NASA CR-132912

USER'S GUIDE

to the

Mission Analysis Evaluation and Space

Trajectory Operations Program

MAESTRO

(NASA-CR-132912) USER'S GUIDE TO THE MISSION ANALYSIS EVALUATION AND SPACE TRAJECTORY OPERATICNS PROGRAM (MAESTRO) (Analytical Mechanics Associates, Inc.) 96 p HC $7.00 CSCL 22C G3/30 N74-16539 Unclas 29273

Contract No. Nas5-11900

March 1973

Report No. 73-9

Prepared by

Analytical Mechanics Associates
11691 National Boulevard
Los Angeles, California 90064

for

Goddard Space Flight Center
Greenbelt, Maryland

ANALYTICAL MECHANICS ASSOCIATES, INC.
11691 NATIONAL BOULEVARD
LOS ANGELES, CALIFORNIA 90064

USER'S GUIDE

to the

Mission Analysis Evaluation and Space Trajectory Operations Program

MAESTRO

Contract No. NAS5-11900

March 1973

Goddard Space Flight Center
Contracting Officer
Mr. Robert Flick

Technical Officer
Mr. Charles Newman

Prepared by

David Lutzky

James Schafer

ANALYTICAL MECHANICS ASSOCIATES, INC.
11691 NATIONAL BOULEVARD
LOS ANGELES, CALIFORNIA 90064

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Section 1

INTRODUCTION

The purpose of this guide is to train personnel to use the MAESTRO system. The MAESTRO system is a mission analysis tool designed to present to the user information necessary to make the various decisions required in the design and execution of a spaceflight mission. The system was designed so that it can be used in both the pre-launch mission planning phase of a mission and during the flight as an in-flight decision making tool. The MAESTRO system can be divided into the following mission analysis modes:

1. Trajectory propagation mode
2. Retro-fire determination mode
3. Midcourse analysis determination mode
4. Monte Carlo mode
5. Verification mode
6. Orbit Stability mode
7. Post injection trim mode

A description of each of the above modes is presented in reference 1. The potential user should first read this reference to understand the operation of the mode of interest before he attempts use of the program.

The guide has a section devoted to each program mode. Each of these sections contains a description of the inputs necessary to run the program mode along with a sample case.

The author hopes that this guide is complete enough so that a new MAESTRO user will experience an absolute minimum training period before he is a competent user. Good luck with MAESTRO.

Section 2

INPUTS

Inputs to MAESTRO are made via cards. The input cards are read by MAESTRO's input editor which in turn loads the input data into the proper common list. The format of the input cards is shown in Table 2.1. "LOC" is the location number of the data in the "FIELD" portion of the card. Three groups can be placed on each card. The value in "LOC" corresponds to the location in the input array where the data in "FIELD" is to be stored. A value of LOC greater than 2000 denotes that the input corresponds to the gravity model. In this case, the data is not stored in the input array.

A description of the entire input array in shown in Table 2.2. This table describes each of the input locations between 1 and 1099 and presents its default value. It is envisioned that this table will be used as a reference. Other tables that detail which inputs are necessary for the individual modes are presented in the following sections. A description of the 2000 series inputs is presented in the next section.

The input editor has case capability. This capability affords the user a means of submitting several runs at one time with a minimum of inputs. Inputs which are not changing from run to run should be loaded into the first case. This is the first block on input cards. Data changing from run to run are loaded into cases. A blank card separates the cases. A run is comprised of all the data read in until a blank card is encountered. If the same location number appears more than once, the value read in last will be used. For example, if it were desired to fly two trans-lunar trajectories which were exactly the same except with different compute intervals, then all of the data defining the trajectory and the first compute interval should be placed first, followed by a blank card. The second case would follow the blank card. This case would only consist of the data defining the second compute interval. A submittal can have as many cases as desired.

There are two important points to note. First, there should not be a blank card at the end of the last case. Second, many locations in the input array are initialized inside the program. If a pre-initialized location is input via cards, the pre-initialized value is lost for all subsequent cases.

TABLE 2.1

FORMAT OF INPUT CARD

Card Column	Description
1	Space
2-6	Loc 1, location in the input array, right justified
7-21	Data to be entered in the Loc 1 location of the input array using D 15.9 format
22-26	Loc 2, location in the input array, right justified
27-41	Data to be entered in the Loc 2 location of the input array using D 15.9 format
42-46	Loc 3, location in the input array, right justified
47-61	Data to be entered in the Loc 3 location of the input array using D 15.9 format

TABLE 2.2

MAESTRO INPUT ARRAY*

LOCATION	FORTRAN SYMBOL	USE***	PRESET VALUE	DESCRIPTION
1	ERRC	I	-	Error control for automatic integration step size. If = 0 assume in fixed-step mode.
2	DELTO	I	-	Initial computer step when in automatic mode. Note: Need not be input when fixed-step.
3	DELMN	I	-	Minimum compute interval. Note: Not necessary in fixed-step mode.
4	TF	I	**	Run stop-time.
5	PCON	I	1.0	Unit conversion factor for positions. The value is determined such that, when PCON multiplies the input units, they will be converted to KMS. The output units will be scaled by 1/PCON so that the output units will be the same units as input.
6	VCON	I	1.0	Used the same as PCON except that velocities are scaled to KM/SEC.
7	EMPTY			
8	TOL	I	0.0	Corrector convergence tolerance in twelfth-order predictor-corrector integration scheme. Values used depend on the accuracy requirements. They range from 10^{-6} to 10^{-12}.
9	EMPTY			

* unless otherwise stated, the units of the input quantities are: KM, SEC, KG, degrees

** preset value depends on program operating mode

*** I integration; A approach analysis; M midcourse analysis; C Monte Carlo analysis; V Midcourse verification; L Lifetime analysis; P Post-injection trim

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
10-12	TMETH(3)	I	**	Times for method table. See KMETH (location 1036) for description.
13-19	EMPTY			
20 21 22 23 24 25	XMONL DAYL YRL HRL XMINL SECL	I	-	Launch epoch
26-29	EMPTY			
30 31 32 33 34 35	ELM(6)	I	-	Input initial conditions as orbital elements. The order is a, e, f, ω, i, Ω. The initial conditions may be accepted as position and velocity vectors (see locations 40-45). The coordinate system is defined in KINPT (location 1019).
36	EMPTY			
37	DJL			Modified julian launch date. Not a program input.
38	WTO	I	331.40	Initial weight
39	ETC	I	-	Ephemeris time correction. If no input, the ephemeris time correction will be calculated from ETC = 38.66 + .0025921DJ where DJ is the number of days since the julian date of 2440000.0.
40 41 42	X(3)	I	-	Initial conditions as position and velocity vectors or spherical coordinates. When spherical coordinates are used the order is velocity, flight path elevation angle, flight path azimuth angle, radius, geocentri latitude, geocentric longitude. The input coordinate system is defined by KINPT (location 1019)
43 44 45	DX(3)	I	-	
46	DJO			Modified julian launch date. Not a program input.
47	RA	I	-	Initial right ascension and declination in Earth equator and equinox of 1950
48	DEC	I	-	

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
50	XMON0			
51	DAY0			Initial time
52	YR0	I	-	Input is month, day and year,
53	HR0			hour, min, second (GMT).
54	MIN0			
55	SEC0			
56-76	COV	C	-	Upper right-hand triangle of the tracking covariance matrix loaded across the rows. Can be input in mean equator and equinox of 1950 or in a local tangent plane. Location 1085 determines the system. When mean of 1950 is used, the order is $X, Y, Z, \dot{X}, \dot{Y}, \dot{Z}$. When local tangent plane is input, the order is the position components R, (RxV) x R, R x V and then the velocity components along the same axes.
77-99	EMPTY			
100-111	GM(12)	I	***	Gravitational coefficient. The order of the planets is defined in locations 1001-1012.
112-123	RE(12)	I	***	Planetary radii.
124-135	WP(12)	I	***	Planetary rotation rates
136-169	EMPTY			
170-179	TCOMP(10)	I	**	Compute interval table when in fixed compute interval mode, (loc (1) = 0.). Compute interval = DELT (I) when TCOMP (I-1) < T < TCOMP(I) or Compute interval = DELT (1) when T < TCOMP(1). Complete compute interval table must be loaded when alterations are made to preset values.
180-189	DELT(10)	I	**	
190-192	XMØØN(3)	I	-	Initial position of Moon if osculating elements are used for Moon's position;
193-195	DXMØØN(3)	I	-	Earth radii and Earth radii/mean solar day
196	TMM	I	-	Moon's epoch in modified julian date.
197	SPRESS	I	$4.7(10)^{-5}$	Solar pressure at 1 AU, $dynes/cm^2$

