221.591	6598.843	9.716	127.560	3.078	-4.972	-29.161
600.000	231.591	6604.348	9.826	127.543	3.384	-5.488	-28.529
610.000	241.591	6610.454	9.938	127.520	3.705	-6.009	-27.889
620.000	251.591	6617.203	10.053	127.490	4.041	-6.535	-27.241
630.000	261.591	6624.637	10.171	127.453	4.393	-7.066	-26.585
632.168	263.759	6626.344	10.197	127.444	4.472	-7.182	-26.442

END BURN

TABLE 6b. (Continued)

PERIGEE BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
368.409	.000	4631.399	4650.479	-114.984	5.522	-5.497	-.068
400.000	31.591	4804.977	4470.987	-116.780	5.467	-5.868	-.045
410.000	41.591	4859.553	4411.711	-117.198	5.448	-5.987	-.038
420.000	51.591	4913.944	4351.243	-117.542	5.430	-6.107	-.031
430.000	61.591	4968.146	4289.576	-117.809	5.411	-6.227	-.023
440.000	71.591	5022.154	4226.700	-117.999	5.391	-6.348	-.015
450.000	81.591	5075.965	4162.610	-118.110	5.371	-6.470	-.007
460.000	91.591	5129.576	4097.297	-118.142	5.351	-6.593	.001
470.000	101.591	5182.982	4030.753	-118.091	5.330	-6.716	.009
480.000	111.591	5236.181	3962.968	-117.958	5.309	-6.841	.018
490.000	121.591	5289.170	3893.932	-117.740	5.288	-6.966	.026
500.000	131.591	5341.945	3823.637	-117.436	5.267	-7.093	.035
510.000	141.591	5394.504	3752.071	-117.044	5.245	-7.220	.044
520.000	151.591	5446.845	3679.223	-116.563	5.223	-7.349	.053
530.000	161.591	5498.965	3605.082	-115.991	5.201	-7.479	.062
540.000	171.591	5550.864	3529.634	-115.326	5.179	-7.611	.071
550.000	181.591	5602.539	3452.867	-114.565	5.156	-7.743	.081
560.000	191.591	5653.991	3374.765	-113.708	5.134	-7.877	.091
570.000	201.591	5705.218	3295.314	-112.752	5.111	-8.013	.101
580.000	211.591	5756.220	3214.498	-111.696	5.089	-8.150	.111
590.000	221.591	5806.997	3132.299	-110.536	5.067	-8.290	.121
600.000	231.591	5857.552	3048.698	-109.270	5.044	-8.431	.132
610.000	241.591	5907.884	2963.675	-107.897	5.022	-8.574	.143
620.000	251.591	5957.997	2877.209	-106.414	5.000	-8.720	.154
630.000	261.591	6007.893	2789.276	-104.817	4.979	-8.867	.165
632.168	263.759	6018.683	2770.015	-104.456	4.974	-8.900	.168

END BURN

TABLE 6b. (Continued)

PERIGEE BURN

BEGIN BURN WEIGHT= .22889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA DEG
368.409	.000	128896.753	284168.700	136.477	4.318	90.088	1.665
400.000	31.591	122001.176	268966.550	41.740	4.366	93.089	1.694
410.000	41.591	119818.398	264154.340	41.176	4.380	95.812	1.821
420.000	51.591	117635.621	259342.150	40.612	4.394	97.043	1.861
430.000	61.591	115452.842	254529.950	40.048	4.408	98.267	1.900
440.000	71.591	113270.065	249717.740	39.484	4.421	99.483	1.938
450.000	81.591	111087.286	244905.550	38.920	4.433	100.691	1.977
460.000	91.591	108904.509	240093.340	38.356	4.445	101.892	2.014
470.000	101.591	106721.731	235281.140	37.792	4.457	103.086	2.052
480.000	111.591	104538.953	230468.940	37.228	4.468	104.272	2.089
490.000	121.591	102356.175	225656.740	36.665	4.479	105.451	2.125
500.000	131.591	100173.397	220844.540	36.102	4.490	106.622	2.162
510.000	141.591	97990.619	216032.330	35.538	4.500	107.786	2.197
520.000	151.591	95807.841	211220.130	34.976	4.509	108.942	2.233
530.000	161.591	93625.064	206407.930	34.413	4.518	110.091	2.268
540.000	171.591	91442.285	201595.730	33.851	4.527	111.233	2.303
550.000	181.591	89259.508	196783.530	33.289	4.535	112.367	2.337
560.000	191.591	87076.730	191971.320	32.728	4.543	113.493	2.372
570.000	201.591	84893.952	187159.130	32.167	4.550	114.612	2.405
580.000	211.591	82711.174	182346.930	31.607	4.557	115.723	2.439
590.000	221.591	80528.397	177534.720	31.047	4.563	116.827	2.472
600.000	231.591	78345.618	172722.520	30.488	4.569	117.922	2.505
610.000	241.591	76162.841	167910.320	29.930	4.575	119.010	2.538
620.000	251.591	73980.062	163098.120	29.373	4.580	120.090	2.570
630.000	261.591	71797.285	158285.920	28.817	4.585	121.162	2.602
632.168	263.759	71324.047	157242.600	28.696	4.586	121.791	2.634

END BURN

TABLE 6b. (Concluded)

PERIGEE BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
368.409	.000	-.002	-.012	.001
400.000	31.591	-.002	-.012	.001
410.000	41.591	-.002	-.012	.001
420.000	51.591	-.002	-.012	.001
430.000	61.591	-.002	-.012	.001
440.000	71.591	-.002	-.012	.001
450.000	81.591	-.002	-.012	.001
460.000	91.591	-.002	-.012	.001
470.000	101.591	-.002	-.012	.001
480.000	111.591	-.002	-.012	.001
490.000	121.591	-.002	-.013	.001
500.000	131.591	-.002	-.013	.001
510.000	141.591	-.002	-.013	.001
520.000	151.591	-.002	-.013	.001
530.000	161.591	-.002	-.013	.001
540.000	171.591	-.002	-.013	.001
550.000	181.591	-.002	-.013	.001
560.000	191.591	-.002	-.013	.001
570.000	201.591	-.002	-.014	.001
580.000	211.591	-.002	-.014	.001
590.000	221.591	-.002	-.014	.001
600.000	231.591	-.002	-.014	.001
610.000	241.591	-.002	-.014	.001
620.000	251.591	-.002	-.015	.001
630.000	261.591	-.0 2	-.015	.001
632.168	263.759	-.0 2	-.015	.001

END BURN

TABLE 6c.

CONIC CONDITIONS AFTER PERIGEE BURN

ORBITAL ELEMENTS

C1	=	67363.12	(KM)SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C3	=	-16.3299	(KM/SEC)SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.730488		ECCENTRICITY
SMA	=	24409.42	KM	SEMI MAJOR AXIS OF CONIC
RCA	=	6578.62	KM	RADIUS AT PERI-CENTER
RAPO	=	42240.22	KM	RADIUS AT APO-CENTER
INC	=	38.026780	DEG	INCLINATION
TANO	=	10.59874	DEG	TRUE ANOMALY
ARPG	=	-178.88951	DEG	ARGUMENT OF PERI-CENTER
PERIOD	=	37952.96	SEC	PERIOD OF CONIC

TABLE 6d.

TRANSFER COAST

BEGIN COAST WEIGHT = .71324047+05 KGS .15724260+06 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
632.168	.000	6626.344	10.197	127.444	4.472	-7.182	-26.442
19494.969	18862.801	42240.230	1.595	51.979	-.034	.692	66.360

END COAST

TRANSFER COAST

BEGIN COAST WEIGHT = .71324047+05 KGS .15724260+06 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
632.168	.000	6018.683	2770.015	-104.456	4.974	-8.900	.168
19494.969	18862.801	-34467.718	-24404.628	792.288	- .921	1.302	- .023

END COAST

TABLE 6e.

APOGEE BURN

BEGIN BURN WEIGHT = .71324047+05 KGS 15724260+06 LBS

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
19494.969	.000	42240.230	1.595	51.979	- .034	.692	66.360
19504.970	10.000	42240.220	1.714	50.191	- .054	.706	66.335
19514.000	19.031	42240.199	1.826	48.738	- .067	.720	66.314
19524.000	29.031	42240.170	1.956	47.284	- .076	.737	66.291
19534.000	39.031	42240.150	2.091	45.970	- .080	.756	66.270
19543.999	49.031	42240.119	2.231	44.778	- .078	.776	66.249
19554.000	59.031	42240.089	2.378	43.692	- .072	.799	66.229
19564.000	69.031	42240.059	2.531	42.698	- .062	.823	66.210
19574.000	79.031	42240.028	2.691	41.785	- .047	.849	66.192
19584.000	89.031	42240.018	2.859	40.943	- .028	.878	66.175
19594.000	99.031	42240.008	3.034	40.165	- .005	.908	66.159
19596.130	101.160	42240.008	3.072	40.006	- .000	.915	66.156

END BURN

TABLE 6e. (Contimued)

APOGEE BURN

BEGIN BURN WEIGHT = .71324047+05 KGS .15724260+06 LBS

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
19494.969	.000	-34467.718	-24404.628	792.288	- .921	1.302	- .023
19504.970	10.000	-34477.264	-24391.133	791.781	- .989	1.398	- .078
19514.000	19.031	-34486.476	-24378.108	790.842	-1.052	1.487	- .130
19524.000	29.031	-34497.350	-24362.727	789.252	-1.124	1.589	- .188
19534.000	39.031	-34508.956	-24346.308	787.066	-1.198	1.695	- .249
19543.999	49.031	-34521.318	-24328.815	784.261	-1.275	1.804	- .312
19554.000	59.031	-34534.465	-24310.208	780.818	-1.355	1.918	- .377
19564.000	69.031	-34548.425	-24290.447	776.710	-1.438	2.035	- .445
19574.000	79.031	-34563.230	-24269.485	771.914	-1.524	2.158	- .515
19584.000	89.031	-34578.914	-24247.276	766.400	-1.614	2.285	- .588
19594.000	99.031	-34595.516	-24223.766	760.138	-1.707	2.418	- .665
19596.130	101.160	-34599.174	-24218.585	758.705	-1.728	2.447	- .681

END BURN

TABLE 6e. (Continued)

APOGEE BURN

BEGIN BURN WEIGHT = .71324047+05 KGS .15724260+06 LBS

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA W DEG
19494.969	.000	71324.047	157242.600	-36.246	-25.142	121.900	2.641
19504.969	10.000	69141.269	152430.400	-36.216	-25.142	183.210	-65.475
19514.000	19.031	67170.107	148084.740	-36.189	-25.143	183.593	-69.056
19524.000	29.031	64987.330	143273.530	-36.159	-25.143	184.083	-72.358
19534.000	39.031	62804.552	138460.330	-36.129	-25.144	184.923	-76.065
19543.000	49.031	60621.774	133648.130	-36.098	-25.145	186.396	-79.795
19554.000	59.031	58438.996	128835.930	-36.068	-25.145	189.572	-83.509
19564.000	69.031	56256.218	124023.730	-36.038	-25.146	200.840	-87.122
19574.000	79.031	54073.440	119211.530	-36.008	-25.146	-45.231	-88.633
19584.000	89.031	51890.662	114399.330	-35.978	-25.147	-11.481	-85.374
19594.000	99.031	49707.884	109587.130	-35.948	-25.147	- 6.232	-81.953
19596.130	101.160	49242.979	108562.180	-35.941	-25.148	- 4.159	-78.626

END BURN

TABLE 6e. (Concluded)

APOGEE BURN

BEGIN BURN WEIGHT = .71324047+05 KGS .15724260+06 LBS

TIME SEC	BURN TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
19494.969	.000	- .007	.009	- .005
19504.970	10.000	- .007	.010	- .006
19514.000	19.031	- .007	.010	- .006
19524.000	24.031	- .007	.010	- .006
19534.000	39.031	- .008	.011	- .006
19544.000	49.031	- .008	.011	- .006
19554.000	59.031	- .008	.012	- .006
19564.000	69.031	- .008	.012	- .007
19574.000	79.031	- .009	.012	- .007
19584.000	89.031	- .009	.013	- .007
19594.000	99.031	- .010	.014	- .008
19596.130	101.160	- .010	.014	- .008

END BURN

TABLE 6f.

CONIC CONDITIONS AFTER APOGEE BURN

ORBITAL ELEMENTS

C_1	=	129757.43 (KM) SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C_3	=	-9.4366 (KM/SEC) SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.000211	ECCENTRICITY
SMA	=	42239.98 KM	SEMI MAJOR AXIS OF CONIC
RCA	=	42231.05 KM	RADIUS AT PERICENTER
RAPO	=	42248.91 KM	RADIUS AT APOCENTER
INC	=	49.999999 DEG	INCLINATION
TANO	=	-140.30661 DEG	TRUE ANOMALY
ARPG	=	140.39682 DEG	ARGUMENT OF PERICENTER
PERIOD	=	86396.28 SEC	PERIOD OF CONIC

TABLE 7. OPTIMAL TRANSFER TRAJECTORY CHARACTERISTICS FOR THE TERMINAL CONIC CONSTRAINT (C_3, C_1) — 6588 x 42 240 km ELLIPTICAL ORBIT IN THE PARKING ORBIT PLANE (C_3 = -16.33 km^2/sec^2, C_1 = 67.40 km^2/sec)

Thrust Event	Time (hr)	Weight (kg)	Weight (lb)	Altitude (km)	Velocity[a] (km/sec)	Latitude[b] (deg)	Longitude[c] (deg)
Parking orbit injection	0.028	128 897	284 169	185.3	7.792	15.762	-55.636
End parking orbit coast and ignition for S-IVB burn	0.028	128 897	284 169	135.3	7.792	15.762	-55.636
End S-IVB burn (terminal constraint satisfied)	0.101	71 362	157 326	257.0	10.189	3.925	-39.880

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

TABLE 8. OPTIMAL TRANSFER TRAJECTORY FOR THE TERMINAL CONIC CONSTRAINT (C_3, C_1)

a. PARKING ORBIT COAST

b. FIRST BURN

c. CONIC CONDITIONS AFTER FIRST BURN

TABLE 8a.

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107

END COAST

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636

END COAST

TABLE 8b.

FIRST BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
150.000	50.000	6564.541	8.160	124.534	.335	13.808	-52.866
160.000	60.000	6565.084	8.237	124.677	.426	13.401	-52.302
170.000	70.000	6565.771	8.316	124.816	.527	12.990	-51.734
180.000	80.000	6566.620	8.396	124.952	.638	12.573	-51.163
190.000	90.000	6567.646	8.478	125.084	.758	12.150	-50.588
200.000	100.000	6568.869	8.561	125.213	.888	11.723	-50.008
210.000	110.000	6570.307	8.645	125.338	1.029	11.289	-49.425
220.000	120.000	6571.980	8.731	125.458	1.179	10.851	-48.838
230.000	130.000	6573.907	8.819	125.575	1.339	10.406	-48.246
240.000	140.000	6576.109	8.908	125.688	1.509	9.957	-47.650
250.000	150.000	6578.606	9.000	125.797	1.689	9.501	-47.050
260.000	160.000	6581.422	9.093	125.901	1.879	9.040	-46.445
270.000	170.000	6584.577	9.188	126.001	2.079	8.573	-45.836
280.000	180.000	6588.096	9.285	126.096	2.290	8.101	-45.222
290.000	190.000	6592.004	9.384	126.187	2.510	7.623	-44.602
300.000	200.000	6596.324	9.485	126.272	2.740	7.139	-43.978
310.000	210.000	6601.082	9.589	126.353	2.981	6.649	-43.349
320.000	220.000	6606.305	9.695	126.428	3.232	6.153	-42.714
330.000	230.000	6612.021	9.803	126.499	3.493	5.652	-42.073
340.000	240.000	6618.259	9.915	126.563	3.764	5.145	-41.427
350.000	250.000	6625.048	10.029	126.623	4.045	4.631	-40.775
360.000	260.000	6632.419	10.146	126.676	4.337	4.112	-40.118
363.586	263.586	6635.210	10.189	126.694	4.444	3.925	-39.880

END BURN

TABLE 8b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107
100.000	.010	2941.137	5866.843	-91.242	6.966	-3.490	-.107
150.000	50.000	3292.373	5678.393	-96.576	7.082	-4.063	-.106
160.000	60.000	3363.301	5637.287	-97.634	7.104	-4.169	-.106
170.000	70.000	3434.449	5595.013	-98.689	7.126	-4.286	-.105
180.000	80.000	3505.414	5551.559	-99.739	7.147	-4.405	-.105
190.000	90.000	3577.392	5506.912	-100.787	7.168	-4.525	-.105
200.000	100.000	3649.181	5461.058	-101.830	7.189	-4.646	-.104
210.000	110.000	3721.177	5413.982	-102.870	7.210	-4.769	-.104
220.000	120.000	3793.378	5365.669	-103.905	7.230	-4.894	-.103
230.000	130.000	3865.782	5316.105	-104.936	7.250	-5.020	-.103
240.000	140.000	3938.385	5265.273	-105.963	7.270	-5.147	-.102
250.000	150.000	4011.185	5213.157	-106.985	7.290	-5.276	-.102
260.000	160.000	4084.181	5159.740	-108.003	7.309	-5.407	-.102
270.000	170.000	4157.369	5105.003	-109.016	7.328	-5.540	-.101
280.000	180.000	4230.749	5048.928	-110.023	7.348	-5.675	-.101
290.000	190.000	4304.319	4991.495	-111.026	7.366	-5.812	-.100
300.000	200.000	4378.078	4932.684	-112.023	7.385	-5.951	-.099
310.000	210.000	4452.024	4872.472	-113.015	7.404	-6.092	-.099
320.000	220.000	4526.158	4810.838	-114.001	7.423	-6.235	-.098
330.000	230.000	4600.479	4747.758	-114.982	7.441	-6.381	-.098
340.000	240.000	4674.987	4683.205	-115.956	7.460	-6.530	-.097
350.000	250.000	4749.682	4617.154	-116.925	7.479	-6.681	-.097
360.000	260.000	4824.568	4549.575	-117.887	7.498	-6.835	-.096
363.586	263.586	4851.465	4524.967	-118.230	7.505	-6.891	-.096

END BURN

TABLE 8b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA W DEG
100.000	.000	128896.753	284168.700	67.483	-.832	64.884	1.145
100.000	.000	128896.753	284168.700	112.470	-.836	64.884	1.145
150.000	50.000	117982.863	260107.690	62.693	-.770	53.888	1.190
160.000	60.000	115800.086	255295.490	61.721	-.756	58.015	1.196
170.000	70.000	113617.308	250483.290	60.748	-.742	59.609	1.197
180.000	80.000	111434.530	245671.090	59.773	-.728	61.200	1.197
190.000	90.000	109251.752	240858.880	58.798	-.713	62.789	1.197
200.000	100.000	107068.974	236046.680	57.822	-.698	64.375	1.197
210.000	110.000	104886.197	231234.480	56.845	-.683	65.958	1.196
220.000	120.000	102703.418	226422.280	55.868	-.668	67.539	1.195
230.000	130.000	100520.641	221610.080	54.891	-.653	69.117	1.194
240.000	140.000	98337.863	216797.870	53.914	-.637	70.692	1.193
250.000	150.000	96155.085	211985.680	52.937	-.622	72.263	1.191
260.000	160.000	93972.307	207173.470	51.961	-.606	73.832	1.189
270.000	170.000	91789.529	202361.270	50.985	-.590	75.397	1.187
280.000	180.000	89606.752	197549.070	50.010	-.573	76.959	1.184
290.000	190.000	87423.973	192736.860	49.037	-.557	78.517	1.181
300.000	200.000	85241.196	187924.670	48.064	-.541	80.071	1.178
310.000	210.000	83058.418	183112.460	47.093	-.524	81.622	1.174
320.000	220.000	80875.640	178300.260	46.124	-.507	83.169	1.170
330.000	230.000	78692.862	173488.060	45.157	-.491	84.711	1.166
340.000	240.000	76510.084	168675.860	44.193	-.474	86.249	1.162
350.000	250.000	74327.306	163863.660	43.231	-.457	87.783	1.157
360.000	260.000	72144.528	159051.460	42.271	-.440	89.312	1.152
363.586	263.586	71361.868	157325.980	41.927	-.433	90.224	1.146

END BURN

TABLE 8b. (Concluded)

FIRST BURN

BEGIN BURN WEIGHT= .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
100.000	.000	-.004	-.008	.000
100.000	.000	.002	-.011	.000
150.000	50.000	.002	-.012	.000
160.000	60.000	.002	-.012	.000
170.000	70.000	.002	-.012	.000
180.000	80.000	.002	-.012	.000
190.000	90.000	.002	-.012	.000
200.000	100.000	.002	-.012	.000
210.000	110.000	.002	-.012	.000
220.000	120.000	.002	-.013	.000
230.000	130.000	.002	-.013	.000
240.000	140.000	.002	-.013	.000
250.000	150.000	.002	-.013	.000
260.000	160.000	.002	-.013	.000
270.000	170.000	.002	-.013	.000
280.000	180.000	.002	-.014	.000
290.000	190.000	.002	-.014	.000
300.000	200.000	.002	-.014	.000
310.000	210.000	.002	-.014	.000
320.000	220.000	.002	-.014	.000
330.000	230.000	.002	-.015	.000
340.000	240.000	.002	-.015	.000
350.000	250.000	.002	-.015	.000
360.000	260.000	.002	-.016	.000
363.586	263.586	.002	-.016	.000

END BURN

TABLE 8c.

CONIC CONDITIONS AFTER FIRST BURN

ORBITAL ELEMENTS

C1	=	67404.60 (KM)SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C3	=	-16.3269 (KM/SEC)SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.730154	ECCENTRICITY
SMA	=	24413.95 KM	SEMI MAJOR AXIS OF CONIC
RCA	=	6588.00 KM	RADIUS AT PERI-CENTER
RAPO	=	42239.91 KM	RADIUS AT APO-CENTER
INC	=	36.873734 DEG	INCLINATION
TANO	=	10.53607 DEG	TRUE ANOMALY
ARPG	=	162.91395 DEG	ARGUMENT OF PERI-CENTER
PERIOD	=	37963.53 SEC	PERIOD OF CONIC

TABLE 9. OPTIMAL TRANSFER TRAJECTORY CHARACTERISTICS FOR THE TERMINAL CONIC CONSTRAINT (C_3, C_1, i) — 6588 km × 42 240 km ELLIPTICAL ORBIT INCLINED AT 50 DEG (C_3 = -16.33 km^2/sec^2, C_1 = 67.40 km^2/sec, i = 50 deg)

Thrust Event	Time (hr)	Weight (kg)	Weight (lb)	Altitude (km)	Velocity[a] (km/sec)	Latitude[b] (deg)	Longitude[c] (deg)
Parking orbit injection	0.028	128 897	284 169	185.3	7.792	15.762	-55.636
End parking orbit coast and ignition for S-IVB burn	0.088	128 897	284 169	186.0	7.792	7.263	-44.220
End S-IVB burn (terminal constraint satisfied)	0.176	59 771	131 774	274.3	10.173	-9.312	-27.857

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

TABLE 10. OPTIMAL TRANSFER TRAJECTORY FOR THE TERMINAL CONIC CONSTRAINT (C_3, C_1, i)

a. PARKING ORBIT COAST

b. FIRST BURN

c. CONIC CONDITIONS AFTER FIRST BURN

TABLE 10a.

PARKING ORBIT COAST

BEGIN COAST WEIGHT = .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
100.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
150.000	50.000	6563.593	7.792	124.518	.025	13.853	-52.933
200.000	100.000	6563.764	7.792	125.156	.025	11.909	-50.279
250.000	150.000	6563.930	7.792	125.691	.024	9.938	-47.666
300.000	200.000	6564.090	7.792	126.125	.023	7.943	-45.086
316.929	216.929	6564.143	7.792	126.249	.023	7.263	-44.220

END COAST

TABLE 10a. (Concluded)

PARKING ORBIT COAST

BEGIN COAST WEIGHT = .12889675+06 KGS .28416870+06 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
100.000	.000	2941.137	5866.843	- 91.242	6.966	-3.490	- .107
150.000	50.000	3284.067	5682.108	- 96.447	6.747	-3.897	- .101
200.000	100.000	3615.427	5477.355	-101.312	6.504	-4.291	- .094
250.000	150.000	3934.051	5253.306	-105.821	6.238	-4.669	- .086
300.000	200.000	4238.816	5010.751	-109.956	5.949	-5.031	- .079
316.929	216.929	4338.672	4924.583	-111.269	5.847	-5.149	- .076

END COAST

TABLE 10b.

FIRST BURN

BEGIN BURN WEIGHT = .12889675+06 KGS .284186870+06 LBS

TIME SEC	BURN TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
316.929	.000	6564.143	7.792	126.249	.023	7.263	-44.219
350.000	33.071	6564.364	7.960	127.711	.090	5.896	-42.530
400.000	83.071	6565.873	8.239	129.884	.373	3.682	-39.976
450.000	133.071	6570.367	8.553	132.007	.892	1.283	-37.418
500.000	183.071	6579.959	8.909	134.077	1.667	-1.313	-34.849
550.000	233.071	6597.240	9.319	136.093	2.723	-4.116	-32.260
600.000	283.071	6625.423	9.799	138.059	4.086	-7.143	-29.642
633.614	316.685	6652.496	10.174	139.355	5.189	-9.312	-27.857

END BURN

TABLE 10b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT = .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
316.929	.000	4338.672	4924.583	-111.269	5.847	-5.149	- .076
350.000	33.071	4530.758	4748.771	-110.884	5.768	-5.484	.101
400.000	83.071	4815.933	4461.810	- 98.680	5.636	-5.996	.391
450.000	133.071	5094.166	4148.990	- 71.250	5.491	-6.519	.711
500.000	183.071	5364.827	3809.694	- 26.996	5.334	-7.056	1.065
550.000	233.071	5627.422	3443.023	36.006	5.169	-7.615	1.463
600.000	283.071	5881.646	3047.630	120.165	5.000	-8.207	1.914
633.614	316.685	6047.819	2764.676	190.172	4.888	-8.633	2.257

END BURN

TABLE 10b. (Concluded)

FIRST BURN

BEGIN BURN WEIGHT = .12889675+06 KGS .28416870+06 LBS

TIME SEC	BURN TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG
316.929	.000	128896.750	284168.690	129.341	45.563
350.000	33.071	121678.080	268254.240	131.728	45.860
400.000	83.071	110764.190	244193.240	135.373	46.215
450.000	133.071	99850.301	220132.230	139.026	46.452
500.000	183.071	88936.411	196071.220	142.679	46.571
550.000	233.071	78022.521	172010.210	146.324	46.574
600.000	283.071	67108.633	147949.210	149.947	46.461
633.614	316.685	59771.490	131773.580	152.336	46.323

END BURN

TABLE 10c.

CONIC CONDITIONS AFTER FIRST BURN

ORBITAL ELEMENTS

C_1	=	67404.50 (KM) SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C_3	=	-16.3272 (KM/SEC) SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	.730144	ECCENTRICITY
SMA	=	24416.21 KM	SEMIMAJOR AXIS OF CONIC
RCA	=	6588.85 KM	RADIUS AT PERICENTER
RAPO	=	42243.56 KM	RADIUS AT APOCENTER
INC	=	49.999970 DEG	INCLINATION
TANO	=	12.22194 DEG	TRUE ANOMALY
PERIOD	=	37968.80 SEC	PERIOD OF CONIC

TABLE 11. OPTIMAL TRANSFER TRAJECTORY CHARACTERISTICS FOR THE TERMINAL CONIC CONSTRAINT (C_3, α, δ) — TYPICAL 1973 MARS MISSION HYPERBOLIC ORBIT INJECTION ($C_3 = 18.0$ km^2/sec^2, $\alpha = 15.55$ deg, $\delta = 31.59$ deg)

Thrust Event	Time (hr)	Weight (kg)	Weight (lb)	Altitude (km)	Velocity[a] (km/sec)	Latitude[b] (deg)	Longitude[c] (deg)
Parking orbit injection	0.000	18 030	39 749	185.3	7.792	15.762	-55.636
End parking orbit coast and ignition for second CSM burn	0.441	18 030	39 749	186.7	7.791	-36.347	39.086
End second CSM burn (terminal constraint satisfied)	0.567	4 817	10 620	425.6	11.626	-31.990	81.564

[a] Inertial velocity.

[b] Geocentric latitude.

[c] West longitude from Greenwich.

TABLE 12. OPTIMAL TRANSFER TRAJECTORY FOR A TYPICAL 1973 MARS MISSION HYPERBOLIC ORBIT INJECTION

a. PARKING ORBIT COAST

b. FIRST BURN

c. CONIC CONDITIONS AFTER FIRST BURN

TABLE 12a.