*** See Table 3.3 of User's Manual

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
198	REFLK	I	0.2	Solar pressure reflectivity coefficient
199	EMPTY			
200-219	TF1(20)	I, A, M, V	***	Tabular thrust history of Motor 1. TF1(20) are times since ignition and F1(20) are the thrust values (newtons) at the corresponding times. For the RAE-B application, this motor is used as the midcourse motor.
260-279	F1(20)	I, A, M, V	***	
220-239	TF2(20)	I	-	Thrust table for motor 2.
280-299	F2(20)	I	-	
240-259	TF3(20)	I	-	Thrust table for motor 3.
300-319	F3(20)	I	-	
320-329	TWDOT1(10)	I, A, M, V	***	Tabular weight flow rate for motor 1. TWDOT1 is the time past ignition and WDOT is the flow rate at the corresponding time. The flow rate is in KG/sec.
350-359	WDOT1(10)	I, A, M, V	***	
330-339	TWDOT2(10)	I	-	Flow rate table for motor 2.
360-369	WDOT2(10)	I	-	
340-349	TWDOT3(10)	I	-	Flow rate table for motor 3.
370-379	WDOT3(10)	I	-	
380-382	TIG(3)	I, V	-	Ignition times for motors 1, 2 and 3.
383-385	TBØ(3)	I, V	-	Burnout times for motors 1, 2 and 3.
386-399	EMPTY			
400	TFIRE1	A	-	First and last trial retro firing time on an approach analysis. Time reference to liftoff epoch. Used when KAPOPT = 3 (location 1055)
401	TFIRE2	A	-	
402	DTFIRE	A	-	Increment in retro firing time.
403	RA0	A	-	Initial right ascension and declination used in the attitude sweep in the approach analysis. If both zero, velocity vector at closest approach is used.
404	DEC0	A	-	

*** See Table 3.3

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
405	DELRA	A	-	Increment in right ascension and declination in attitude sweep. Used when KAPOPT = 2 or 3
406	DELDEC	A	-	
407	EMPTY			
408	CAR1	V	4.0095D8	Telemetry carrier frequency No. 1
409	CAR2	V	4.0D8	Telemetry carrier frequency No. 2
410-419	OBSLON(10)	A, M, V	***	Observation site geocentric longitude for sites 1-10.
420	PSID(1)	M	2838.	Lunar radius (Midcourse analysis desired end conditions)
421	PSID(2)	M	116.5	inclination w.r.t. target planet equator. (Midcourse analysis desired end conditions)
422	PSID(3)	M	.396D6	time of flight w.r.t. liftoff (Midcourse analysis desired end conditions)
423	PSID(4)	M	0.62	Hyperbolic excess speed (Midcourse analysis desired end conditions)
424	PSID(5)	M	0.0	circular excess speed (Midcourse analysis desired end conditions)
425-429	PSID(6-10)	M		Empty
430-432	DV(3)	I	-	Impulsive velocity of engines 1 to 3. Used when KFMØN (location 1047) is set to 2. Velocities are added at ignition times in location (380-382).
433	SOLARA	I	13560	Area of the spacecraft used in solar pressure calculation, square centimeter
434	DELTMC	M	7200.	Increment in execution time
435	SIGATM	C, M	0.7	One sigma pointing error during midcourse maneuver.
436	SIGDVM	C, M	0.02	One sigma percentage error of midcourse velocity. Loaded as percent/100
437	SIGATR	C	0.7	One sigma pointing error during retro.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
438	SIGDVR	C	0.0003	One sigma percentage error of retro velocity. Loaded as percent/100.
439	TMC1	C	36000.	Time of first correction
440	TMC2	C	324000.	Time of second correction
441	ASPMC	A, M, C	226.0	Midcourse motor specific impulse
442	ASPR	A, M, C	282.5	Retro Motor specific impulse
443	WRETRO	A, M, C	71.44	Mass of retro fuel
444	RO	A, M, C, P	2838.	Desired lunar orbit radius used in trim maneuver
445	VC	A, M, C, P		Circular velocity at RO. Program calculation, not to be input.
446	CIO	A, M, C, P	116.5	Desired lunar oribt inclination w.r.t. lunar equator used in trim maneuver
447	BVD(1)	M	6000.	Desired B · T } Midcourse analysis desired end conditions. Used when IBTR flag set to 1. (loc 1062)
448	BVD(2)	M	6000.	Desired B · R }
449	TRINC	M, C, P	0.	Tolerance band on inclination correction during post injection trim. If inclination change is less than TRINC, no inclination adjustment is made.
450-459	TOUT(10)	I	TOUT(1)= 1.D20	Print table
460-469	DTOUT(10)	I	DTOUT(1)= 18000.	Print interval = DTOUT(1) when TOUT(I-1) < T < TOUT(I) or print interval = DTOUT(1) when T < TOUT(1)
470	ATFULA	C	6.0	Available attitude control fuel and constant to determine attitude control fuel, KG/RAI
471	AFUEL	C	0.1678	Attitude fuel used = AFUEL * attitude angle change.
472	FTØT	C	20.4	Total midcourse fuel available

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
473	WDROP	A, M, C	13.77	Retro drop weight. Weight dropped after retro firing.
474	CONE	A, M	5.0	Cone angle used in approach analysis. The attitude range is this cone angle about the velocity vector or input attitude when KAPOPT=1 (loc 1055). Also used in midcourse fixed attitude scan.
475	TRUE	A, M, C	20	True anomaly range for trial retro firings in approach analysis, deg. Trial retro firings are made from -True to +True true anomaly on the approach hyperbola. Used when KAPOPT =1. Also used as firing range in retro optimization.
476	BURNT	V	-	Midcourse motor burn time. Used when the intitial state is not obtained from a midcourse analysis.
477	EMPTY			
478	TMC	M	7200.	Initial execution time
479	DINK	M	0.0003	Secant partial step size in midcourse analysis also velocity increment when using the fixed attitude mode.
480-489	OBSLAT(10)	A, M, V	***	Observation site geocentric latitude for sites 1-10
490	TØL(1)	M	10.	B·T (Midcourse analysis tolerances on desired end conditions)
491	TØL(2)	M	10.	B·R
492	TØL(3)	M	10.	time of flight
493	TØL(4)	M	.0001	hyperbolic excess speed
494	TØL(5)	M	.0001	circular excess speed
495	TØL(6)	M	.02	Total fuel optimization
496	TØL(7)	M	5.	closest approach radius
497	TØL(8)	M	.2	inclination
498-499	TØL(9, 10)			Empty
500-511	RSWTCH(12)	I	***	Spheres of influence of the planets used to determine the central planet. If the distance from the planet is less than the value in RSWTCH the planet is the central planet. If none of the planets are central, then the Sun is considered central.

*** See Table 3.3

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
512	RBURN	A	20.	Retro burn time
513	TCATST	I	0.	Time to begin closest approach testing logic.
516	SPNRA	I	12.0	Spin rate, RPM.
517	PTI	I	238.0	Initial midcourse motor tank pressure, PSIA.
518	TPI	I	20.	Initial midcourse motor temperature, ^{o}C.
519	FMC	I	20.4	Current midcourse motor fuel, ke.
520	FMULT	I	1.	Thrust multiplier.
521	WMULT	I	1.	Weight multiplier.
522	WDOTT	M	.0183	Midcourse motor weight flow used with Hamilton Standard thrust in midcourse targeting.
523	DTM	M	0.	Compute interval during motor burn in midcourse targeting. Compute interval equals burntime when value is zero.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1001-1012	KP(12)	I	-	Bodies in system. Set to 1 if only position is necessary, 2 if both position and velocity are desired. The order is as follows:

1001 MERCURY	1005 JUPITER	1009 PLUTO
1002 VENUS	1006 SATURN	1010 SUN
1003 EARTH	1007 URANUS	1011 MOON
1004 MARS	1008 NEPTUNE	1012 ODDBALL