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	COAST TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
.000	.000	6563.418	7.792	123.774	.026	15.762	-55.636
50.000	50.000	6563.593	7.792	124.518	.025	13.853	-52.516
100.000	100.000	6563.764	7.792	125.156	.025	11.909	-49.861
150.000	150.000	6563.930	7.792	125.691	.024	9.938	-47.248
200.000	200.000	6564.090	7.792	126.125	.023	7.943	-44.669
250.000	250.000	6564.244	7.791	126.458	.022	5.930	-42.117
300.000	300.000	6564.392	7.791	126.693	.021	3.903	-39.585
350.000	350.000	6564.534	7.791	126.831	.020	1.868	-37.067
400.000	400.000	6564.667	7.791	126.871	.019	-.171	-34.555
450.000	450.000	6564.792	7.791	126.814	.018	-2.210	-32.042
500.000	500.000	6564.909	7.791	126.661	.017	-4.244	-29.522
550.000	550.000	6565.017	7.791	126.409	.015	-6.269	-26.988
600.000	600.000	6565.116	7.790	126.059	.014	-8.278	-24.433
650.000	650.000	6565.204	7.790	125.609	.012	-10.269	-21.850
700.000	700.000	6565.284	7.790	125.057	.011	-12.235	-19.231
750.000	750.000	6565.353	7.790	124.402	.009	-14.172	-16.571
800.000	800.000	6565.412	7.790	123.640	.008	-16.075	-13.861
850.000	850.000	6565.460	7.790	122.770	.006	-17.936	-11.096
900.000	900.000	6565.496	7.790	121.789	.005	-19.752	-8.269
950.000	950.000	6565.523	7.790	120.694	.003	-21.516	-5.372
1000.000	1000.000	6565.538	7.790	119.484	.001	-23.220	-2.401
1050.000	1050.000	6565.542	7.790	118.155	-.000	-24.859	.651
1100.000	1100.000	6565.535	7.790	116.706	-.002	-26.425	3.788
1150.000	1150.000	6565.517	7.790	115.137	-.003	-27.912	7.016
1200.000	1200.000	6565.488	7.790	113.446	-.005	-29.310	10.336
1250.000	1250.000	6565.448	7.790	111.636	-.007	-30.614	13.751
1300.000	1300.000	6565.397	7.790	109.708	-.008	-31.814	17.261
1350.000	1350.000	6565.335	7.790	107.667	-.010	-32.904	20.864
1400.000	1400.000	6565.263	7.790	105.519	-.011	-33.875	24.557
1450.000	1450.000	6565.182	7.790	103.272	-.013	-34.721	28.334
1500.000	1500.000	6565.089	7.790	100.937	-.014	-35.434	32.187
1550.000	1550.000	6564.988	7.791	98.527	-.016	-36.009	36.105
1587.585	1587.585	6564.906	7.791	96.674	-.017	-36.347	39.086

END COAST

TABLE 12a. (Continued)

PARKING ORBIT COAST

BEGIN COAST   WEIGHT= .18029707+05 KGS   .39748699+05 LBS

TIME SEC	COAST TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
.000	.000	2941.137	5866.843	-91.242	6.966	-3.490	-.107
50.000	50.000	3284.067	5682.108	-96.447	6.747	-3.897	-.101
100.000	100.000	3615.427	5477.355	-101.312	6.504	-4.291	-.094
150.000	150.000	3934.051	5253.306	-105.821	6.238	-4.669	-.086
200.000	200.000	4238.816	5010.751	-109.956	5.949	-5.031	-.079
250.000	250.000	4528.651	4750.547	-113.704	5.641	-5.375	-.071
300.000	300.000	4802.536	4473.611	-117.052	5.312	-5.700	-.063
350.000	350.000	5059.507	4180.920	-119.988	4.964	-6.005	-.055
400.000	400.000	5298.660	3873.505	-122.501	4.599	-6.288	-.046
450.000	450.000	5519.155	3552.450	-124.582	4.218	-6.550	-.037
500.000	500.000	5720.216	3218.886	-126.225	3.822	-6.789	-.028
550.000	550.000	5901.136	2873.989	-127.424	3.413	-7.003	-.019
600.000	600.000	6061.278	2518.972	-128.173	2.991	-7.193	-.010
650.000	650.000	6200.081	2155.087	-128.472	2.559	-7.358	-.001
700.000	700.000	6317.057	1783.615	-128.318	2.118	-7.497	.008
750.000	750.000	6411.794	1405.864	-127.713	1.670	-7.609	.017
800.000	800.000	6483.959	1023.164	-126.658	1.216	-7.695	.026
850.000	850.000	6533.299	636.862	-125.157	.757	-7.753	.034
900.000	900.000	6559.642	248.318	-123.216	.296	-7.784	.043
950.000	950.000	6562.894	-141.099	-120.840	-.166	-7.788	.052
1000.000	1000.000	6543.045	-530.021	-118.040	-.628	-7.764	.060
1050.000	1050.000	6500.164	-917.076	-114.824	-1.087	-7.713	.068
1100.000	1100.000	6434.402	-1300.903	-111.204	-1.543	-7.635	.076
1150.000	1150.000	6345.992	-1680.152	-107.192	-1.993	-7.530	.084
1200.000	1200.000	6235.243	-2053.486	-102.803	-2.436	-7.399	.091
1250.000	1250.000	6102.546	-2419.591	-98.052	-2.870	-7.241	.099
1300.000	1300.000	5948.367	-2777.179	-92.956	-3.295	-7.058	.105
1350.000	1350.000	5773.248	-3124.991	-87.533	-3.708	-6.850	.112
1400.000	1400.000	5577.806	-3461.802	-81.802	-4.108	-6.618	.118
1450.000	1450.000	5362.727	-3786.426	-75.782	-4.493	-6.363	.123
1500.000	1500.000	5128.769	-4097.720	-69.496	-4.863	-6.085	.128
1550.000	1550.000	4876.753	-4394.586	-62.965	-5.215	-5.786	.133
1587.585	1587.585	4675.955	-4607.612	-57.909	-5.468	-5.548	.136

END COAST

TABLE 12a. (Concluded)

PARKING ORBIT COAST

BEGIN COAST WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	COAST TIME SEC	X KM	Y KM	Z KM	DX KM/SEC	DY KM/SEC	DZ KM/SEC
.000	.000	-3094.446	5506.731	1782.911	-6.225	-2.144	-4.168
50.000	50.000	-3400.062	5389.875	1571.491	-5.996	-2.529	-4.286
100.000	100.000	-3693.699	5254.029	1354.533	-5.746	-2.904	-4.389
150.000	150.000	-3974.323	5099.675	1132.804	-5.476	-3.269	-4.477
200.000	200.000	-4240.948	4927.356	907.084	-5.186	-3.622	-4.549
250.000	250.000	-4492.635	4737.681	678.170	-4.878	-3.963	-4.605
300.000	300.000	-4728.498	4531.321	446.866	-4.553	-4.289	-4.645
350.000	350.000	-4947.708	4309.001	213.989	-4.212	-4.601	-4.668
400.000	400.000	-5149.495	4071.507	-19.641	-3.857	-4.896	-4.675
450.000	450.000	-5333.148	3819.675	-253.203	-3.487	-5.174	-4.665
500.000	500.000	-5498.022	3554.394	-485.873	-3.106	-5.434	-4.639
550.000	550.000	-5643.537	3276.597	-716.832	-2.713	-5.675	-4.597
600.000	600.000	-5769.182	2987.264	-945.267	-2.311	-5.895	-4.538
650.000	650.000	-5874.516	2687.414	-1170.375	-1.901	-6.095	-4.464
700.000	700.000	-5959.169	2378.103	-1391.362	-1.484	-6.274	-4.373
750.000	750.000	-6022.843	2060.420	-1607.450	-1.062	-6.430	-4.268
800.000	800.000	-6065.314	1735.484	-1817.881	-.636	-6.564	-4.147
850.000	850.000	-6086.435	1404.438	-2021.911	-.208	-6.674	-4.012
900.000	900.000	-6086.130	1068.448	-2218.825	.220	-6.761	-3.862
950.000	950.000	-6064.402	728.698	-2407.928	.648	-6.825	-3.699
1000.000	1000.000	-6021.327	386.383	-2588.555	1.074	-6.864	-3.523
1050.000	1050.000	-5957.057	42.707	-2760.070	1.496	-6.879	-3.335
1100.000	1100.000	-5871.818	-301.119	-2921.870	1.913	-6.870	-3.135
1150.000	1150.000	-5765.911	-643.885	-3073.385	2.322	-6.837	-2.924
1200.000	1200.000	-5639.707	-984.384	-3214.082	2.724	-6.779	-2.702
1250.000	1250.000	-5493.651	-1321.419	-3343.465	3.116	-6.698	-2.471
1300.000	1300.000	-5328.256	-1653.801	-3461.078	3.498	-6.593	-2.232
1350.000	1350.000	-5144.105	-1980.362	-3566.507	3.866	-6.465	-1.984
1400.000	1400.000	-4941.845	-2299.952	-3659.382	4.222	-6.315	-1.730
1450.000	1450.000	-4722.188	-2611.445	-3739.373	4.562	-6.142	-1.469
1500.000	1500.000	-4485.905	-2913.743	-3806.200	4.886	-5.947	-1.203
1550.000	1550.000	-4233.829	-3205.784	-3859.626	5.194	-5.731	-.933
1587.585	1587.585	-4034.477	-3417.937	-3890.849	5.413	-5.556	-.728

END COAST

TABLE 12b.

FIRST BURN

BEGIN BURN WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
1587.585	6564.906	7.791	96.674	-.017	-36.347	39.086
1600.000	6564.841	7.852	96.048	-.058	-36.441	40.081
1610.000	6564.744	7.903	95.537	-.081	-36.510	40.890
1620.000	6564.621	7.954	95.021	-.093	-36.574	41.705
1630.000	6564.488	8.007	94.501	-.096	-36.632	42.528
1640.000	6564.359	8.060	93.975	-.088	-36.684	43.358
1650.000	6564.247	8.114	93.444	-.069	-36.729	44.195
1660.000	6564.168	8.170	92.909	-.041	-36.769	45.039
1670.000	6564.136	8.226	92.369	-.001	-36.802	45.890
1680.000	6564.169	8.283	91.824	.049	-36.828	46.747
1690.000	6564.282	8.341	91.274	.109	-36.848	47.612
1700.000	6564.492	8.401	90.720	.181	-36.860	48.483
1710.000	6564.817	8.461	90.162	.263	-36.866	49.361
1720.000	6565.275	8.523	89.600	.356	-36.864	50.245
1730.000	6565.883	8.585	89.033	.460	-36.855	51.136
1740.000	6566.661	8.649	88.463	.576	-36.839	52.034
1750.000	6567.629	8.714	87.889	.703	-36.815	52.938
1760.000	6568.806	8.780	87.311	.841	-36.783	53.848
1770.000	6570.214	8.848	86.730	.991	-36.743	54.764
1780.000	6571.874	8.917	86.146	1.153	-36.695	55.687
1790.000	6573.810	8.987	85.559	1.326	-36.639	56.615
1800.000	6576.043	9.059	84.969	1.512	-36.574	57.549
1810.000	6578.596	9.132	84.376	1.709	-36.500	58.489
1820.000	6581.497	9.207	83.781	1.919	-36.418	59.434
1830.000	6584.770	9.283	83.183	2.141	-36.326	60.384
1840.000	6588.442	9.362	82.584	2.375	-36.226	61.340
1850.000	6592.539	9.442	81.983	2.622	-36.116	62.301
1860.000	6597.092	9.524	81.381	2.882	-35.997	63.266
1870.000	6602.128	9.609	80.777	3.156	-35.869	64.236
1880.000	6607.681	9.695	80.172	3.442	-35.730	65.211
1890.000	6613.781	9.784	79.566	3.742	-35.582	66.190
1900.000	6620.462	9.876	78.960	4.055	-35.424	67.173

TABLE 12b. (Continued)

FIRST BURN

TIME SEC	R KM	INER VELOCITY KM/SEC	AZIMUTH S DEG	PTH DEG	LATITUDE DEG	LONGITUDE DEG
1910.000	6627.759	9.970	78.354	4.382	-35.256	68.160
1920.000	6635.709	10.067	77.748	4.723	-35.077	69.150
1930.000	6644.350	10.167	77.142	5.079	-34.888	70.145
1940.000	6653.723	10.271	76.537	5.448	-34.688	71.143
1950.000	6663.869	10.378	75.932	5.833	-34.478	72.144
1960.000	6674.834	10.490	75.328	6.233	-34.257	73.148
1970.000	6686.663	10.606	74.726	6.648	-34.024	74.156
1980.000	6699.406	10.726	74.125	7.079	-33.781	75.166
1990.000	6713.116	10.852	73.526	7.525	-33.526	76.179
2000.000	6727.849	10.983	72.929	7.988	-33.260	77.195
2010.000	6743.663	11.121	72.334	8.468	-32.983	78.213
2020.000	6760.623	11.266	71.741	8.965	-32.693	79.234
2030.000	6778.798	11.419	71.151	9.479	-32.391	80.258
2040.000	6798.261	11.581	70.563	10.012	-32.078	81.285
2042.715	6803.779	11.626	70.404	10.160	-31.990	81.564

END BURN

TABLE 12b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
1587.585	4675.955	-4607.612	-57.909	-5.468	-5.548	.136
1600.000	4607.270	-4676.221	-56.211	-5.597	-5.505	.137
1610.000	4550.774	-4731.100	-54.831	-5.702	-5.470	.138
1620.000	4493.235	-4785.629	-53.441	-5.806	-5.435	.140
1630.000	4434.651	-4839.802	-52.041	-5.911	-5.399	.140
1640.000	4375.020	-4893.613	-50.631	-6.015	-5.363	.141
1650.000	4314.341	-4947.058	-49.212	-6.120	-5.326	.142
1660.000	4252.612	-5000.130	-47.784	-6.225	-5.288	.143
1670.000	4189.832	-5052.826	-46.347	-6.331	-5.251	.144
1680.000	4125.998	-5105.139	-44.902	-6.436	-5.212	.145
1690.000	4061.107	-5157.065	-43.449	-6.542	-5.173	.146
1700.000	3995.158	-5208.600	-41.988	-6.648	-5.134	.146
1710.000	3928.146	-5259.739	-40.520	-6.754	-5.094	.147
1720.000	3860.070	-5310.478	-39.045	-6.861	-5.054	.148
1730.000	3790.925	-5360.811	-37.564	-6.968	-5.013	.148
1740.000	3720.708	-5410.737	-36.076	-7.075	-4.972	.149
1750.000	3649.414	-5460.250	-34.583	-7.183	-4.931	.150
1760.000	3577.040	-5509.347	-33.084	-7.292	-4.889	.150
1770.000	3503.579	-5558.026	-31.580	-7.401	-4.847	.151
1780.000	3429.027	-5606.283	-30.071	-7.510	-4.805	.151
1790.000	3353.377	-5654.116	-28.559	-7.620	-4.762	.151
1800.000	3276.623	-5701.521	-27.042	-7.731	-4.719	.152
1810.000	3198.758	-5748.499	-25.522	-7.842	-4.676	.152
1820.000	3119.773	-5795.045	-24.000	-7.955	-4.633	.152
1830.000	3039.661	-5841.161	-22.475	-8.068	-4.590	.153
1840.000	2958.411	-5886.844	-20.948	-8.182	-4.547	.153
1850.000	2876.014	-5932.094	-19.420	-8.297	-4.503	.153
1860.000	2792.458	-5976.912	-17.891	-8.414	-4.460	.153
1870.000	2707.730	-6021.298	-16.361	-8.532	-4.417	.153
1880.000	2621.818	-6065.253	-14.832	-8.651	-4.374	.153
1890.000	2534.704	-6108.780	-13.303	-8.772	-4.331	.153
1900.000	2446.375	-6151.880	-11.776	-8.894	-4.289	.153

TABLE 12b. (Continued)

FIRST BURN

TIME SEC	XP KM	YP KM	ZP KM	DXP KM/SEC	DYP KM/SEC	DZP KM/SEC
1910.000	2356.810	-6194.557	-10.251	-9.019	-4.247	.152
1920.000	2265.990	-6236.814	-8.728	-9.145	-4.205	.152
1930.000	2173.893	-6278.657	-7.209	-9.274	-4.164	.152
1940.000	2080.495	-6320.091	-5.693	-9.406	-4.123	.151
1950.000	1985.767	-6361.122	-4.182	-9.540	-4.083	.151
1960.000	1889.682	-6401.758	-2.676	-9.678	-4.044	.150
1970.000	1792.204	-6442.008	-1.177	-9.819	-4.006	.150
1980.000	1693.298	-6481.882	.315	-9.964	-3.969	.149
1990.000	1592.922	-6521.390	1.800	-10.113	-3.933	.148
2000.000	1491.027	-6560.547	3.275	-10.267	-3.899	.147
2010.000	1387.566	-6599.366	4.741	-10.427	-3.866	.146
2020.000	1282.480	-6637.864	6.195	-10.592	-3.834	.145
2030.000	1175.697	-6676.061	7.637	-10.765	-3.805	.144
2040.000	1067.152	-6713.975	9.065	-10.946	-3.778	.142
2042.715	1037.361	-6724.225	9.451	-10.997	-3.771	.142

END BURN

TABLE 12b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	X KM	Y KM	Z KM	DX KM/SEC	DY KM/SEC	DZ KM/SEC
1587.585	-4034.477	-3417.937	-3890.849	5.413	-5.556	-.728
1600.000	-3966.558	-3486.788	-3899.469	5.529	-5.536	-.661
1610.000	-3910.794	-3542.066	-3905.805	5.623	-5.520	-.606
1620.000	-3854.090	-3597.177	-3911.593	5.717	-5.503	-.551
1630.000	-3796.444	-3652.116	-3916.831	5.812	-5.485	-.496
1640.000	-3737.856	-3706.879	-3921.516	5.906	-5.467	-.441
1650.000	-3678.324	-3761.461	-3925.644	6.000	-5.449	-.385
1660.000	-3617.848	-3815.857	-3929.212	6.095	-5.430	-.329
1670.000	-3556.425	-3870.065	-3932.216	6.190	-5.411	-.272
1680.000	-3494.055	-3924.080	-3934.653	6.284	-5.392	-.215
1690.000	-3430.735	-3977.898	-3936.519	6.379	-5.372	-.158
1700.000	-3366.464	-4031.517	-3937.811	6.475	-5.352	-.100
1710.000	-3301.240	-4084.931	-3938.525	6.570	-5.331	-.042
1720.000	-3235.059	-4138.139	-3938.659	6.666	-5.310	.016
1730.000	-3167.920	-4191.137	-3938.207	6.762	-5.289	.075
1740.000	-3099.818	-4243.922	-3937.167	6.858	-5.268	.134
1750.000	-3030.751	-4296.493	-3935.536	6.955	-5.246	.193
1760.000	-2960.715	-4348.846	-3933.308	7.052	-5.224	.253
1770.000	-2889.706	-4400.980	-3930.482	7.150	-5.202	.313
1780.000	-2817.718	-4452.894	-3927.052	7.248	-5.180	.373
1790.000	-2744.746	-4504.586	-3923.015	7.347	-5.158	.434
1800.000	-2670.786	-4556.054	-3918.368	7.446	-5.136	.495
1810.000	-2595.830	-4607.299	-3913.106	7.546	-5.113	.557
1820.000	-2519.871	-4658.321	-3907.225	7.646	-5.091	.619
1830.000	-2442.903	-4709.119	-3900.721	7.748	-5.069	.682
1840.000	-2364.916	-4759.695	-3893.590	7.850	-5.047	.745
1850.000	-2285.901	-4810.050	-3885.827	7.953	-5.025	.808
1860.000	-2205.848	-4860.186	-3877.428	8.058	-5.003	.872
1870.000	-2124.745	-4910.105	-3868.388	8.163	-4.981	.936
1880.000	-2042.582	-4959.811	-3858.702	8.270	-4.960	1.001
1890.000	-1959.342	-5009.307	-3848.365	8.378	-4.939	1.066
1900.000	-1875.012	-5058.599	-3837.372	8.488	-4.919	1.132

TABLE 12b. (Continued)

.18029707+05 KGS .39748699+05 LBS FIRST BURN

TIME SEC	X KM	Y KM	Z KM	DX KM/SEC	DY KM/SEC	DZ KM/SEC
1910.000	-1789.574	-5107.691	-3825.716	8.600	-4.900	1.199
1920.000	-1703.011	-5156.591	-3813.392	8.713	-4.881	1.266
1930.000	-1615.302	-5205.306	-3800.393	8.829	-4.862	1.334
1940.000	-1526.425	-5253.844	-3786.712	8.947	-4.845	1.402
1950.000	-1436.353	-5302.215	-3772.342	9.068	-4.829	1.472
1960.000	-1345.061	-5350.430	-3757.275	9.191	-4.814	1.542
1970.000	-1252.516	-5398.503	-3741.501	9.318	-4.801	1.613
1980.000	-1158.686	-5446.446	-3725.012	9.449	-4.788	1.685
1990.000	-1063.532	-5494.277	-3707.796	9.583	-4.778	1.758
2000.000	-967.008	-5542.013	-3689.841	9.722	-4.770	1.833
2010.000	-869.071	-5589.675	-3671.136	9.866	-4.763	1.909
2020.000	-769.666	-5637.285	-3651.665	10.016	-4.759	1.986
2030.000	-668.725	-5684.872	-3631.410	10.173	-4.758	2.065
2040.000	-566.190	-5732.462	-3610.355	10.337	-4.760	2.146
2042.715	-538.061	-5745.389	-3604.497	10.382	-4.762	2.169

END BURN

TABLE 12b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT = .18029707+05 KGS .39748699+05 LBS

TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA I DEG
1587.585	18029.707	39748.699	230.865	.327	-87.151	1.422
1600.000	17669.314	38954.171	-51.417	.305	-83.999	1.348
1610.000	17379.016	38314.171	-51.862	.287	-82.662	1.314
1620.000	17088.716	37674.171	-52.308	.270	-81.504	1.287
1630.000	16798.417	37034.170	-52.755	.252	-80.352	1.260
1640.000	16508.118	36394.171	-53.202	.235	-79.206	1.232
1650.000	16217.819	35754.171	-53.649	.217	-78.065	1.204
1660.000	15927.520	35114.171	-54.097	.200	-76.930	1.176
1670.000	15637.221	34474.171	-54.546	.183	-75.801	1.148
1680.000	15346.922	33834.171	-54.995	.166	-74.678	1.119
1690.000	15056.623	33194.171	-55.444	.148	-73.560	1.091
1700.000	14766.324	32554.171	-55.893	.131	-72.448	1.062
1710.000	14476.025	31914.171	-56.343	.114	-71.342	1.033
1720.000	14185.725	31274.171	-56.793	.097	-70.242	1.004
1730.000	13895.426	30634.171	-57.244	.080	-69.148	.975
1740.000	13605.127	29994.171	-57.694	.063	-68.060	.946
1750.000	13314.828	29354.171	-58.144	.046	-66.978	.916
1760.000	13024.529	28714.171	-58.595	.030	-65.902	.887
1770.000	12734.230	28074.171	-59.045	.013	-64.833	.857
1780.000	12443.931	27434.171	-59.496	-.004	-63.770	.827
1790.000	12153.632	26794.171	-59.946	-.021	-62.714	.797
1800.000	11863.332	26154.171	-60.396	-.038	-61.665	.767
1810.000	11573.033	25514.171	-60.845	-.054	-60.622	.737
1820.000	11282.734	24874.171	-61.294	-.071	-59.586	.707
1830.000	10992.435	24234.170	-61.743	-.088	-58.558	.676
1840.000	10702.136	23594.171	-62.191	-.105	-57.536	.646
1850.000	10411.837	22954.171	-62.638	-.121	-56.522	.615
1860.000	10121.538	22314.171	-63.085	-.138	-55.516	.585
1870.000	9831.239	21674.171	-63.531	-.155	-54.516	.554
1880.000	9540.940	21034.171	-63.976	-.171	-53.526	.523
1890.000	9250.640	20394.171	-64.420	-.188	-52.542	.492
1900.000	8960.341	19754.171	-64.863	-.205	-51.568	.461

TABLE 12b. (Continued)

FIRST BURN

TIME SEC	MASS KGS	WEIGHT LBS	CHI P DEG	CHI Y DEG	ALPHA N DEG	ALPHA W DEG
1910.000	8670.042	19114.171	-65.306	-.221	-50.601	.430
1920.000	8379.743	18474.171	-65.746	-.238	-49.644	.399
1930.000	8089.444	17834.171	-66.185	-.255	-48.694	.368
1940.000	7799.145	17194.171	-66.623	-.272	-47.755	.337
1950.000	7508.846	16554.171	-67.059	-.288	-46.824	.305
1960.000	7218.547	15914.171	-67.493	-.305	-45.903	.274
1970.000	6928.248	15274.171	-67.926	-.322	-44.991	.242
1980.000	6637.948	14634.171	-68.357	-.338	-44.090	.211
1990.000	6347.649	13994.171	-68.786	-.355	-43.199	.179
2000.000	6057.350	13354.171	-69.213	-.372	-42.319	.147
2010.000	5767.051	12714.171	-69.637	-.389	-41.449	.116
2020.000	5476.752	12074.171	-70.060	-.405	-40.591	.084
2030.000	5186.453	11434.171	-70.479	-.422	-39.744	.052
2040.000	4896.154	10794.171	-70.897	-.439	-38.907	.019
2042.715	4817.330	10620.394	-71.010	-.443	-38.385	-.013

END BURN

TABLE 12b. (Continued)

FIRST BURN

BEGIN BURN WEIGHT= .18029707+05 KGS .39748699+05 LBS

TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
1587.585	-.010	.003	.000
1600.000	-.010	.003	.000
1610.000	-.010	.004	.000
1620.000	-.010	.004	.000
1630.000	-.010	.004	.000
1640.000	-.010	.004	.000
1650.000	-.010	.004	.000
1660.000	-.011	.004	.000
1670.000	-.011	.004	.000
1680.000	-.011	.004	.000
1690.000	-.011	.004	.000
1700.000	-.011	.004	.000
1710.000	-.011	.004	.000
1720.000	-.011	.004	.000
1730.000	-.011	.004	.000
1740.000	-.011	.004	.000
1750.000	-.011	.004	.000
1760.000	-.011	.004	.000
1770.000	-.011	.004	.000
1780.000	-.011	.004	.000
1790.000	-.011	.004	.000
1800.000	-.011	.004	.000
1810.000	-.011	.004	.000
1820.000	-.011	.004	.000
1830.000	-.011	.004	.000
1840.000	-.011	.004	.000
1850.000	-.012	.004	.000
1860.000	-.012	.004	.000
1870.000	-.012	.004	-.000
1880.000	-.012	.004	-.000
1890.000	-.012	.004	-.000
1900.000	-.012	.004	-.000

TABLE 12b. (Concluded)

FIRST BURN

TIME SEC	DDXP KM/SEC(SQ)	DDYP KM/SEC(SQ)	DDZP KM/SEC(SQ)
1910.000	-.013	.004	-.000
1920.000	-.013	.004	-.000
1930.000	-.013	.004	-.000
1940.000	-.013	.004	-.000
1950.000	-.014	.004	-.000
1960.000	-.014	.004	-.000
1970.000	-.014	.004	-.000
1980.000	-.015	.004	-.000
1990.000	-.015	.004	-.000
2000.000	-.016	.003	-.000
2010.000	-.016	.003	-.000
2020.000	-.017	.003	-.000
2030.000	-.018	.003	-.000
2040.000	-.019	.003	-.000
2042.715	-.019	.003	-.000

END BURN

TABLE 12c.

CONIC CONDITIONS AFTER FIRST BURN

ORBITAL ELEMENTS

C1	=	77862.46	(KM)SQ/SEC	ANGULAR MOMENTUM PER UNIT MASS
C3	=	18.0000	(KM/SEC)SQ	TWICE THE TOTAL ENERGY PER UNIT MASS
ECC	=	1.298779		ECCENTRICITY
SMA	=	22144.63	KM	SEMI MAJOR AXIS OF CONIC
RCA	=	6616.35	KM	RADIUS AT PERI-CENTER
RAPO	=	50905.60	KM	RADIUS AT APO-CENTER
INC	=	36.964011	DEG	INCLINATION
TANO	=	17.96575	DEG	TRUE ANOMALY
ARPG	=	-79.73333	DEG	ARGUMENT OF PERI-CENTER
PERIOD	=	32795.33	SEC	PERIOD OF CONIC

APPENDIX A

OUTPUT FORMAT FOR EACH PRINT TIME INTERVAL AND OPTIONAL SUMMARY PRINT TABLE DESCRIPTION

OUTPUT FORMAT FOR EACH PRINT TIME INTERVAL

TIME	XP	X	DXP	DX	R
MASS	YP	Y	DYP	DY	ALT
WTLBS	ZP	Z	DZP	DZ	V
DDXP	DDXPG	W1	P1	LATR	RDOT
DDYP	DDYPG	W2	P2	LONGR	PTH
DDZP	DDZPG	W3	P3	AZ	VPER
LATP	CHIP	ALPN	DCHIP	DALPN	VAPO
LONGP	CHIY	ALPW	DCHIY	DALPW	GRADV
SMA	C3	C1	ECC	RCA	RAOP
INC	RASNOD	ARPG	TANO	PERIOD	MEOR
S1	S2	S3	SD1	SD2	SD3