Note: 1003 = 2, 1010 = 1, 1011 = 2 are preset

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1013	METH			Current trajectory propagation method. Not a program input.
1014	KINT	I	3	Numerical Integration Scheme 3. 7th-Order Runge-Kutta 5. 12th-Order Multistep, single step size only
1015	JL	I	3	Launch planet number.
1016	ENGID	A	2	Engine number of the retro motor. Used in a MODE=1 analysis.
1017	JMN	I	5	Lunar and solar ephemeris flag 1. Mean elements 2. Mean elements for Sun Mean elements + 1st-order corrections for Moon 3. Ephemeris tape 4. Mean elements for Sun, osculating elements for Moon (loaded in locations 190-196) 5. Ephemeris tape using Goddard's direct read feature
1018	KOBLTE	I	1	Set to 1 for Earth oblateness. Should be set to 0 when 1029 = 3.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1019	KINPT	I	1	Input coordinate system flag 1. Mean equator and equinox of 1950 2. Mean equator and equinox of date 3. Mean ecliptic and equinox of date 4. True equator and prime meridian of launch planet 5. True equator and equinox of date 6. True lunar equator and node. 7. Earth spherical. See location 40-50 of INPUT common
1021-1028	EMPTY			
1029	KOBL	I	**	Set to the number of the planet in which the gravitational field is to be simulated using FIELD2. See location 1035.
1030	KOUT	I	**	If 1, output according to print table. If zero, output only at beginning and end of run. If -1, no output.
1031	JT	I	11	Target planet number
1032	KCRASH	I	**	Closest approach flag 0 No closest approach test 1 Continue after closest approach 2 Stop on closest approach
1033	EMPTY			
1034	JOCC	I	0	Occultation flag. Set to the planet number where the observer is located.
1035	MODLEM	I, L	1	Lunar gravity model flag 1 for Houston L1 model of Lunar field 2 for Earth J_2, J_3, J_4 3 for JPL 15 by 8 Lunar Field 5 zeroes initial field so new field can be input 10 Used field set in last case
1036-1038	KMETH(3)	I	** 13	Trajectory propagation method If T < TMETH(1) METH = KMETH(1) If TMETH (I-1) < TC < TMETH(I) METH = KMETH(I) TMETH is in location 10. 1. Cowell 2. Encke 3. NICE/True 4. NICE/Mean 5. Averaged Equations of 4 6. Multiconic, fixed stepsize only 7. Integrals e cos ω, $\omega + f$ 8. Equations 7 are used in averaging

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1039-1040	KOUTPT(2)	I	3,2	Output coordinate systems - Launch and target planets 1. Mean equinox and ecliptic of date 2. True equator and prime meridian 3. Mean Earth equator and equinox of 1950 4. True Earth equator and equinox of date 5. No output
1041	JRA	A, M	10	Number of right ascensions and declination angles used in the attitude sweep of the approach analysis. Must be less than 16. Also used in midcourse fixed attitude analysis.
1042	JDEC	A, M	15	
1043	KFIRE	A,M	20	Number of trial retro firing times on approach analysis less than 20
1044	MODE	ALL		Program mode 0 Fly to TF or closest approach 1, 2 Approach analyses 3 Midcourse analyses 4 Montecarlo analyses 5 Midcourse verification mode 6 Lunar lifetime mode 7 Post-injection trim
1045	KDØP	V	0	Set to one for doppler analysis
1046	KAPOUT	A	0	Set to one if retro firing time analysis is to be output for each attitude
1047	KFMOD	I	0	Thrusting mode 0 Tabular thrust / weight 2 Impulsive velocity 3 Hamilton Standard subroutine
1048	KAPSAD	A	1	Set to one for lunar orbit shadow calculations during approach analysis.
1049	KSADØW	I	0	Shadow calculation flag during trajectory propagation: 0 No shadows determined. 1 Shadow time determined by interpolation while numerically integrating trajectory. 2 Osculating orbit used to determine times. Note: KSADOW=1 should not be used when averaging.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1050	MCOUT	M	0	Extra output flag in midcourse analysis. 1. Outputs targeted solution from PROTO 2. Prints ΔV, constraint errors for each iteration. 3. Prints jet iteration information along with 2.
1051	JMC	M	10	Number of midcourse execution times simulated
1052	KMONTE	C	2	Monte Carlo description flag 1. retro only 2. midcourse and retro 3. two midcourses and retro If negative, the first correction will be calculated from the nominal assuming that the tracking data is good.
1053	KMAX	C	50	Sample size of Monte Carlo analysis.
1054	KSTART	C	17	Random number starter.
1055	KAPOPT	A	1	Approach analysis option flag. KAPOPT = 1 Firings made between an input range of true anomaly about perigee on the approach hyperbola. The attitude range is an input cone angle about the velocity vector at closest approach. KAPOPT = 2 Firings made from asymptote to asymptote on the approach hyperbola. The attitude range is input as initial right ascension and declination, increment in right ascension and declination, and number of attitude angles. KAPOPT = 3 Firings made between input times. The attitude range is input as in 2.
1056	NGRAPH			If positive, Element set number, for MAESTR graphics data base. If negative, replace $\lvert NGRAPH \rvert$ element set.
1057	KREAD	A, V	-	Integer used to obtain initial conditions from a midcourse analysis. KREAD corresponds to the midcourse correction number desired. If KREAD is zero, this option is ignored and the initial state must be input.
1058	KOUT9	I, L	**	Auxiliary peripheral output unit number

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1059	KTERM	I, L	0	Extra output flag. Used when KOUT9 ≠ 0 0. Orbital elements printed 1. Position and velocity vectors printed 2. Both 0 and 1
1060	INPWT	I	1	Input array write flag 0 no write 1 write
1061	MCUNIT	A, M, V	11	Unit number of auxiliary midcourse output unit.
1062	IBTR	M	2	Miss vector option flag in Midcourse Analysis 1. Use B•T and B•R loaded in BVD 2. Use PSID(1) and PSID(2)
1063	KGLAW	M	2	Midcourse guidance law 1. Minimum fuel 2. Fixed time of arrival 3. Fixed target energy 4. Variable target energy 5. Total fuel optimization
1064	NGROPT	M	1	Number of trials for which secant matrix is recomputed in Midcourse Analysis.
1065	NT	M	10	Number of trials allowed in Midcourse convergence.
1066	JET	M	1	If set, preliminary targeting will be done in the Midcourse Analysis.
1067	MCLIM	M	100	Limiting factor in the Midcourse Analysis. The midcourse correction is limited to MCLIM * DINK (KM/SEC) on each iteration.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1068	NORD	I, L	6	Number of ordinates in averaging – less than 16.
1069	INT	I, L	3	Number of intervals in averaging – less than 16
1070	KPROB	M	95	Output probability for midcourse execution error. Second midcourse execution time and errors are input through locations 440, 435, and 436. Negative or zero skips error propagation.
1071	IBURN	M	6	Trajectory propagation method during finite burn of midcourse motor. Impulsive calculations are used when set to zero.
1072	KROUT	M, C	0	Extra output flag during retro optimization calculations.
1073	KORECT	I	0	If set nonzero, the derivative at the end of an integration step will not be calculated.
1074	KMTOUT	C	0	Flag used to output initial state for each sample in a Monte Carlo analysis.
1075	KMETHP	M	6	Trajectory propagation method when generating partial derivatives.
1076	IFIND	A11	-	Element set number of the anchor vector to be transferred from the differential correction program.
1077	KTF	M	0	Flag used to determine the type of Midcourse analysis. = 0 One-dimensional scan of midcourse execution times > 0 Two-dimensional scan of midcourse execution times and flight times. Flight times are scanned in KTF one-hour steps beginning at the desired flight time in location 422. < 0 Two-dimensional scan of midcourse execution times and midcourse impulsive velocity. The impulsive velocity is centered about value, loaded into 426 and varied in -KTF steps of size DINK (location (479).

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1078	IVTI	M	0	Overburn option key 0. in-plane retro antiparallel at periapsis, ± 1. variable inclination procedure approaching above or below desired inclination ± 2. variable periapsis procedure circularizing in-plane before or after periapsis.
1079	KHIGH	I	0	Farthest approach flag. If set, furthest approach will be found.
1080	NORMIN	M, C	0	Retro optimization flag 0 in-plane at periapsis maneuver for underburns, according to IVTI for overburns ± 1. optimize retro to trim inclination in PROTO 2. Same as 1, but in TARGET also.
1081	NREV	A	0	Number of revolutions the transfer orbit completes before stopping at closest approach in an approach analysis
1082	KAPWT	A	0	Flag used to write information from the approach analysis in an auxiliary unit. It is set to the output unit number when the option is desired.
1083	NAPUNT	P, L	11	Unit numbers where initial conditions are stored from a previous approach analysis on post-injection trim analysis.
1084	KSOLP	I	0	Solar pressure flag. 0. no solar pressure 1. pressure in radial direction only (s/c assumed to be sphere) 2. spacecraft assumed to be a cylinder spinning along attitude vector.
1085	KCOV	C	0	Coordinate system of covariance matrix 0. mean Equator and equinox of 1950 1. local tangent plane
1086				Used in PEST version
1087	IDATT	all	0	Element set number of attitude file. Used when attitude is to be input via read from ADP.

LOCATION	FORTRAN SYMBOL	USE	PRESET VALUE	DESCRIPTION
1088	NATUNT	all	12	Unit number of attitude data.
1089	IDSAT	all	1234567	Satellite identification number.
1090	INIT	all	0	Initial line number of MAESTRO's space allotted on the director's display. If INIT is zero, no writes are made on the director's display. This option is only used during real-time operations.
1091	KPIT	P	0	Flag used to indicate post-injection trim targeting.
1092	ISET	all	0	Element set number when using subroutine PUTELS to transfer state to GTDS program.
1093	KPLOT	all	0	Set to the plot unit number when plotting.
1094	NMOD	I, L	0	Maximum number of zonals and tesserals used to define the gravity field.
1095	NMOD	I, L	0	
1096				Used in PEST version.
1097	KATMOS	I	0	Atmosphere drag flag. Set to 3 for Earth Drag.
1098	KASTRT	all	0	Flag used to initiate start-up procedure to obtain average elements from osculating elements.
1099	KTIST	I	0	Flag used to determine thrusters used in Hamilton Standard program 0 both thrusters 1 first thruster only 2 second thruster only

Section 3

TRAJECTORY PROPAGATION MODE

In this mode, MAESTRO is used as a trajectory propagator. Inputs to this mode are the most extensive and probably the most important as this mode is also used by almost all of the other modes. Table 3.1 presents the inputs that pertain to this mode. Many of the inputs are automatically pre-initialized. The pre-initialized values are designed for an Earth-Moon trajectory. Thus, if another type of trajectory is desired, many of the preset values will probably have to be changed. Since the inputs for this mode are so extensive, they are divided into catagories according to their use.

3.1 Initial Conditions

The initial conditions can be input as position and velocity vectors, orbital elements or in an Earth-fixed spherical system. These values are input in locations 30-35 or 40-45. If the initial semi-major axis in location 30 is zero, the program assumes the initial conditions are position and velocity vectors or spherical conditions. If location 30 is non-zero, orbital elements are used as the initial conditions even if one of the other methods is input. The coordinate system designation is input via the flag in location 1019. This flag is also used to indicate the Earth-fixed spherical inputs. The time corresponding to the initial state is input in locations 50-55. The constants input in locations 5 and 6 are used to convert the units of the initial conditions to program units. The program units are kms and kms/sec.

3.2 Compute Interval

The compute interval can be input in one of two ways. The first is via the compute interval table in locations 170-189. In this table ,constant compute intervals are input for segments of the trajectory. The times to switch from one constant compute interval to the next are also input. The compute interval can also be determined automatically inside the program. When this option is used, the error control limit, initial compute interval, and minimum compute interval are input in locations 1 to 3. The error control limit determines the accuracy of the propagation. The larger the number,the less accurate. Values of this number between .001 and .0001 give reasonably accurate results for all the methods except Cowell. When this scheme is used, the error control should be between 10 and 100 times larger. There are few restrictions in the selection of the compute interval. The twelfth and eighth-order multistep must be used with a constant compute interval for the whole flight. Multiconic can also be used with the automatic compute interval mode. The use is the same as with numerical integration.

3.3 Outputs

The outputs are obtained with respect to the launch and target planets. The frequency of the prints are determined by the print table in locations 450 and 469. In this table, constant print intervals are input along with time to switch from one print interval to the next. The flags in locations 1030, 1039, 1040 define the frequency and coordinate systems of output. Prints can only be obtained at compute points when the multiconic propagator is used.

The trajectory output consists of the time since launch epoch followed by a designation of the planet and coordinate system. The third line contains the X, Y, Z components and magnitude of the position vector from the designated planet to the spacecraft. The next line has the velocity vector and magnitude. The osculating orbit is presented next. The order of the elements is semi-major axis, eccentricity, true anomaly, argument of perigee, inclination, and longitude of the ascending node. See the sample case for an example of the output.

An alternate abbreviated print is also available. The flags in locations 1058 and 1059 are used to select this form. The first flag specifies the unit number of the prints. Be sure that this input does not conflict with previously defined units. The second flag specifies the outputs to be presented-orbital elements, position and velocity vectors or both. The flags in locations 1030, 1039, and 1040 also apply to this output. When orbital elements are output, the output consists of the days since launch epoch, semi-major axis, eccentricity, true anomaly, argument of the perigee, inclination, longitude of the ascending node, the planet number, the coordinate system (number corresponds to flag 1039 and 1040), and the periapsis radius. When position and velocity vectors are output, the output consists of the hours since launch epoch, position vector, radius planet number, the coordinate system (number corresponding to the flag input in 1039 and 1040), the velocity vector, and the magnitude of the velocity.

3.4 Force Model

A. Planets

The planets in the system are denoted by the flags in locations 1001-1012. A one or two is input in the proper location for the desired planet. If the planet will never become the central planet, e.g., Sun in an Earth-Moon trajectory, a one should be input. Otherwise, input a two for the desired planets. If the planet is included in the system, the perturbing acceleration due to that planet will be determined and included in the force model.

B. Gravity

A simplified Earth model containing only J_2, J_3, J_4 will be used by setting the flag in 1018 to 1. However, a more extensive gravity model of any planet including the Earth can also be used. The flags in locations 1029 and 1035 are used to select this option. Location 1029 is set to the planet number while 1035 is set to the model number. The perturbing acceleration will be determined when the central planet is the planet specified in location 1029. Some gravity models are preset in the program. The flag in location 1035 is used to pick up one of these models or to indicate that a new model is to be input.

The following fields are available in MAESTRO: (1) Houston L1 model of the lunar field, (2) JPL 15-8 model of the lunar field, and (3) Post Mariner 1971 model of Mars. A description of these models is shown in Table 3.2. The numbers in parentheses represent the corresponding model numbers loaded into location 1035. Any changes in these fields can be accomplished by additional input through the input array in locations starting at 2001. The value for C_{ij} is loaded into 2000 + j x 16 + (i+1), and the value for S_{ij} is loaded into 2300 + j x 16 + (i+1). For instance, $C_{2,0}$ corresponds to 2003, $C_{6,4}$ with 2071, $S_{3,3}$ with 2352, etc.

The C and S arrays are the cosine and sine terms, respectively, of the gravity field expansion. For a further description of these arrays, see reference 1. The elements input in the 2000 series override elements preset in the chosen model. Thus, to change one element in the JPL 15-8 field, MODLEM (1035) should be set to 3 and the new element should be input in the proper 2000 location. When new fields are to be input, MODLEM should be set to 5 to zero out the initial field. If the field used in the previous case is to be used again with minor changes, then MODLEM should be set to 10 and the appropriate changes input in the 2000 section. If a new field is to be input, or the size of a preset model is to be changed through inputs, then the flags INMOD(1094) and IMMOD(1095) should be set to the new size. INMOD represents the number of zonals and IMMOD represents the size of the tesseral array. For instance, if the JPL 15-8 field is to be expanded to a 16-9 field by adding a zonal and several tesserals, the INMOD should be set to 16 and IMMOD should be set to 9. It is important to note that the 2000 section inputs must be the last inputs in each case and that these inputs must always be on separate cards from the 1 to 1099 inputs.

The acceleration due to the field is only determined when the planet number input in location 1029 is the current central planet. Care should be taken not to use the Earth field twice. If an Earth model is used and 1029 set to 3, be sure location 1018 is zero.

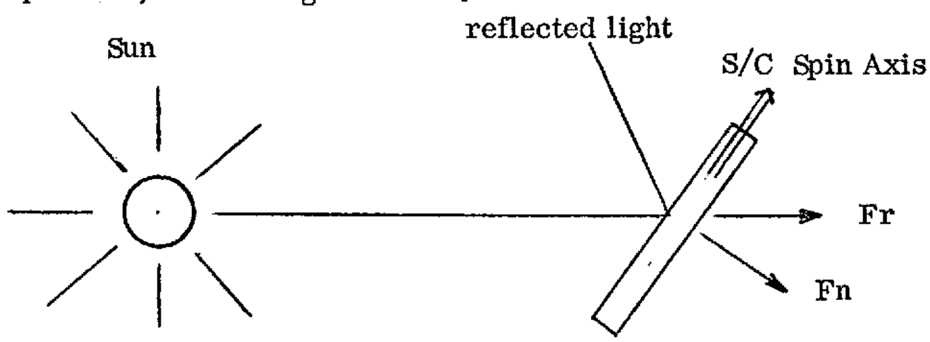
C. Thrusting

The program has the capability of firing three separate engines; however, only one engine can be burning at a time. The engine thrust characteristics are loaded into the tables in locations 200 to 319. In these tables, the thrust values are input at the corresponding times since ignition. Linear interpolation is used to obtain the thrust at times between the input values. The weight flow rate is input in locations 320 to 379. In these tables, the weight flow rate is input at the corresponding times since ignition. Linear interpolation is used to obtain the flow rate at times between the input times. The program integrates the weight flow rate to obtain the current spacecraft weight. The ignition and burnout times of the engines are input in location 380-385. The engine may also be simulated by an impulsive velocity approximation. When this approximation is used, the impulsive velocity is input in location 430 to 432 and the flag in 1047 must be set. The ignition times in locations 380-382 are used to determine when the velocities are applied.