DEFINITION OF OUTPUT SYMBOLS FOR EACH PRINT TIME INTERVAL

1. TIME . . . . time (sec)
2. MASS . . . . mass (kg)
3. WTLBS . . . . weight (lb)
4. XP, YP, ZP . . . . position coordinates in the plumbline system (m)
5. X, Y, Z . . . . position coordinates in the ephemeris system (m)
6. DXP, DYP, DZP . . . . velocity components in the plumbline system (m/sec)
7. DX, DY, DZ . . . . velocity components in the ephemeris system (m/sec)
8. DDXP, DDYP, DDZP . . . . acceleration components in the plumbline system (m/sec^2)
9. DDXPG, DDYPG, DDZPG . . . . gravitational acceleration components in the plumbline system (m/sec^2)
10. W1, W2, W3 . . . . unit vector in the angular momentum direction
11. P1, P2, P3 . . . . unit vector in the direction of periapsis
12. LATR, LONGR . . . . latitude (geocentric) and longitude of radius vector (deg)
13. LATP, LONGP . . . . latitude (geocentric) and longitude of periapsis (deg)
14. R . . . . magnitude of radius vector (m)
15. ALT . . . . altitude above ellipsoid (m)
16. V . . . . magnitude of velocity vector (m/sec)
17. AZ . . . . velocity heading angle (deg)
18. RDOT . . . . time derivative of radius vector (m/sec)
19. PTH . . . . flight path angle (deg)
20. ALPN . . . . angle-of-attack measured from the velocity vector to the projection of the thrust direction in the flight plane (deg)
21. ALPW . . . . out-of-plane angle-of-attack measured from the projection of the thrust vector in the flight plane to the thrust vector positive toward the angular momentum vector (deg)
22. CHIP, CHIY . . . . control angles CHI_{pitch} and CHI_{yaw} (deg)

DEFINITION OF OUTPUT SYMBOLS FOR EACH PRINT TIME INTERVAL

23.	DALPN, DALPW..........	time derivatives of ALPN and ALPW (rad/sec^2)
24.	DCHIP, DCHIY............	time derivatives of CHI_{pitch} and CHI_{yaw} (rad/sec^2)
25.	VPER, VAPO.............	velocity at periapsis and apoapsis (m/sec)
26.	SMA....................	semimajor axis (m)
27.	RASNOD................	right ascension of the ascending node (deg)
28.	ECC....................	eccentricity
29.	RCA....................	radius at periapsis (m)
30.	RAOP..................	radius at apoapsis (m)
31.	GRADV................	gravity loss (m/sec)
32.	ARPG..................	argument of periapsis (deg)
33.	TANO..................	true anomaly (deg)
34.	PERIOD................	orbital period (sec)
35.	MEOR..................	mean orbital rate (rad/sec)
36.	S1, S2, S3..............	calculated outgoing asymptote
37.	SD1, SD2, SD3...........	desired outgoing asymptote
38.	C3.....................	twice the specific energy (m^2/sec^2)
39.	C1.....................	specific angular momentum (m^2/sec)

DESCRIPTION OF OPTIONAL SUMMARY PRINT TABLES (QUANTITIES REQUIRED TO BE SPECIFIED)

(1) Print interval for parking orbit coast.

(2) Print interval for first burn.

(3) Print interval for transfer coast.

(4) Print interval for second burn.

If the terminal condition is a circular orbit, the following tables are printed:

a. Parking Orbit Coast
b. Perigee Burn
c. Conic Conditions After Perigee Burn
d. Transfer Coast

e. Apogee Burn
f. Conic Conditions After Apogee Burn

If the terminal condition is an elliptical orbit, the following tables are printed:

a. Parking Orbit Coast
b. First Burn
c. Conic Conditions After First Burn
d. Orbit Coast
e. Second Burn
f. Conic Conditions After Second Burn

} If second burn required

If the terminal condition is an outgoing hyperbolic asymptote, the following tables are printed:

a. Parking Orbit Coast
b. First Burn
c. Conic Conditions After First Burn

Tables 1-12 are examples of the different summary print tables available.

APPENDIX B

EQUATIONS FOR THE COORDINATE SYSTEM TRANSFORMATION AND COMPUTATION OF ADDITIONAL ORBITAL PARAMETERS

DEFINITION OF SYMBOLS[3]

$\bar{i}, \bar{j}, \bar{k}$	Unit vectors along the X, Y, Z (ephemeris) axes, respectively.
μ	Gravitational constant
V	Inertial velocity magnitude
r	Magnitude of radius vector $\bar{R}$
i	Inclination of orbital plane
ω	Argument of periapsis
Ω	Right ascension of ascending node
$\| \|$	Indicates vector magnitude
[ ]	Matrix or determinant notation

SUPERSCRIPTS

$\cdot$	Time derivative
h	Hour (universal time)
—	Indicates vector quantity

SUBSCRIPTS

p	Plumbline coordinate system
$\frac{e}{p}$	Transformation from plumbline to ephemeris coordinates
1, 2, 3	Indicates reference to X, Y, Z (ephemeris) axes, respectively.

(5)[4] Transformation from plumbline to ephemeris coordinate system: X, Y, Z [3, 4]

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} T_{\frac{e}{p}} \end{bmatrix} \begin{bmatrix} X_p \\ Y_p \\ Z_p \end{bmatrix}$$

---

3. Undefined symbols used carry the same connotation as in Reference 1.

4. These numbers correspond to those numbering the output symbols of Appendix A.

$$\begin{bmatrix} T_{\frac{e}{p}} \end{bmatrix} = \begin{bmatrix} \sin\theta\cos K + \cos\theta\sin\phi\sin K & \cos\theta\cos\phi & \sin\theta\sin K - \cos\theta\sin\phi\cos K \\ -\cos\theta\cos K + \sin\theta\sin\phi\sin K & \sin\theta\cos\phi & -\cos\theta\sin K - \sin\theta\sin\phi\cos K \\ -\cos\phi\sin K & \sin\phi & \cos\phi\cos K \end{bmatrix}$$

$\theta =$ (GHA) 0^h UT $\omega_e t + \lambda$

GHA = Greenwich hour angle measured west from Greenwich at 0^hUT of the launch day.

0^hUT = Zero hour universal time.

λ = Launch longitude (east through 360°) (279°.395645)

K = $(3/2)\pi - A$

A = Launch azimuth, ϕ = Geodetic latitude (28°.6079927)

t = GMT of launch, ω_e = Earth's rotation rate

GHA = $100°.07554260 + 0°.9856473460\ T_d + 2°.9015 \times 10^{-13}\ T_d^{\,2}$

T_d = Days past 0^h January 1, 1950.

$$\omega_e = \frac{360}{86164.09892 + 0.00164\ T} \quad \text{deg/sec}$$

T = Number of Julian Centuries of 36 525 days from 1900 Jan. 0.5 UT (Julian Date = 2415020.0)

(7) Velocity components in the ephemeris system: DX, DY, DZ

$$\begin{bmatrix} DX \\ DY \\ DZ \end{bmatrix} = \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \begin{bmatrix} T_{\frac{e}{p}} \end{bmatrix} \begin{bmatrix} \dot{X}p \\ \dot{Y}p \\ \dot{Z}p \end{bmatrix}$$

(10) Unit vector in angular momentum direction: W_1, W_2, W_3

$$C_1 = \sqrt{A^2 + B^2 + C^2}$$

$A = Y\dot{X} - Z\dot{Y}, \ B = Z\dot{X} - X\dot{Z}, \ C = X\dot{Y} - Y\dot{X}$

$$\bar{C}_1 = \frac{A}{C_1}\ \bar{i} + \frac{B}{C_1}\ \bar{j} + \frac{C}{C_1}\ \bar{k}$$

$$W_1 = \frac{A}{C_1}, \quad W_2 = \frac{B}{C_1}, \quad W_3 = \frac{C}{C_1}$$

(11) Unit vector in direction of periapsis: P_1, P_2, P_3

$$\bar{P} = \frac{1}{\mu}\left[\left(V^2 - \frac{\mu}{r}\right)\bar{R} - r\dot{r}\bar{V}\right] \quad \text{— Vector in perigee direction}$$

$$= \frac{1}{\mu}\left[\left(V^2 - \frac{\mu}{r}\right)(X\bar{i} + Y\bar{j} + Z\bar{k}) - r\dot{r}(\dot{X}\bar{i} + \dot{Y}\bar{j} + \dot{Z}\bar{k})\right]$$

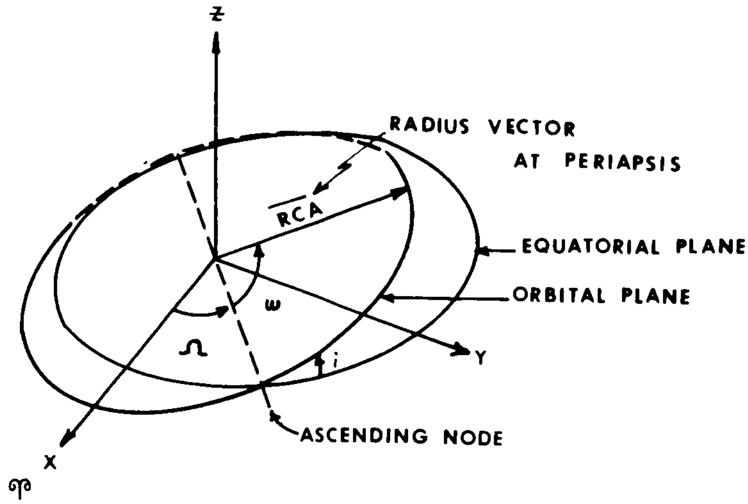
$$\bar{P} = \frac{1}{\mu}\left\{\bar{i}\left[X\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{X}\right] + \bar{j}\left[Y\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Y}\right] + \bar{k}\left[Z\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Z}\right]\right\}$$

$$|\bar{P}| = \sqrt{\left\{\frac{1}{\mu}\left[X\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{X}\right]\right\}^2 + \left\{\frac{1}{\mu}\left[Y\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Y}\right]\right\}^2 + \left\{\frac{1}{\mu}\left[Z\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Z}\right]\right\}^2}$$

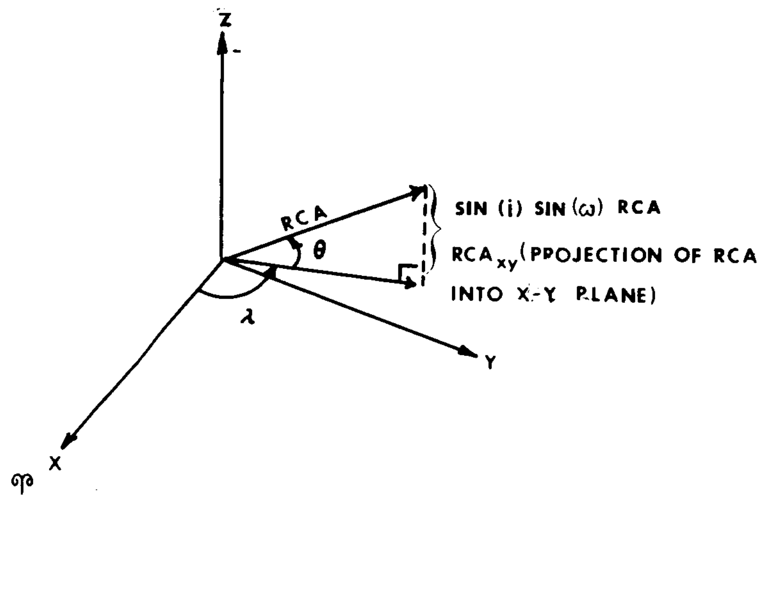
$$P_1 = \frac{\frac{1}{\mu}\left[X\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{X}\right]}{|\bar{P}|}, \qquad P_2 = \frac{\frac{1}{\mu}\left[Y\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Y}\right]}{|\bar{P}|}$$

$$P_3 = \frac{\frac{1}{\mu}\left[Z\left(V^2 - \frac{\mu}{r}\right) - r\dot{r}\dot{Z}\right]}{|\bar{P}|}$$

(13) Latitude and longitude of periapsis: LATP, LONGP



LATP = sin (i) sin (ω)



$$\sin\theta = \sin(i)\,\sin(\omega)$$

$$\theta = \sin^{-1}[\sin(i)\,\sin(\omega)]$$

$$RCA = |\overline{RCA}|, \quad RCA_{xy} = |\overline{RCA}_{xy}|$$

$$RCA_{xy} = RCA \cos\theta$$

$$P_1 = RCA_{xy} \cos\lambda$$

$$P_2 = RCA_{xy} \sin\lambda$$

$$\lambda = \cos^{-1}\left(\frac{P_1}{RCA_{xy}}\right)$$

$$\lambda = \sin^{-1}\left(\frac{P_2}{RCA_{xy}}\right)$$

P_1 = X - component of unit vector in direction of periapsis

P_2 = Y - component of unit vector in direction of periapsis

$r = r_1$, $E = Eo$ at $t = t_{inj}$ — t_{inj} = time at injection

$r = a(1 - e\cos E)$ — r_1 = magnitude of radius vector ($\overline{R}$) at injection

$\frac{r_1}{a} = 1 - e\cos Eo$ — E = eccentric anomaly

$$\cos Eo = \frac{a - r_1}{ae}$$

$$Eo = \cos^{-1}\left(\frac{a - r_1}{ae}\right)$$

$Eo = \sin^{-1}\dfrac{(r_1 \sin\theta)}{a\sqrt{1 - e^2}}$ — θ = true anomaly

$M = n(t - \tau) = E - e\sin E$ — M = mean anomaly

$$n = \sqrt{\frac{\mu}{a^3}}$$

$$(t_{inj} - \tau) = \frac{Eo - e \sin Eo}{n}$$ τ = time at periapsis passage

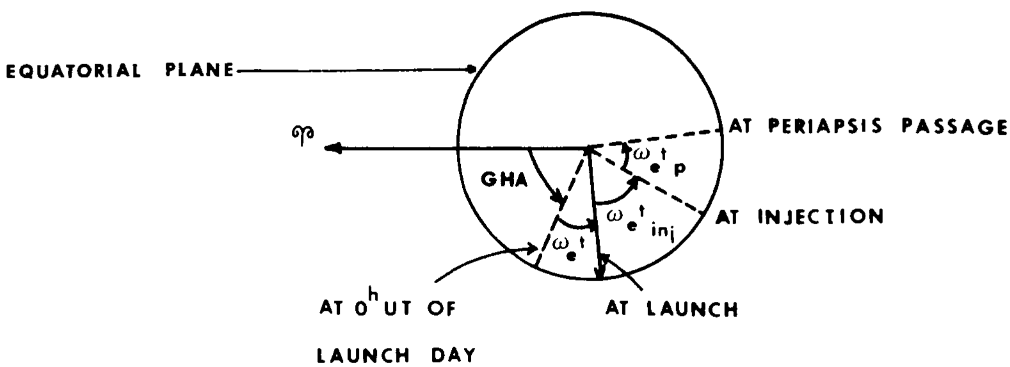
= Time increment past periapsis passage for $r = r_1$.

$$\text{Period} = T = \frac{2\pi}{n}$$

$t_p = T - (t_{inj} - \tau)$ = Time at periapsis passage

The t_{inj} value used should be that time of injection computed on the last iteration of a converged run.