D. Solar Pressure

The acceleration due to solar pressure is included when the flag in location 1084 is non-zero. When this option is used, the solar pressure at one astronomical unit and the spacecraft area and reflectivity are also required. These constants are input in locations 197, 433, and 198, respectively.

The solar pressure force can be determined in two different ways. One of the methods considers the spacecraft to be a sphere. Thus, the solar pressure force is only acting along the radial rays from the Sun. The other method assumes that the spacecraft is a spinning cylinder with the spin axis along the spacecraft attitude, input in locations 47 and 48. In this model, the solar pressure force consists of two components. One, Fr, in the radial direction from the Sun and the other, Fn, normal to the spin axis, see the figure below.



The flag in location 1084 is used to select the desired solar pressure model.

3.5 Physical Constants

Although all the physical constants are pre-set in the program, the user has the option to change any of these values. A table describing the preset constants is shown in Table 3.3.

3.6 Program Options

There are a variety of program options keyed to input flags. The table below describes the options available to the user.

Input Location	Description
*1014	This flag is used to select the numerical integration scheme desired when the state is to be propagated by numerical integration. The 12th-order multistep method can only be used with a constant compute interval.
*1017	This flag is used to select the desired ephemeris.
1018, 1029, 1035	These flags are used to describe the desired gravity mode. The 1018 flag denotes a simplified Earth model. If a more complex model for the Earth or any planet is desired, the flags in locations 1029 and 1035 are to be used. See Table 3.2 for a description of the available preset gravitational models.
*1019	This flag is used to indicate the coordinate system of the input spacecraft state.
1032	This flag is used to indicate the stopping criterion of the trajectory propagator.
*1036-1038	These flags are used to select the trajectory propagation scheme. A variety of schemes are available. See reference 2 for a description of the schemes.
*1039-1040	These flags define the coordinate system of the state output from the trajectory propagation portion of the program.
1044	This flag is used to select the desired MAESTRO analysis mode. Descriptions of the modes available are presented in the following sections.
1079	Flag used to read initial state from GTDS 24-hour hold file.
1087	Flag used to read initial attitude from Attitude Determination Program.
1047	Flag used to key doppler analysis. This analysis presents histories of thrust, weight acceleration due to thrust, and doppler shift during a motor burn.

* Flag must be input.

3.7 Optional Startup for Methods 5 and 8

The numerical averaging methods can be started with osculating orbital elements by setting the value of KAVST (location 1098) equal to 1. Normally, it is assumed that the input orbital elements for these methods represent an average state.

If KAVST is set to 1, however, the program performs a one-revolution integration of the osculating elements to obtain a set of mean elements for starting the averaged equations integration. The time corresponding to these mean initial elements is the average of the time for the first revolution or $\tau/2$, where τ is the orbital period.

The initial time is advanced from zero to $\tau/2$, and the averaging integration is started with the mean elements at this new epoch. Print times and compute steps are advanced by the same amount and the output is given at times one-half revolution later than they would have if the averaged equations integration had been started with input mean elements.

3.8 Shadow Calculations

The shadow times are determined in two different manners. In one method, the time of shadow crossing is determined from an iteration procedure in the numerical integrator. The distance from the shadow cone is determined at each compute step. Tests are made to determine of the shadow cone was crossed or a minimum to the cone passed on the last step. If one of these conditions is satisfied, an iteration is made to find the time of crossing. The iteration consists of a Newton-Raphson hunt to find the time which results in the spacecraft's position at the shadow cone. During this hunt, the spacecraft's position is determined by interpolation. This shadow scheme can not be used with the averaging methods or multiconic. This method is also used to determine occultation times. The flag in location 1034 is used to select this option. The flag is set to the planet number where the observer is located.

The other shadow method uses the osculating orbit to determine the intersection of the orbit with the shadow cone. The method uses the assumption that the osculating orbit will not change during one revolution. This method can be used with all of the trajectory propagation schemes; however, the orbit must neither impact nor escape the planet.

The flag in input location 1049 is used to select the desired shadow calculation technique.

3.9 Run Stopping Criteria

The run is stopped either by the time reaching the final time, location 4, or the spacecraft flying through closest approach to , or farthest distance from, the target planet. The flag in location 1032 indicates that a closest approach or farthest distance determination is desired. The 1079 flag determines whether it is to be closest approach or the farthest distance. The test for closest approach will not be attempted until the time since state epoch is greater than the time input in location 513.

3.10 Sample Case

A sample run using the trajectory propagator is shown in Figure 3.2. The first part of the figure is a listing of the input data cards. The sample shown uses position and velocity vectors as the initial spacecraft state loaded into locations 40 - 45. The epoch of the state is loaded into locations 50 - 55. The trajectory propagation scheme used was the NICE/MEAN method and the automatic compute interval option was specified by the inputs in locations 1 - 3.

The second part of this figure is the sample case output. The first part of the output presents a listing of the data cards read. This is followed by a complete listing of the input array including all of the program preset inputs. The trajectory output begins after the listing of the input array. This output consists of position and velocity vectors and magnitude in the designated coordinate systems. The orbital elements printed are semi-major axis, eccentricity, true anomaly, argument of perigee, inclination and longitude of the ascending node. The output frequency flag in location 1030 is preset to zero, thus only first and last points of the trajectory were printed. The run stopped at closest approach to the target planet (Moon) because the KCRASH flag is preset to 2.

Table 3.1

Trajectory Propagation Mode Inputs

MODE = 0

LOCATION	INITIALIZED VALUE	DESCRIPTION
1	0	error control limit
2	30	initial compute interval
3	30	minimum compute interval
4	540000	Run stop time
*30-35 or 40-45	-	initial s/c orbital elements or position and velocity vectors
38	333.40	initial s/c mass, kg
39	0	ephemeris time correction
47,48	-	s/c attitude, right ascension and declination
*50-55	-	epoch of s/c state
170-189	-	compute interval table
197	$4.7(10)^{-5}$	solar pressure at 1 au
198	.2	s/c reflectivity
200-380	-	s/c motor characteristics
430-432	-	engine impulsive velocities
433	13560	solar pressure area
450-469	-	print table
513	0	time to begin closest approach testing
*1001-1012	S, E, M	Planets in system
*1014	3	numerical integration scheme
*1015	3	launch planet number
*1017	5	ephemeris flag
1018	1	Earth oblateness flag
*1019	1	input coordinate system
1029	0	gravitational field flag

LOCATION	INITIALIZED VALUE	DESCRIPTION
1030	0	output frequency flag
1031	11	target planet number
1032	2	closest approach test flag
1035	0	gravitational model number
*1036-1038	4	trajectory propagation method
1039-1040	3, 2	output coordinate systems
1047	0	thrusting mode
1049	0	shadow flag
1058	0	auxiliary output flag
1059	0	type of auxiliary output
1068	6	number of ordinates used in averaging
1069	3	number of intervals used in averaging
1079	0	farthest approach flag
1084	0	solar pressure flag
1087	0	input attitude element set number
1088	12	unit number of attitude data
1089	1234567	satellite ID number
1090	0	director's display write
1094-1095	0, 0	maximum number of zonals and tesserals used in gravity model

* input required

TABLE 3.7

PRESET GRAVITY MODELS

HOUSTON L1 MODEL OF LUNAR FIELD, NMOD = 3, MMOD = 3

```
C( 2, J)= -0.2071D-03  0.0          0.2072D-04
C( 3, J)=  0.2100D-04  0.3400D-04   0.0          0.2583D-05
S( 2, J)=  0.0         0.0          0.0
S( 3, J)=  0.0         0.0          0.0          0.0
```

JPL 15-8 MODEL OF LUNAR FIELD, NMOD = 15, MMOD = 8

```
C( 2, J)= -0.1993D-03  0.8171D-05  0.2359D-04
C( 3, J)= -0.5878D-05  0.3001D-04  0.4698D-05  0.4947D-05
C( 4, J)=  0.1195D-04 -0.2226D-05 -0.2419D-05  0.2306D-06 -0.4547D-06
C( 5, J)= -0.4544D-05 -0.2455D-05  0.8880D-06 -0.7774D-06  0.1027D-06
          -0.3044D-09
C( 6, J)=  0.1088D-05 -0.6373D-05 -0.6917D-06 -0.2041D-06  0.4620D-07
          -0.7564D-08 -0.7277D-09
C( 7, J)=  0.1779D-04  0.1324D-05 -0.1293D-06 -0.1905D-06 -0.3523D-08
           0.6961D-08 -0.2937D-09  0.2454D-10
C( 8, J)= -0.5967D-05 -0.8040D-05  0.2659D-06 -0.6771D-07  0.1925D-07
           0.4944D-09  0.1252D-09 -0.4523D-10 -0.2178D-11
C( 9, J)= -0.3206D-05  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(10, J)=  0.1367D-05  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(11, J)= -0.7311D-05  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(12, J)=  0.1251D-04  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(13, J)= -0.3315D-04  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(14, J)=  0.1044D-04  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
C(15, J)= -0.2977D-04  0.0         0.0         0.0         0.0
           0.0         0.0         0.0         0.0
S( 2, J)=  0.0        -0.7213D-05  0.4538D-05
S( 3, J)=  0.0         0.1421D-05  0.5748D-06 -0.2919D-05
S( 4, J)=  0.0         0.3299D-05 -0.2389D-05 -0.6223D-06  0.4248D-06
S( 5, J)=  0.0        -0.6925D-05 -0.3178D-06  0.1159D-05  0.6296D-07
          -0.3012D-07
S( 6, J)=  0.0         0.5342D-05 -0.1157D-05 -0.3484D-06 -0.9870D-07
          -0.1654D-07  0.2373D-08
S( 7, J)=  0.0        -0.1579D-05  0.1152D-06  0.2440D-06  0.1295D-07
           0.5582D-08  0.1227D-08 -0.9131D-10
S( 8, J)=  0.0         0.6208D-05 -0.1767D-06 -0.1437D-06 -0.1757D-07
           0.2391D-08 -0.2390D-09 -0.5913D-10  0.7798D-11
```

TABLE 3.2 (CONT)

MARS FIELD-POST MARINER 1971, NMOD = 4, MMOD = 3

C(2, J)=	-0.1960D-02	0.0	-0.5400D-04	
C(3, J)=	-0.3050D-04	0.2770D-05	0.0	0.0
C(4, J)=	-0.3140D-04	0.0	0.0	0.0
S(2, J)=	0.0	0.0	0.2900D-04	
S(3, J)=	0.0	0.2500D-04	0.0	0.0

Table 3.3

Preset Physical Constants

PLANET	GRAVITATIONAL COEFFICIENT (KM^3/SEC^2)	MEAN RADIUS (KM)	ROTATION RATE (RAD/SEC)	SPHERE OF INFLUENCE (KM)
Mercury	2.168553×10^4	2.329816×10^3	0.	0.
Venus	3.24853×10^5	6.098636×10^3	0.	6.16×10^5
Earth	3.986008×10^5	6.37814×10^3	$7.29212361 \times 10^{-5}$	9.25×10^5
Mars	4.2915515×10^4	3.40953×10^3	7.0882×10^{-5}	5.65×10^5
Jupiter	1.267106×10^8	6.98389×10^4	1.758549×10^{-4}	4.8×10^7
Saturn	3.791869×10^7	5.7505×10^4	0.	5.4×10^7
Uranus	5.80329×10^6	2.5484×10^4	0.	5.1×10^7
Neptune	7.02607×10^6	2.4983×10^4	0.	8.6×10^7
Pluto	3.31788×10^5	6.3450×10^3	0.	3.33×10^7
Sun	1.3271545×10^{11}	7.06×10^5	0.	$1. \times 10^{10}$
Moon	4.902778×10^3	1.73809×10^3	2.6616995×10^{-6}	1.1×10^5
Oddball	0.	0.	0.	0.

Table 3.3 (CONT'D)

Preset Observation Stations

STATION NAME	LONGITUDE*	LATITUDE*
JOHANNESBURG	27.707280	-25.735782
TANANARIVE	47.303168	-18.903224
CARNARVON	113.716372	-24.757607
ORRORAL	148.956961	-35.448009
FAIRBANKS	-147.511732	64.823643
ROSMAN	-82.876093	35.013815
GREENBELT	-76.842965	38.810366
SANTIAGO	-70.666519	-32.975938

* geocentric

FIGURE 3.1

TRAJECTORY PROPAGATION SAMPLE CASE

INPUT DATA CARDS

```
   50 6.                 51 10.                52 1973.
   53 15.                54 14.                55 43.268
   40 1051.8313          41 5932.0483          42 2604.2559
   43-10.127676          44 3.0265591          45-2.8035218
    1 .0001               2 30.                 3 20.
 1036 4.
```

MAESTRO OUTPUT

DATA CARDS FOR CASE 1

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.100000000D 01	25	0.325000000D 01
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.432680000D 02
40	0.105183130D 04	41	0.593204830D 04	42	0.260425590D 04
43	-0.101276760D 02	44	0.302655910D 01	45	-0.280352180D 01
1	0.100000000D-03	2	0.300000000D 02	3	0.200000000D 02
1036	0.400000000D 01	0	0.0	0	0.0

LUNAR FIELD, NMOD= 0 MMOD=***

INITIAL JULIAN DATE 2441844.1352

INPUT COMMON

1	0.100000000D-03	2	0.300000000D 02	3	0.200000000D 02
4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.100000000D 01	25	0.325000000D 01	37	0.418441257D 05
38	0.333390000D 03	40	0.105183130D 04	41	0.593204830D 04
42	0.260425590D 04	43	-0.101276760D 02	44	0.302655910D 01
45	-0.280352180D 01	46	0.418441352D 05	47	0.163361728D 03
48	-0.148544293D 02	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.432680000D 02	100	0.216855300D 01	101	0.324835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816503D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.709820000D-04	128	0.175854900D-03	134	0.266169950D-05
170	0.360000000D 04	171	0.180000000D 05	172	0.100000000D 20
180	0.300000000D 03	181	0.180000000D 04	182	0.180000000D 05
197	0.470000000D-04	198	0.210000000D 00	201	0.900000000D 03
202	0.200000000D 05	221	0.190000000 02	222	0.200000000D 02
260	0.533784000D 02	261	0.266892000D 02	262	0.266892000D 02
280	-0.978500000D 04	281	-0.978500000D 04	321	0.900000000D 03
322	0.200000000D 05	331	0.190000000D 02	332	0.200000000D 02
350	0.240400000D-01	351	0.120200000D-01	352	0.120200000D-01
360	0.353200000D 01	361	0.353200000D 01	380	0.100000000D 21
381	0.100000000D 21	382	0.100000000D 21	383	0.100000000D 21
384	0.100000000D 21	385	0.100000000D 21	407	0.580000000D 00

408	0.136000000D 09	409	0.400000000D 09	410	0.483582263D 00
411	0.825596028D 00	412	0.193472510D 01	413	0.259978941D 01
414	0.379361990D 01	415	0.483672461D 01	416	0.434202256D 01
417	0.504982188D 01	420	0.283800000D 04	421	0.116500000D 03
422	0.396000000D 06	423	0.620000000D 00	433	0.135500000D 05
434	0.720000000D 04	435	0.700000000D 00	436	0.200000000D-01
437	0.700000000D-01	438	0.300000000D-03	439	0.360000000D 05
440	0.259200000D 06	441	0.226000000D 03	442	0.282500000D 03
443	0.705792000D 02	444	0.283800000D 04	445	0.131435176D 01
446	0.116500000D 02	447	0.600000000D 04	448	0.600000000D 04
459	0.100000000D 21	460	0.180000000D 05	470	0.600000000D 01
471	0.167800000D 00	472	0.204000000D 02	473	0.123377000D 02
474	0.500000000D 01	475	0.200000000D 02	478	0.720000000D 04
479	0.300000000D-03	480	-0.449174131D 00	481	-0.329923498D 00
482	-0.432101757D 00	483	-0.619684470D 00	484	0.113138600D 01
485	0.611106355D 00	486	0.677368671D 00	487	-0.575538692D 00
490	0.100000000D 02	491	0.100000000D 02	492	0.100000000D 02
493	0.100000000D-03	494	0.100000000D-03	495	0.200000000D-01
496	0.500000000D 01	497	0.200000000D 00	501	0.616000000D 06
502	0.925000000D 06	503	0.565000000D 06	504	0.480000000D 08
505	0.540000000D 03	506	0.510000000D 08	507	0.860000000D 08
508	0.330000000D 08	509	0.100000000D 11	510	0.110000000D 06
1009	0.200000000D 01	1010	0.100000000D 01	1011	0.200000000D 01
1014	0.300000000D 01	1015	0.300000000D 01	1017	0.500000000D 01
1018	0.100000000D 01	1019	0.100000000D 01	1023	0.100000000D 01
1031	0.110000000D 02	1032	0.200000000D 01	1035	0.100000000D 01
1036	0.400000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.100000000D 02	1042	0.150000000D 02	1043	0.210000000D 02
1048	0.100000000D 01	1051	0.100000000D 02	1052	0.200000000D 01
1053	0.500000000D 02	1054	0.170000000D 02	1055	0.100000000D 01
1060	0.100000000D 01	1061	0.110000000D 02	1062	0.200000000D 01
1063	0.200000000D 01	1064	0.100000000D 01	1065	0.100000000D 02
1066	0.100000000D 01	1067	0.100000000D 03	1068	0.600000000D 01
1069	0.300000000D 01	1070	0.950000000D 02	1071	0.600000000D 01
1075	0.600000000D 01	1083	0.110000000D 02	1088	0.120000000D 02
1089	0.123456700D 07				

```
TIME=     0.0
 EARTH                MEAN EQUATOR AND EQUINOX OF 1950
      0.10518313D 04      0.59320483D 04      0.26042559D 04      0.65633600D 04
     -0.10127676D 02      0.30265591D 01     -0.28035218D 01      0.10935704D 02
ORBITAL ELEMENTS W.R.T.  EARTH
     0.21275440D 06      0.96915053D 00     -0.60795360D-07      0.12286650D 03
      0.28190248D 02     -0.46298148D 02
  MOON                TRUE EQUATOR AND PRIME MERIDIAN
      0.39482691D 06      0.48300479D 05      0.45751978D 05      0.40039290D 06
     -0.92660062D 01      0.52873023D 01     -0.40638106D 01      0.11416172D 02
ORBITAL ELEMENTS W.R.T.   MOON
     -0.37625544D 02      0.65905817D 04     -0.51744050D 02      0.21686032D 03
      0.26414798D 02     -0.15963664D 03
    0     4
CLOSEST APPROACH TO TARGET PLANET
TIME=  110.0075
 EARTH                MEAN EQUATOR AND EQUINOX OF 1950
     -0.95471364D 05     -0.35863126D 06     -0.16807776D 06      0.40740802D 06
     -0.37932812D 00      0.91152741D 00     -0.10228497D 01      0.14216165D 01
ORBITAL ELEMENTS W.R.T.  EARTH
     -0.62071096D 07      0.10629573D 01     -0.22956473D 02      0.22962048D 03
      0.11317251D 03      0.86270685D 02
  MOON                TRUE EQUATOR AND PRIME MERIDIAN,
      0.33254056D 00      0.14054162D 01     -0.14168534D 01      0.20231786D 01
ORBITAL ELEMENTS W.R.T.   MOON
     -0.79359554D 04      0.13555174D 01      0.17207320D-01      0.14114581D 03
      0.11594837D 03     -0.74796668D 02
  367     4
NO MORE DATA, RUN TERMINATED
```