LOCATION OF GREENWICH MERIDIAN:



$$\text{LONGP} = \lambda\,[\text{GHA} + \omega_e\,(t + t_{inj} + t_p)]$$

(26) Semimajor axis: SMA

$$V^2 = \mu\left(\frac{2}{r} - \frac{1}{a}\right)$$

$$\frac{V^2}{\mu} - \frac{2}{r} = -\frac{1}{a}$$

$$\frac{1}{a} = \frac{2}{r} - \frac{V^2}{\mu} = \frac{2\mu - rV^2}{\mu r}$$

$$\text{SMA} = a = \frac{\mu r}{2\mu - rV^2}$$

(27) Right ascension of the ascending node: RASNOD

$$W_x = W_1 = \sin \Omega \sin i = \frac{A}{C_1}$$

$$\sin \Omega = \frac{W_1}{\sin i}$$

$$\cos \Omega = -\frac{W_2}{\sin i}$$

$$\text{RASNOD} = \Omega = \sin^{-1}\left(\frac{W_1}{\sin i}\right)$$

$$\text{RASNOD} = \Omega = \cos^{-1}\left(-\frac{W_2}{\sin i}\right)$$

(28) Eccentricity: $\text{ECC} = e = \left\{ 1 + \frac{1}{\mu^2} \left[C_3 \left(r^2 V^2 - r^2 \dot{r}^2\right)\right] \right\}^{1/2}$

(29) Radius at periapsis: $\text{RCA} = a\,(1-e)$

(30) Radius at apoapsis: $\text{RAOP} = a\,(1+e)$

(31) Gravity loss: $\text{GRADV} = V_c - \Delta V$

$$V_c = V_{ex} \, \mathrm{Ln}\left(\frac{1}{1 - \zeta}\right) \qquad V_{ex} = I_{sp}(g_o)$$

$$\zeta = \frac{W_p}{W_f + W_p}$$

W_p = weight of propellant burned

W_f = final weight of vehicle

$$\Delta V = \sqrt{V^2 + 2\mu\left(\frac{1}{r_i} - \frac{1}{r_f}\right)} - V_i$$

r_i = initial radius

V_i = initial velocity

r_f = final radius

(32) Argument of periapsis: ARPG

$$P_z = P_3$$

$$Q_z = Q_3 = W_1 P_2 - W_2 P_1$$

$$\sin\omega = \frac{P_z}{\sin i}$$

$$\cos\omega = \frac{Q_z}{\sin i}$$

$$\mathrm{ARPG} = \omega = \sin^{-1}\left(\frac{P_z}{\sin i}\right)$$

$$\mathrm{ARPG} = \omega = \cos^{-1}\left(\frac{Q_z}{\sin i}\right)$$

(33) True anomaly: TANO

$$\mathrm{TANO} = \theta = \cos^{-1}\left[\frac{a\,(1-e^2) - r}{er}\right]$$

$$\text{TANO} = \theta = \sin^{-1}\left\{ \frac{\dot{r}}{e} \left[\frac{a\,(1-e^2)}{\mu} \right]^{1/2} \right\}$$

(34) Period: Period

$$\text{Period} = T = \frac{2\pi}{\mu^{1/2}\, a^{-3/2}}$$

(35) Mean orbital rate: MEOR

$$\text{MEOR} = \frac{2\pi}{T}$$

(36) Calculated outgoing asymptote: S_1, S_2, S_3

$$\overline{S} = \left(-\frac{1}{e}\right)\overline{P} + \frac{\sqrt{|e^2-1|}}{e}\,\overline{Q}$$

$$\overline{P} = \bar{i}(P_1) + \bar{j}(P_2) + \bar{k}(P_3)$$

$$\overline{Q} = \overline{W} \times \overline{P} = \begin{vmatrix} i & j & k \\ W_1 & W_2 & W_3 \\ P_1 & P_2 & P_3 \end{vmatrix} = \bar{i}(W_2P_3 - W_3P_2) - \bar{j}(W_1P_3 - W_3P_1) + \bar{k}(W_1P_2 - W_2P_1)$$

$$\overline{S} = -\frac{1}{e}\left[\bar{i}(P_1) + \bar{j}(P_2) + \bar{k}(P_3)\right] + \frac{\sqrt{e^2-1}}{e}\left[\bar{i}(W_2P_3 - W_3P_2) + \bar{j}(W_3P_1 - W_1P_3) + \bar{k}(W_1P_2 - W_2P_1)\right]$$

$$S_1 = -\left(\frac{1}{e}\right)P_1 + \frac{\sqrt{|e^2-1|}}{e}(W_2P_3 - W_3P_2)$$

$$S_2 = -\left(\frac{1}{e}\right)P_2 + \frac{\sqrt{|e^2-1|}}{e}(W_3P_1 - W_1P_3)$$

$$S_3 = -\left(\frac{1}{e}\right)P_3 + \frac{\sqrt{|e^2-1|}}{e}(W_1P_2 - W_2P_1)$$

APPENDIX C

ADDITIONAL INPUT VARIABLES REQUIRED AND INPUT DATA LISTINGS

Program Input Description

Input for ROBOT modified for the special printout shown in Appendix A is the same as that in Reference 1, with the addition of the following input variables:

Input Symbol	Internal Symbol	Explanation
AAETC+50	EPRNT	= 1 if special printout is desired = 0 is normal ROBOT printout is desired
AAETC+24	RA	Right ascension as measured in ephemeris coordinates (deg)
AAETC+25	DC	Declination (deg)
AAETC+54	MO	Month of launch
AAETC+55	IDAY	Day of launch
AAETC+56	IYR	Year of launch (years since 1900)
AAETC+57	HOUR	Hour and minute of launch (military time)
AAETC+58	SEC	Fractional minutes of launch time expressed in seconds

If summary print tables are desired, the following variables must be set.

JRBETC+7	The thrust event number where tables begin
JRBETC+29	= 1 if the cutoff condition is a circular orbit = 2 if the cutoff condition is an elliptical orbit = 3 if the cutoff condition is an outgoing hyperbolic asymptote

Input Data Lists

The following lists give the input data for the terminal conic constraints.

INPUT DATA LISTING FOR TERMINAL CONIC CONSTRAINT (V, γ, r)

```
INPUT:
HEAD=(BRADFORD-CHKOUT TERM. CUTOFF SURFACES AND TRANS. EQS.(
F=0.,0.,205000.,0.,205000.,
TNE+8=1.,
TNE+16=1.,
XMD=0.,0.,481.22015,0.,481.22015,
TAUT=0.,0.,263.3,18643.1,97.5,
NOFVNT=1,1,1,1,1,
PRINT=50.,50.,10.,50.,10.,
STEP=16.,16.,8.,16.,8.,
AAETC=115.,
AAETC+6=.4,
AAETC+8=284168.7,
JRBETC=1,2,0,3,3,40,
JRBETC+18=4,
KDB=0,0,1,1,1,
NBGCT=3,5,
NENDCT=4,6,
NP=25,25,0,0,
TTBL=0.,131.,263.,
CPTBL=2.609,2.740,2.869,
CYTBL=.00132,.0052,.0085,
TTBL+50=19906.,18947.,19003.,
CPTBL+50=-.380,-.378,-.375,
CYTBL+50=-.00054,-.00058,-.00064,
VIV=6966.323,-3490.034,-107.378,294137.,5866843.,-91242.,0.,
KCDPHI=1,2,3,4,
PSIREQ=3071.909617,0.,42240000.,
WIBT=2.,.2,2.,
JRBETC+29=1,
JRBETC+7=1,
AAETC+54=8.,6.,73.,1438.,15.85,
AAETC+50=1.,
AAETC+24=15.55,31.59,
```

INPUT DATA LISTING FOR TERMINAL CONIC CONSTRAINT (V, γ, r, i)

```
INPUT:
HEAD=(RODNEY BRADFORD MODIFIED CUTOFF SURFACES AND TRANS.  (
F=0.,0.,205000.,0.,205000.,
TNE+8=1.,
TNE+16=1.,
XMD=0.,0.,481.22015,0.,481.22015,
TAUT=0.,269.05,263.76,18861.96,101.16,
NOEVNT=1,1,1,1,1,
PRINT=50.,50.,10.,50.,10.,
STEP=16.,16.,8.,16.,8.,
AAETC=115.,
AAETC+6=.4,
AAETC+8=284168.7,
JRBETC=1,2,0,3,3,40,
JRBETC+18=4,
KDB=0,1,1,1,1,
NBGCT=3,5,
NENDCT=4,6,
NP=25,25,0,0,
TTBL=269.551,401.430,533.309,
CPTBL=2.384,2.513,2.642,
CYTBL=.0754,.0783,.0800,
TTBL+50=19395.04,19445.62,19496.20,
CPTBL+50=-.6317,-.6291,-.6265,
CYTBL+50=-.4389,-.4389,-.4389,
VIV=6966.323,-3490.034,-107.378,2941137.,5866843.,-91242.,0.,
WIBT=2.,.2,2.,
KCDPHI=1,2,3,4,10,
PSIREQ=3071.909617,0.,42240000.,50.,
JRBETC+29=1,
JRBETC+7=2,
AAETC+54=8.,6.,73.,1438.,15.85,
AAETC+50=1.,
AAETC+24=15.55,31.59,
JRBETC+10=1,
```

INPUT DATA LISTING FOR TERMINAL CONIC CONSTRAINT (C_3, C_1)

```
INPUT:
HEAD=(BRADFORD'CHKOUT TERM. CUTOFF SURFACES AND TRANS. EQS.(
TZERO=100.,0.,0.,0.,0.,0.,
F=0.,0.,205000.,
XMD=0.,0.,481.22015,
TNE+8=1.,
TNE+16=1.,
TAUT=0.,0.,264.,
NOEVNT=1,1,1,
PRINT=50.,50.,10.,
STEP=16.,16.,8.,
AAETC=115.,
AAETC+6=.4,
AAETC+8=284168.7,
JRBETC=1,2,0,3,3,80,
JRBETC+10=1,
KDB=0,0,1,
NBGCT=3,
NENDCT=4,
NP=25,
TTBL=100.1,231.,363.,
CPTBL=2.609,2.740,2.869,
CYTBL=.00132,.00523,.00854,
VIV=6966.323,-3490.034,-107.378,2941137.,5866843.,-91242.,0.,
KCDPHI=1,5,6,
PSIREQ=-16.3268288E6,67.4046207E9,
JRBETC+7=2,
JRBETC+29=2,
AAETC+50=1.,
AAETC+24=14.38,
AAETC+54=8.,6.,73.,1438.,15.85,
```

INPUT DATA LISTING FOR TERMINAL CONIC CONSTRAINT (C_3, C_1, i)[5]

```
KDB=0,0,0,1,1,
WIBT=.1,1.,
KCDPHI=1,5,6,10,
PSIREQ=-16.3268288E6,67.4046207E9,50.,
```

---

5. Run as a "stacked case" behind terminal constraint (C_3, C_1) input data.

INPUT DATA LISTING FOR TERMINAL CONIC CONSTRAINT (C_3, α, δ)

```
INPUT:
HEAD=(BRADFORD*CHKOUT TERM. CUTOFF SURFACES AND TRANS. EQS.(
TZERO=0.,0.,0.,0.,0.,0.,
NBGCT=3,
NENDCT=4,
NP=25,0,0,0,
PRINT=50.,50.,10.,
STEP=16.,16.,16.,
JRBETC=1,2,0,3,3,40,
AAETC+8=39748.7,
KDB=0,1,1,
TTBL=0.,460.,
CPTBL=3.,3.,
KCDPHI=1,5,18,19,
PSIREQ=18.E6,0.,0.,
F=0.,0.,20000.,
TNE+8=1.,
XMD=0.,0.,64.,
TAUT=0.,735.,460.,
AAETC+24=15.55,31.59,
NOEVNT=1,1,1,
AAETC=115.,
JRBETC+10=1,
VIV=6966.323,-3490.034,-107.378,2933546.5,-506451.3,-107518.8,0.,
VIV+3=2941137.,5866843.,-91242.,
AAETC+50=1.,
AAETC+54=8.,6.,73.,1438.,15.85,
WIBT=2.,4.,
TAUT=0.,1500.,456.,
TTBL=1500.,5000.,
CPTBL=3.68,4.37,
CYTBL=0.,0.,
JRBETC+7=2,
JRBETC+29=3,
```