Section 4

RETRO-FIRE ANALYSIS MODE

This mode is used to determine the retro motor's firing time and attitude. When the MODE flag is set to one, the entire analysis is performed using numerical integration. MODE set to 2 option uses some conic approximations to propagate the state. See reference 1 for a detailed description of the approximations.

The retro motor's firing time and attitude are determined by making repeated trial retro firings at various times and attitudes. The firing times and attitudes are scanned in a systematic order so that displays can be presented. The user can then select the desired firing time and attitude by studying the displays. The analysis mode does not automatically select a firing time or attitude.

The user has three available options to scan the firing time and attitude space.

The desired option is selected through the KAPOPT flag as follows:

KAPOPT = 1. Firings are made between an input range of true anomaly about perigee on the approach hyperbola. The number of firings is determined by the KFIRE input in location 1043. The attitude range is an input cone angle about the initial right ascension and declination in locations 403 and 404. If these values are zero, the cone is centered about the velocity vector at the final time.

2. Firings are made from asymptote to asymptote on the approach hyperbola. The number of firings is selected by the KFIRE input in location 1043. The attitude range is input through initial right ascension and declination, increment in right ascension and declination, and number of right ascensions and declinations to be tried. These values are input via locations 403 to 406 and 1041 to 1042. If locations 403 and 404 are both zero, the initial right ascension and declination is defined by the velocity vector at closest approach to the target planet.

3. Firings are made between input times from liftoff. The firings are made between the initial time in location 400 and the last

time in location 401. When MODE = 2, the range is divided into KFIRE steps of constant true anomaly in the range. When MODE = 1, the range is divided into KFIRE number of equal time steps. The attitude range is input the same as described in 2.

If MODE = 1 option is used, KAPOPT ≐ 3 must also be used.

When the retro motor is to be numerically integrated (MODE = 1), its thrust and weight characteristics should be loaded into engine number two.

The RAE-B retro-motor characteristics are pre-set in engine 2. Table 4.1 presents these characteristics.

This mode has the ability to save the post-retro state on an auxiliary unit for use in other analyses. The flag in location 1082 controls this option. It is set to the desired unit number.

If the flag in location 1092 is nonzero, the post-retro state for every firing will be written on an auxiliary unit using subroutine PUTELS for retrieval by the GTDS program.

The inputs preset in the trajectory Propagation Mode also must apply in this mode. Table 4.2 presents the necessary inputs for an approach analysis plus the preset value of the inputs pertinent to this mode. Notice that it is possible to obtain the initial state from the previous Midcourse Correction Analysis. This is accomplished by setting KREAD (location 1057) to the midcourse number of the desired execution time. A sample approach analysis is shown in Figure 4.1. The first part of this figure contains the input data. For this run, it consists of the initial date, MODE set to 2 for an approach analysis, and the KREAD flag set to 2 to pick the initial conditions at the second midcourse execution time. The second part of this figure is the approach analysis output. A listing of the input is presented first. This is followed by the input array with the preset values. The approach analysis output shown is the minimum eccentricity grid and minimum trim fuel grid. The value in the first grid is the minimum lunar orbit eccentricity for all the firings made at the indicated attitude. The value in the second grid is the minimum trim fuel required to obtain the desired lunar orbit for all firings made at the indicated attitude. The desired lunar orbit is defined as a circular orbit at the radius and inclination with respect to lunar equator described in locations 444 and 446. Thus a quick scan of this grid should indicate a range of desired attitudes.

A second sample of the approach analysis is shown in Figure 4.2. This run is similar to the last except that the KAPOUT flag (1046) is set to one and fewer attitudes are studied. The KAPOUT flag set to one will print information about each firing on the approach hyperbolas. The fewer attitudes were used to reduce the output. If a 15 x 10 grid were used, as in the first run, 150 pages would be printed. The output from this run is similar to the other runs in that both the input cards and input array is presented. The next part is a firing time analysis at the attitude shown. This output presents information about the lunar orbit for each firing time. This output is divided into two parts for easier readability. The first part contains

FIRING TIME	Time the retro is fired, time since liftoff
NEXT SHADOW	Time until shadow. If this quantity is negative,it is the time until there is no shadow.
SHAD FREE TIME	Time between shadows
DELTA V TRIM	Trim maneuver to correct the inclination to the desired value and circularize at the desired radius.
TRIM FUEL	Fuel used in the trim maneuver.
NORMAL VECTOR RT. ASC DEC	The right ascension and declination of a vector normal to the orbit plane in mean Earth equator and equinox of 1950.

The second part contains the elements of the post-retro lunar state with respect to the true lunar equator and node at the time of closest approach.

FIRING TIME	Time the retro is fired, time since liftoff
SEM	Semi-major axis of the lunar orbit.
ECC	Eccentricity of the lunar orbit.

TRUE ANOMALY	True anomaly of the spacecraft in the orbit.
AOP	Argument of pericynthion
INCLIN	Inclination of the lunar orbit to the lunar equator.
LON	Longitude of the ascending node.

Table 4.1

Retro Motor Thrust/Weight Characteristics

Time since ignition (sec)	Thrust (Newtons)	Mass flow rate (KG/SEC)
0	-9785.0	3.532
19	-9785.0	3.532
20	0	0

Table 4.2

Retro Fire Analysis Mode *

MODE = 1 or 2

LOCATION	INITIALIZED VALUE	DESCRIPTION
20-25	-	liftoff epoch
**30-35, 40-45 or 1057	-	initial state
220-386	-	retro motor in engine 2 for MODE = 1
400	-	initial firing time
401	-	final firing time
402	-	increment between firings
403	-	initial right ascension
404	-	initial declination
**405	-	increment in right ascension
**406	-	increment in declination
407	.68	impulsive velocity of retro
410-419	-	observation site longitude
**441	226	midcourse motor ISP
**442	282.5	retro motor ISP
**443	71.11	mass of retro fuel
**444	2838	desired final orbit radius
**446	59.0	desired final orbit inclination
473	13.77	retro drop weight
474	5	attitude cone angle
475	20	true anomaly firing range
480-489	-	observation site latitude

LOCATION	INITIALIZED VALUE	DESCRIPTION
512	0	retro motor burn time
**1016	2	retro motor number
**1041	10	number of right ascensions
**1042	15	number of declinations
**1043	20	number of firings
**1044	-	mode flag set to 2
1046	0	firing analysis output flag
1048	1	Lunar orbit shadow flag
**1055	1	approach analysis option flag
1061	11	midcourse auxiliary unit number
1076	-	Element set no. of state from GTDS
1081	0	no. of revolutions before firing analysis
1082	0	auxiliary approach analysis write set to unit no. for write
1087	-	Element set no. of input attitude data
1088	12	attitude unit number
1089	1234567	satellite ID number
1092	-	Element set no. of write for GTDS