APPENDIX D

UNIVAC 1108 FORTRAN LISTING OF SUBROUTINE APRTN

```
      SUBROUTINE APRTN(NN)
      COMMON/CONTST/CONTST,STATE(15,7)
      COMMON/XTRA/GHA,OMEGAL,HOUR
      COMMON/EPRNT/EPRNT,CHIPS,CHIYS,ALPW,ALPN,ALPWS,ALPNS,DCHIP,DCHIY,
     1 DALPW,DALPN,TEP(3,2),SD1,SD2,SD3,TSAV
      COMMON/GRAV/GTO,G11,G22,G23,G33
      COMMON/ALONGO/ALONGO
      COMMON/CHIROL/TCHIR,FAZ,CHRDOT
      COMMON/SPHI/SPHI,CPHI
      COMMON/NTABLE/NTABLE
      COMMON/REST/JSTR,NCNRS,KCDRES(6),TR,LSB,NFB,NOPAR,NIST(17)
      COMMON/CONST/RAD,PI,RE,FLAT,CJ,H,DJ,CMUE,OMEGA,ALT1,ALT2,PSL
      COMMON/AGEN1/TIME(2,15),TAUT(15),TAUM(15),TZERO,TDRAG,TLIFT,TTILT,
     1  TCHFRZ,DTZ,T2,TL,XMAUG,ANE(2),TNE(4,15),AE(15),S(15),WD(15),
     2  WJET(15),XWD(15),F(15),CHIFRZ,HEAD(15),PRINT(15),STEP(15),
     3  HNOM(15),HMAX(15)
      COMMON/AGEN2/AA,SA,CA,ALF,SIG,SSIG,CSIG,CHIP,SCHIP,CCHIP,CHIY,
     1  SCHIY,CCHIY,THZ,STH,CTH,THGT,THETL,STHL,CTHL,DPHIZ,GR,GTH,
     2  RTHE,RTHZ,R,R2,VR,THR,XM,XMDOT,SW,SM,SV,WZ,UZ,VZ,XZ,YZ,ZZ,WRZ,
     3  VIV(8), DVARS(7), DELXDW(15,3),DELXDR(7),DELXD(15,7),EXIT,
     4  DRAG1,CHIDOT,WZERO,CZERO,ALT,RHO,PAM,SS,XMACH,Q,QDOT,CAX,CNP,CN,
     5 FAA,FAN,FX,FY,FZ,A(3,3),BL(3,3),BO(3,3),D(3,3),DQDX(6),CASE,
     6  CT2,UMF,A12W,A22W,A32W,XJEXT,GNU(10),KINDR,KRDERR,REU,RYL,
     7  RHMAX(15),RHMN,RSTEP(15)
      COMMON/AGEN3/IORB,ITHR,IWD,IWDCHI,IXR,JORB,JUMP,KAT,KCST,
     1  KCYTAB,KDIR,KPAGE,KPRT,KS1,KWTA,LINES,NBGCT(4),NENDCT(4),NMAX,
     2  NOEVNT(5),NOTRAC,NOWD(15),NVNT,NVRST,NWVNT
      COMMON/FORINT/FRANK(2),T,TT,U,W,V,X,Y,Z,XMI,AHI,DVAR(8),
     1FSAVE(200),NTRG1,TV1,NTRG2,TV2,NTRG3,TV3,NTRG4,TV4,NTRG5,TV5,
     2NTRG6,TV6,NTRG7,TV7,KIND,KRDER,FU,FL,AYL,HMX,HMN,HNM
      COMMON/BAKINT/BRANK(2),TBK,TBKD,YL(7,10),YLD(7,10),BSAVE(1350),
     1  NBTRG1,TBV1,NBTRG2,TBV2,NBTRG3,TBV3,NBTRG4,TBV4,NBTRG5,TBV5,
     2 TEND,DTB4,DU3,D23,D43,WISSD(10,10)
      DIMENSION RID(40),TE(6)
      LOGICAL CONTST
      DATA(RID(I),I=3,40)/6HLIFT-O,2HFF,6HIGNITI,2HON,6HBOOST ,6HIMPACT,
     16HTHRUST,6H EVENT,6HENG CU,4HTOFF,6HBEGIN ,4HTILT,4HEND ,4HTILT,
     2  6HSEPARA,4HTION,6HSTART ,5HCOAST,6HEND CO,3HAST,6H10 KMS,1H.,
     26H14 KMS,1H.,
     36HO MAXI,3HMUM,6HINJECT,5HION  ,6HBEGIN ,6HCHIFRZ,6HWEIGHT,
     36H DROP ,
     46HBEGIN ,5HMIN-H,6HEND AT,3HMOS,6HREIGNI,4HTION/
      DATA(RID(I),I=1,2)/6H      ,6H      /
      IF(LSB.EQ.1)RETURN
      DAZ=ABS(FAZ-AA)
      CHIR=DAZ
      IF(T.GT.TCHIR)CHIR=DAZ-ABS(CHRDOT)*(T-TCHIR)
      IF(CHIR.LT.0.)CHIR=0.
      CHIR=CHIR*SIGN(1.,DAZ)
      XM=XMI+XMAUG
      D(1,2)=X/R
      D(2,2)=Y/R
      D(3,2)=Z/R
      CTH=A(1,2)*D(1,2)+A(2,2)*D(2,2)+A(3,2)*D(3,2)
      SPHI=A(1,1)*D(1,2)+A(2,1)*D(2,2)+A(3,1)*D(3,2)
      CPHI=A(1,3)*D(1,2)+A(2,3)*D(2,2)+A(3,3)*D(3,2)
      PHI=ATAN2(SPHI,CPHI)
      IF(T.LT..1)PHI=DTZ*OMEGA
      XNOD=PHI
      IF(PHI.LT.0.)PHI   =PHI+2.*PI
      PHI=(PHI-OMEGA*(T+DTZ))*RAD-ALONGO
```

```
      VI=(W*W+U*U+V*V)**.5
      GAM=(W*X+U*Y+V*Z)/(R*VI)
      GAM=ARKSIN(GAM,IER)
      IF(GAM.GT.PI)GAM=GAM-2.*PI
      C1=VI*R*COS(GAM)
      GAM=GAM*RAD
      C3=VI*VI-2.*CMUE/R
      THE=THP
      IF(IORB.EQ.0)GO TO 20
      THE=THE-FXIT*RAM
      CHIP=ATAN2(SCHIP,CCHIP)
      ALFP=ATAN2(SW,SU)-CHIP
      ALFY=ARKSIN(SV/VR,IER)
      CHIY=ATAN2(SCHIY,CCHIY)
      IF(CHIY.GT.PI)CHIY=CHIY-2.*PI
      SIG=ARKSIN(SSIG,IER)
      SDEG=SIG*RAD
   20 CONTINUE
      XLACC=(THE-FAA)/XM
      CPDG=CHIP*RAD
      CYDG=CHIY*RAD
      IF(IORB.EQ.1)GO TO 30
      SW=W-(Z*A22W-Y*A32W)
      SU=U-(X*A32W-Z*A12W)
      SV=V-(Y*A12W-X*A22W)
      VR=(SW*SW+SU*SU+SV*SV)**.5
      TEMP=(W*CCHIY*SCHIP+U*CCHIY*CCHIP+V*SCHIY)/VI
      ALF=ARKCOS(TEMP,IER)
      ALFP=ATAN2(W,U)-CHIP
      ALFY=ARKSIN(V/VI,IER)
      TEMP=RE
      IF(JORB.EQ.0)TEMP=UMF*RE/(UMF*UMF*(1.-CT2)+CT2)**.5
      ALT=R-TEMP
   30 ALTP=ALT
      ADEG=ALF*RAD
      ALFP=ALFP*RAD
      ALFY=ALFY*RAD
      THEP=THE/4.44822162
      XMLB=XM/.45359237
      TISP=F(ITHR)/(GZERO*XMD(ITHR))
      STH=(1.-CTH*CTH)**.5
      RSTH=R*STH
      D(1,3)=(D(1,2)*CTH-A(1,2))/STH
      D(2,3)=(D(2,2)*CTH-A(2,2))/STH
      D(3,3)=(D(3,2)*CTH-A(3,2))/STH
      D(1,1)=(-Y*A(3,2)+Z*A(2,2))/RSTH
      D(2,1)=(X*A(3,2)-Z*A(1,2))/RSTH
      D(3,1)=(-X*A(2,2)+Y*A(1,2))/RSTH
      VTH=D(1,3)*W+D(2,3)*U+D(3,3)*V
      VPH=D(1,1)*W+D(2,1)*U+D(3,1)*V
      XI=-VTH/SQRT(VTH*VTH+VPH*VPH)
      AZ=ARKCOS(XI,IER)
      THET=ARKCOS(CTH,IER)
      THETA=90.-THET*RAD
      THETG=ATAN2(SIN(THETA/RAD),UMF*UMF*COS(THETA/RAD))*RAD
      XINC=ARKCOS(SIN(AZ)*SIN(THET),IER)
      XNOD=(XNOD+ATAN2(CTH*VPH,VTH))*RAD
      IF(XNOD.LT.0.)XNOD=XNOD+360.
      XINC=XINC*RAD
      A1=ABS(CMUE/C3)
      P=C1*C1/CMUE
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```
      ECC=1.+P*C3/CMUE
      IF(ECC.LT.0.)GO TO 31
      ECC=SQRT(ECC)
      IF(RE-P/(1.+ECC).LT.RE/10.)GO TO 31
      CETANW=(P-R)/(R*ECC)
      ETANW=ARKCOS(CETANW,IER)
      CETATN=(P-RE)/(RE*ECC)
      ETATN=ARKCOS(CETATN,IER)
      DELETA=ABS(ETATN-ETANW)
      IF(GAM.GT.0.)DELETA=2.*(PI-ETANW)+DELETA
      PGENOW=ARKCOS((A1-R )/(A1*ECC),IER)
      IF(GAM.LT.0.)PGENOW=2.*PI-PGENOW
      PGETHN=2.*PI-ARKCOS((A1-RE)/(A1*ECC),IER)
      DELPGE=PGETHN-PGENOW
      DTI=(DELPGE-ECC*(SIN(PGETHN)-SIN(PGENOW)))/SQRT(CMUE/(A1*A1*A1))
      THT1=ARKCOS(CTH*COS(DELETA)+STH*SIN(DELETA )*COS(AZ),IER)
      DLPHI=ARKSIN(SIN(DELETA)*SIN(AZ)/SIN(THT1),IER)
      PHIMP=PHI+(DLPHI-OMEGA*DTI)*RAD
      THIMP=90.-THT1*RAD
   31 AZ=AZ*RAD
      N=2*NN-1
   50 IF(LINES)55,55,60
C     WRITE HEADER
   55 KPAGE=KPAGE+1
      WRITE(  6,56)CASE,(HEAD(I),I=1,10),KPAGE
   56 FORMAT(1H1,6H ROBOT,2X,6HCASE =,F11.4,10X,10A6,10X,4HPAGE,I3)
      LINES=54
   60 IF(FPRNT.NE.0.)GO TO 91
      WRITE(  6,61)RID(N),RID(N+1),T,VI,VR,THE,XLACC,X,Y,Z,W,U,V,ALTP,
     1XMACH,FAA,ADEG,SDEG,CPDG,CYDG,R,XM,Q,TISP,FAN,THIMP,PHIMP,THETG,
     2XINC,XNOD,SW,SU,SV  ,AHI,GAM,THEP,XMLB,C1,C3,THETA,PHI,AZ
   61 FORMAT( /1X,2A6,6H  TIME,E15.8,6H VSUBI,E15.8,6H VSUBR,E15.8,
     16H THRST,E15.8,6H  LACC,E15.8,/13X,6H Z13-X,E15.8,6H X13-Y,E15.8
     26H Y13-Z,E15.8,6H ZD13W,E15.8,6H XD13U,E15.8,/13X,6H YD13V,E15.8
     36H   ALT,E15.8,6H  MACH,E15.8,6H   FAA,E15.8,6H ALPHA,E15.8,/13X
     46H SIGMA,E15.8,6H  CHIP,E15.8,6H  CHIY,E15.8,6H     R,E15.8,
     56H  MASS,E15.8,/13X,6H     Q,E15.8,6H   ISP,E15.8,6H   FAN,E15.8,
     66H LTIMP,E15.8,6H LNGMP,E15.8,/13X,6H GDLAT,E15.8,6H  INCL,E15.8,
     76H  NODS,E15.8,6H    SW,E15.8,6H    SU,E15.8,/13X,6H    SV,E15.8,
     86H   AHI,E15.8,6H   GAM,E15.8,6H  THEP,E15.8,6H  XMLB,E15.8,/13X,
     96H    C1,E15.8,6H    C3,E15.8,6H   LAT,E15.8,6H  LONG,E15.8,
     96H  AZ.S,E15.8)
      LINES=LINES-9
      IF(NTABLE.EQ.0)RETURN
      IF(NMAX.NE.0)RETURN
C
C***  WRITE OUTPUT FOR REPORT
      GAMR=(SW*X+SU*Y+SV*Z)/(R*VR)
      GAMR=ARKSIN(GAMR,IER)
      IF(GAMR.GT.PI)GAMR=GAMR-2.*PI
      GAMR=GAMR*RAD

      ALFQ=ALF*Q
      CPDG=-CPDG
      WRITE(  9)RID(N),RID(N+1),T,VI,VR,GAM,GAMR,XM,XMLB,THE,THEP,
     A XLACC,ALTP,R,XMACH,Q,ALFP,ALFY,AZ,CPDG,CYDG,CHIR,AHI,X,Y,Z,
     B  W,U,V,ALFQ,THETA,PHI,(DVAR(I),I=1,3)
      RETURN
C***  VELOCITY IN EPHEMERIS SYSTEM
   91 DXE=TEP(1,1)*W+TEP(1,2)*U+TEP(1,3)*V
      DYE=TEP(2,1)*W+TEP(2,2)*U+TEP(2,3)*V
```

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      DZE=TEP(3,1)*W+TEP(3,2)*U+TEP(3,3)*V
C***  POSITION IN EPHEMERIS SYSTEM
      XE=TEP(1,1)*X+TEP(1,2)*Y+TEP(1,3)*Z
      YE=TEP(2,1)*X+TEP(2,2)*Y+TEP(2,3)*Z
      ZE=TEP(3,1)*X+TEP(3,2)*Y+TEP(3,3)*Z
      TEMPA=YE*DZE-ZE*DYE
      TEMPB=ZE*DXE-XE*DZE
      TEMPC=XE*DYE-YE*DXE
      C1E=1./(TEMPA*TEMPA+TEMPB*TEMPB+TEMPC*TEMPC)**.5
C***  UNIT VECTOR IN ANGULAR MOMENTUM DIRECTION
      W1E=TEMPA*C1E
      W2E=TEMPB*C1E
      W3E=TEMPC*C1E
C***  RDOT
      RD=(W*X+U*Y+V*Z)/R
      TEMPA=VI*VI-CMUE/R
      TEMPB=R*RD
      PEMP1=XE*TEMPA-TEMPB*DXE
      PEMP2=YE*TEMPA-TEMPB*DYE
      PEMP3=ZE*TEMPA-TEMPB*DZE
      PBARMU=(PEMP1*PEMP1+PEMP2*PEMP2+PEMP3*PEMP3)**.5
C***  UNIT VECTOR IN DIRECTION OF PERIAPSIS
      P1E=PEMP1/PBARMU
      P2E=PEMP2/PBARMU
      P3E=PEMP3/PBARMU
C***  SEMIMAJOR AXIS
      SMA=ABS(CMUE/C3)
C***  RIGHT ASCENSION OF ASCENDING NODE
      W2M=-W2E
      RASNOD=ATAN2(W1E,W2M)*RAD
C***  ECCENTRICITY
      TEMPE=C3*R*R/(CMUE*CMUE)
      ECCTEM=(1.+TEMPE*(VI*VI-RD*RD))
      ECC=0.
      IF(ECCTEM.GT.0.)ECC=(ECCTEM)**.5
C***  RADIUS AT PERIAPSIS
      RCA=ABS(SMA*(1.-ECC))
C***  RADIUS AT APOAPSIS
      RAOP=SMA*(1.+ECC)
C***  VELOCITY AT PERIAPSIS
      VPER=C1/RCA
C***  VELOCITY AT APOAPSIS
      VAPO=C1/RAOP
C***  CALCULATED OUTGOING ASYMPTOTE (S1,S2,S3)
      TEMPAR=W1E*P2E-W2E*P1E
      TEMS1=-(1./ECC)
      TEMS2=-(ABS(ECC*ECC-1.))**.5
      S1=TEMS1*(P1E+TEMS2*(W2E*P3E-W3E*P2E))
      S2=TEMS1*(P2E+TEMS2*(W3E*P1E-W1E*P3E))
      S3=TEMS1*(P3E+TEMS2*TEMPAR)
      SBAR=(S1*S1+S2*S2+S3*S3)**.5
      S1=S1/SBAR
      S2=S2/SBAR
      S3=S3/SBAR
C***  ARGUMENT OF PERIAPSIS
      ARPG=ATAN2(P3E,TEMPAR)
C***  TRUE ANOMALY
      TEMPT=ABS(SMA*(1.-ECC*ECC))
      STANO=TEMPB*(TEMPT/CMUE)**.5
      CTANO=TEMPT-R
      TANO=ATAN2(STANO,CTANO)*RAD
```

```
C***  PERIOD
      XMEOR=(CMUE/SMA**3)**.5
      PERIOD=2.*PI/XMEOR
C***  ACCELERATION COMP. IN PLUMBLINE SYSTEM
      DDXP=DVAR(1)
      DDYP=DVAR(2)
      DDZP=DVAR(3)
      IF(JORB.EQ.0)GO TO 501
      DDXPG=X*G11
      DDYPG=Y*G11
      DDZPG=Z*G11
      GO TO 502
  501 DDXPG=X*G11-A(1,2)*GTO
      DDYPG=Y*G11-A(2,2)*GTO
      DDZPG=Z*G11-A(3,2)*GTO
C***  GRAVITY LOSS
  502 IF(T.EQ.TZERO)VZE=(WZ*WZ+UZ*UZ+VZ*VZ)**.5
      DUMB=(1./RE-1./R)
      IF(DUMB.LT.0.)DUMB=0.
      DVSTR=(VI*VI+2.*CMUE*DUMB)**.5-VZE
      DEL=WZERO/(XM+WZERO)
      VEX=TISP*GZERO
      VC=VEX*ALOG(1./(1.-DEL))
      GRADV=VC-DVSTR
      TEMPX=XINC/RAD
      XLATP=(SIN(TEMPX)*SIN(ARPG))*RAD
      XLNGP=0.
      IF(.NOT.CONTST)GO TO 602
      TEMLAM=ATAN2(P2E,P1E)
      ENGHT=ARKCOS((SMA-R)/(SMA*ECC),IER)
      SENGHT=SIN(ENGHT)
      TTAU=TEND-((ENGHT-ECC*SENGHT)/XMEOR)
      TTP=PERIOD-(TEND-TTAU)
      XLNGP=(TEMLAM-(GHA/RAD+OMEGAL*(HOUR*3600.+TEND+TTP)))*RAD
  603 AXLN=ABS(XLNGP)
      IF(AXLN.LE.360.)GO TO 602
      XLNGP=XLNGP-360.*SIGN(1.,XLNGP)
      GO TO 603
  602 IF(KS1.NE.7)GO TO 601
      DCHIP=CHIDOT
      DCHIY=0.
  601 IF(TV5.EQ.TCHFRZ)DCHIP=0.
      ARPG=ARPG*RAD
      APND=ALPN*RAD
      APWD=ALPW*RAD
      DCHPD=DCHIP*RAD
      DCHYD=DCHIY*RAD
      DLPND=DALPN*RAD
      DLPWD=DALPW*RAD
      WRITE(6,64)RID(N),RID(N+1),T,X,XE,W,DXE,R,X1,Y,YE,U,DYE,
     1  ALTP,XMLB,Z,ZE,V,DZE,VI,DDXP,DDXPG,W1E,P1E,THETA,RD,DDYP,DDYPG,
     2  W2E,P2E,PHI,GAM,DDZP,DDZPG,W3E,P3E,AZ,VPER
      WRITE(6,65)XLATP,CPDG,APND,DCHPD,DLPND,VAPO,XLNGP,CYDG,APWD,DCHYD,
     1   DLPWD,GRADV,SMA,C3,C1,ECC,RCA,RAOP,XINC,RASMOD,ARPG,TANO,PERIOD
     2,XMEOR,S1,S2,S3,SD1,SD2,SD3
      LINES=LINES-14
      IF(NMAX.NE.0)RETURN
      IF(ITHR.NE.NTABLE) GO TO 301
      TZ=TIME(1,NTABLE)
      DO 302 I=1,6
      IZ=NTABLE-1+I
```

```
302 TE(I)=TIME(1,IZ)
301 IF(ITHR.LT.NTABLE) RETURN
     WRITE(9) T,T,R,VI,AZ,GAM,THETA,PHI,X,Y,Z,W,U,V,XE,YE,ZE,DXE,DYE,
    1DZE,DDXP,DDYP,DDZP,C1,C3,ECC,SMA,RCA,RAOP,XINC,TANO,ARPG,PERIOD,
    2XM,XMLB,TZ,TE,CPDG,CYDG,APND,APWD
 64 FORMAT(/1X,2A6,/5X4HTIMEE14.8,5X2HXPE14.8,6X1HXE14.8,4X3HDXPE14.8,
    15X2HDXE14.8,6X1HRE14.8/5X4HMASSE14.8,5X2HYPE14.8,6X1HYE14.8,
    24X3HDYPE14.8,5X2HDYE14.8,4X3HALTE14.8/4X5HWTLBSE14.8,5X2HZPE14.8
    3,6X1HZE14.8,4X3HDZPE14.8,5X2HDZE14.8,6X1HVE14.8/5X4HDDXPE14.8,2X5
    4HDDXPGE14.8,5X2HW1E14.8,5X2HP1E14.8,3X4HLATRE14.8,3X4HRDOTE14.8/
    55X4HDDYPE14.8,2X5HDDYPGE14.8,5X2HW2E14.8,5X2HP2E14.8,2X5HLONGRE14.
    68,4X3HPTHE14.8/5X4HDDZPE14.8,2X5HDDZPGE14.8,5X2HW3E14.8,
    75X2HP3E14.8,5X2HAZE14.8,3X4HVPERE14.8)
 65 FORMAT(5X4HLATPE14.8,3X4HCHIPE14.8,3X4HALPNE14.8,2X5HDCHIPE14.8,
    12X5HDALPNE14.8,3X4HVAPOE14.8/4X5HLONGPE14.8,3X4HCHIYE14.8,3X4HALPW
    2E14.8,2X5HDCHIYE14.8,2X5HDALPWE14.8,2X5HGRADVE14.8/6X3HSMAE14.8,
    35X2HC3E14.8,5X2HC1E14.8,4X3HECCE14.8,4X3HRCAE14.8,3X4HRAOPE14.8/
    46X3HINCE14.8,7H RASNODE14.8,3X4HARPGE14.8,3X4HTANOE14.8,7H PERIOD
    5E14.8,3X4HMEORE14.8/7X2HS1E14.8,5X2HS2E14.8,5X2HS3E14.8,4X3HSD1
    6E14.8,4X3HSD2E14.8,4X3HSD3E14.8)
100 RETURN
    END
```

APPENDIX E

UNIVAC 1108 FORTRAN LISTING OF SUBROUTINE TRASH

```
      SUBROUTINE TRASH(MODE)
      DIMENSION OFF(2),TITLE(17),A(7),S(15),ORBL(10),TE(6)
      STEMP=.5**24
      DATA (OFF(I),I=1,2)/6H      ,6H      /
      DATA ENDPRT/6HENDPRT/
      DATA BLANK/6H      /
      DATA(TITLE(I),I=1,17)/6H     P,6HARKING,6H ORBIT,6H COAST,6HPERIGE
     1,6HE BURN,6H CONIC,6H CONDI,6HTIONS ,6HAFTER ,6HFIRST ,6HBURN  ,
     2 6H    TR,6HANSFER,6HAPOGEE,6H BURN ,6HSECOND/
      NOT=1
  500 REWIND 9
      READ( 9)EP,T,R,VI,AZ,PTH,LAT,LONG,S,ORBL,XMKG,XMLB,TZ,TE,CHIP,CHIY
     1  ,ALPN,ALPW
      REWIND 9
      GO TO 400
    5 NTAB=1
      IBCK=0
    2 WRITE(6,1000)OFF,A,XMKG,XMLB
      GO TO 100
    3 WRITE(6,1001)OFF,(A(I),I=1,6)
C***  CIRCULAR ORBIT
  100 GO TO (110,110,130,110,110,130),NOT
  110 GO TO (111,112,113,124,125),NTAB
  111 WRITE(6,1111)A(7)
   12 LINES=32
   11 READ (9) EP,T,R,VI,AZ,PTH,LAT,LONG,S,ORBL,XMKG,XMLB,TZ,TE,CHIP,
     1 CHIY,ALPN,ALPW
      IF(EP.EQ.ENDPRT)GO TO 173
      IBCK=IBCK+1
      TC=ABS(T-TZ)
      R=R*.001
      VI=VI*.001
      DO 170 I=1,15
  170 S(I)=S(I)*.001
      ORBL(1)=ORBL(1)*.001*.001
      ORBL(2)=ORBL(2)*.001*.001
      DO 600 I=4,6
  600 ORBL(I)=ORBL(I)*.001
      GO TO (1110,1120,1130,1240,1250,11),NTAB
 1110 WRITE(6,999) T,TC,R,VI,AZ,PTH,LAT,LONG
      GO TO 171
 1120 WRITE(6,999) T,TC,(S(I),I=1,6)
      GO TO 171
 1130 WRITE(6,999) T,TC,(S(I),I=7,12)
      GO TO 171
 1240 WRITE(6,999) T,TC,XMKG,XMLB,CHIP,CHIY,ALPN,ALPW
      GO TO 171
 1250 WRITE(6,997) T,TC,(S(I),I=13,15)
  171 LINES=LINES-1
      IF(LINES.EQ.0) GO TO 3
      IF(ABS(T-TE(NOT+1)).GT.STEMP*TE(NOT+1))GO TO 11
  173 WRITE(6,998) A(7)
  172 IF(EP.EQ.ENDPRT)GO TO 174
      NTAB=NTAB+1
      IF(NTAB.LE.NTBL)GO TO 502
      NOT=NOT+1
      GO TO 400
  174 WRITE(6,996)
  502 DO 503 I=1,IBCK
  503 BACKSPACE 9
      IBCK=0
```

```
      IF(EP.EQ.ENDPRT)RETURN
      GO TO 2
  112 WRITE(6,1112) A(7)
      GO TO 12
  113 WRITE(6,1113) A(7)
      GO TO 12
  124 WRITE(6,1124) A(7)
      GO TO 12
  125 WRITE(6,1125) A(7)
      GO TO 12
  130 WRITE(6,1131) ORBL
      GO TO 172
C$$$$$$NOT TRANSITION
  400 DO 2400 I=1,7
 2400 A(I)=BLANK
      GO TO (410,420,420),MODE
  410 GO TO (411,412,413,414,415,416),NOT
  411 DO 401 I=1,4
  401 A(I)=TITLE(I)
  407 A(7)=A(4)
      NTBL=3
      GO TO 5
  412 A(3)=TITLE(5)
      A(4)=TITLE(6)
  405 A(7)=TITLE(16)
      NTBL=5
      GO TO 5
  413 DO 402 I=1,4
      A(I)=TITLE(I+6)
  402 A(I+2)=TITLE(I+2)
  404 NTBL=1
      GO TO 3
  414 A(1)=TITLE(13)
      A(2)=TITLE(14)
      A(3)=TITLE(4)
      A(7)=A(3)
      NTBL=3
      GO TO 5
  415 A(3)=TITLE(15)
      A(4)=TITLE(16)
      GO TO 405
  416 DO 403 I=1,4
      A(I)=TITLE(I+6)
  403 A(I+2)=TITLE(I+12)
      GO TO 404
  420 GO TO (411,422,423,411,425,423),NOT
  422 A(3)=TITLE(11)
      A(4)=TITLE(12)
      GO TO 405
  423 DO 406 I=1,6
  406 A(I)=TITLE(I+6)
      GO TO 404
  425 A(3)=TITLE(17)
      A(4)=TITLE(16)
      GO TO 405
 1000 FORMAT(1H1,78X12HTABLE NUMBER/1X2A6,29X6A6/6H BEGIN,A6,4X7HWEIGHT=
     1E13.8,4H KGS,8X,E13.8,4H LBS//)
 1111 FORMAT(4X4HTIME,6XA6,5H TIME,5X1HR,6X13HINER VELOCITY2X9HAZIMUTH S
     15X3HPTH5X8HLATITUDE3X9HLONGITUDE/5X3HSEC11X3HSEC8X2HKM10X6HKM/SEC,
     17X3HDEG8X3HDEG8X3HDEG8X3HDEG/)
  996 FORMAT(1H1)
```

```
 998 FORMAT(/4H ENDA6)
 999 FORMAT(3(F11.3,1X),2X,F11.3,4F11.3)
1001 FORMAT(1H1,78X12HTABLE NUMBER/1X2A6,29X6A6//)
1112 FORMAT(4X4HTIME6XA6,5H TIME6X2HXP,10X2HYP10X2HZP9X3HDXP9X3HDYP9X3H
    1DZP/5X3HSEC11X3HSEC9X2HKM10X2HKM10X2HKM,      8X6HKM/SEC,6X6HKM/SE
    2C,6X6HKM/SEC/)
1113 FORMAT(4X4HTIME6XA6,5H TIME6X1HX11X1HY11X1HZ10X2HDX10X2HDY10X2HDZ/
    15X3HSEC11X3HSEC8X2HKM10X2HKM10X2HKM,      8X6HKM/SEC6X6HKM/SEC,
    26X6HKM/SEC/)
1124 FORMAT(4X4HTIME6XA6,5H TIME5X4HMASS,8X6HWEIGHT7X5HCHI P,6X5HCHI Y,
    15X7HALPHA N5X7HALPHA W/5X3HSEC11X3HSEC,      8X3HKGS10X3HLBS,
    29X3HDEG8X3HDEG8X3HDEG9X3HDEG/)
1125 FORMAT(4X4HTIME6XA6,5H TIME8X4HDDXP,10X4HDDYP,10X4HDDZP/5X3HSEC,
    111X3HSEC7X10HKM/SEC(SQ)4X10HKM/SEC(SQ)4X10HKM/SEC(SQ)/)
 997 FORMAT(5(F11.3,2X),3(F11.5,2X))
1131 FORMAT(17H ORBITAL ELEMENTS//8H C1     =F12.2,11H (KM)SQ/SEC,5X,
    130HANGULAR MOMENTUM PER UNIT MASS/
    28H C3     =F12.4,11H (KM/SEC)SQ5X36HTWICE THE TOTAL ENERGY PER UNIT
    3 MASS/8H ECC    =F12.6,16X12HECCENTRICITY/
    48H SMA    =F12.2,3H KM,13X24HSEMI MAJOR AXIS OF CONIC/
    58H RCA    =F12.2,3H KM,13X21HRADIUS AT PERI-CENTER/
    68H RAPO   =F12.2,3H KM13X20HRADIUS AT APO-CENTER/
    78H INC    =F12.6,4H DEG,12X11HINCLINATION/
    98H TANO   =F12.5,4H DEG,12X12HTRUE ANOMALY/
    18H ARPG   =F12.5,4H DEG,12X23HARGUMENT OF PERI-CENTER/
    28H PERIOD=F12.2,4H SEC,12X15HPERIOD OF CONIC)
     END
```

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APPROVAL

OPTIMAL TRANSFER TRAJECTORIES FROM EARTH PARKING ORBIT TO VARIOUS TERMINAL CONIC CONSTRAINTS AND MODIFICATIONS TO THE ROBOT COMPUTER PROGRAM

By Rodney Bradford

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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ERICH E. GOERNER
Director, Preliminary Design Office

W. R. Lucas

W. R. LUCAS
Director, Program Development

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