* inputs for trajectory propagation also set

** required inputs

FIGURE 4.1

RETRO MOTOR DETERMINATION SAMPLE CASE
MINIMUM ECCENTRICITY AND MINIMUM FUEL GRIDS

INPUT CARDS

```
  20 6.          21 10.         22 1973.
  23 15.         24 1.          25 3.25
  50 6.          51 10.         52 1973.
  53 15.         54 14.         55 43.268
1057 1.        1044 2.
```

MAESTRO OUTPUT

```
DATA CARDS FOR CASE   2
   20   0.600000000D 01   21  0.100000000D 02   22   0.197300000D 04
   23   0.150000000D 02   24  0.100000000D 01   25   0.325000000D 01
   50   0.600000000D 01   51  0.100000000D 02   52   0.197300000D 04
   53   0.150000000D 02   54  0.140000000D 02   55   0.432680000D 02
 1057   0.100000000D 01 1044  0.200000000D 01    0   0.0
LUNAR FIELD, NMOD=***  MMOD=***

INITIAL JULIAN DATE 2441844.1352
   INPUT COMMON
    4   0.540000000D 06    5   0.100000000D 01    6   0.100000000D 01
    8   0.100000000D-10   10   0.100000000D 21   20   0.600000000D 01
   21   0.100000000D 02   22   0.197300000D 04   23   0.150000000D 02
   24   0.100000000D 01   25   0.325000000D 01   37   0.418441257D 05
   38   0.333390000D 03   40   0.105183130D 04   41   0.593204830D 04
   42   0.260425590D 04   43  -0.101415680D 02   44   0.303071049D 01
   45  -0.280736700D 01   46   0.418441352D 05   47   0.163361728D 03
   48  -0.148544276D 02   50   0.600000000D 01   51   0.100000000D 02
   52   0.197300000D 04   53   0.150000000D 02   54   0.140000000D 02
   55   0.432680000D 02  100   0.216855300D 01  101   0.324835400D 06
  102   0.399603200D 06  103   0.429155150D 05  104   0.126710600D 09
  105   0.379136900D 08  109   0.132715450D 12  110   0.490277790D 04
  112   0.232931600D 04  113   0.609863600D 04  114   0.637816503D 04
  115   0.340953000D 04  116   0.714220000D 05  117   0.575050000D 05
  118   0.254840000D 05  119   0.249830000D 05  120   0.634500000D 04
  121   0.706000000D 06  122   0.173800000D 04  126   0.729212361D-04
  127   0.708820000D-04  128   0.175854900D-03  134   0.266169950D-05
  170   0.360000000D 04  171   0.180000000D 05  172   0.100000000D 20
  180   0.300000000D 03  181   0.180000000D 04  182   0.180000000D 05
  197   0.470000000D-04  198   0.210000000D 00  201   0.900000000D 03
  202   0.200000000D 05  221   0.190000000D 02  222   0.200000000D 02
  260   0.533784000D 02  261   0.266892000D 02  262   0.266892000D 02
  280  -0.978500000D 04  281  -0.978500000D 04  321   0.900000000D 03
  322   0.200000000D 05  331   0.190000000D 02  332   0.200000000D 02
```

350	0.240400000D-01	351	0.120200000D-01	352	0.121200000D-01
360	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
381	0.100000000D 21	382	0.100000000D 21	383	0.100000000D 21
384	0.100000000D 21	385	0.100000000D 21	407	0.68[illegible]D 00
408	0.136000000D 09	409	0.400000000D 09	410	0.483583263D 00
411	0.825596028D 00	412	0.198472510D 01	413	0.259978941D 01
414	0.370861990D 01	415	0.483672461D 01	416	0.494202256D 01
417	0.504982188D 01	420	0.283800000D 04	421	0.116500000D 03
422	0.396000000D 06	423	0.620000000D 00	433	0.135600000D 05
434	0.720000000D 04	435	0.700000000D 00	436	0.200000000D-01
437	0.700000000D-01	438	0.300000000D-03	439	0.360000000D 05
440	0.259200000D 06	441	0.226000000D 03	442	0.282500000D 03
443	0.705792000D 02	444	0.283800000D 04	445	0.131436176D 01
446	0.116500000D 03	447	0.600000000D 04	448	0.600000000D 04
450	0.100000000D 21	460	0.180000000D 05	470	0.600000000D 01
471	0.167800000D 00	472	0204000000D 02	473	0.123377000D 02
474	0.500000000D 01	475	0.200000000D 02	478	0.720000000D 04
479	0.300000000D-03	480	-0.449174131D 00	481	-0.329923498D 00
482	-0.432101751D 00	483	-0.618684470D 00	484	0.113138600D 01
485	0.611106355D 00	486	0.677368671D 00	487	-0.575538692D 00
490	0.100000000D 02	491	0.100000000D 02	492	0.100000000D 02
493	0.100000000D-03	494	0.100000000D-03	495	0.200000000D-01
496	0.500000000D 01	497	0.200000000D 00	501	0.616000000D 06
502	0.925000000D 06	503	0.565000000D 06	504	0.480000000D 08
505	0.540000000D 08	506	0.510000000D 08	507	0.860000000D 08
508	0.330000000D 08	509	0.100000000D 11	510	0.110000000D 06
1003	0.200000000D 01	1010	0.100000000D 01	1011	0.200000000D 01
1014	0.300000000D 01	1015	0.300000000D 01	1017	0.500000000D 01
1018	0.100000000D 01	1019	0.100000000D 01	1023	0.100000000D 01
1031	0.110000000D 02	1032	0.200000000D 01	1035	0.100000000D 01
1036	0.400000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.100000000D 02	1042	0.150000000D 02	1043	0.210000000D 02
1044	0.200000000D 01	1048	0.100000000D 01	1051	0.500000000D 01
1052	0.200000000D 01	1053	0.500000000D 02	1054	0.170000000D 02
1055	0.100000000D 01	1057	0.100000000D 01	1060	0.100000000D 01
1061	0.110000000D 02	1062	0.200000000D 01	1063	0.200000000D 01
1064	0.100000000D 01	1065	0.100000000D 02	1066	0.100000000D 01
1067	0.100000000D 03	1068	0.600000000D 01	1069	0.300000000D 01
1070	0.950000000D 02	1071	0.600000000D 01	1075	0.600000000D 01
1077	0.200000000D 01	1083	0.110000000D 02	1088	0.120000000D 02
1089	0.123456700D 07				

ATTITUDE SCAN

MINIMUM ECCENTRICITY

ANCHOR VECTOR EPOCH
15.HR 14.MIN 43.268SEC

CURRENT ATTITUDE
R.A.= 163.36 DEC.= -14.95

DEC	R.A. 135.1	136.1	137.1	138.1	139.1	140.1	141.1	142.1	143.1	144
-28.74	0.0686	0.0669	0.0656	0.0649	0.0652	0.0656	0.0668	0.0688	0.0709	0.07
-29.40	0.0676	0.0656	0.0645	0.0635	0.0635	0.0640	0.0649	0.0668	0.0690	0.071
-30.07	0.0669	0.0647	0.0634	0.0625	0.0621	0.0628	0.0635	0.0650	0.0672	0.069
-30.74	0.0665	0.0641	0.0625	0.0619	0.0611	0.0615	0.0623	0.0636	0.0657	0.06
-31.40	0.0661	0.0639	0.0620	0.0611	0.0605	0.0605	0.0615	0.0625	0.0543	0.066
-32.07	0.0661	0.0639	0.0619	0.0607	0.0602	0.0599	0.0606	0.0618	0.0633	0.065
-32.74	0.0663	0.0639	0.0621	0.0606	0.0600	0.0597	0.0601	0.0613	0.0626	0.06
-33.40	0.0669	0.0643	0.0625	0.0608	0.0599	0.0599	0.0599	0.0608	0.0623	0.06
-34.07	0.0678	0.0650	0.0629	0.0614	0.0603	0.0600	0.0601	0.0607	0.0622	0.063
-34.74	0.0689	0.0660	0.0637	0.0623	0.0610	0.0604	0.0607	0.0610	0.0622	0.06
-35.40	0.0701	0.0673	0.0648	0.0631	0.0620	0.0612	0.0612	0.0616	0.0625	0.06
-36.07	0.0715	0.0689	0.0662	0.0643	0.0633	0.0623	0.0620	0.0626	0.0632	0.064
-36.74	0.0733	0.0704	0.0680	0.0659	0.0645	0.0637	0.0632	0.0635	0.0643	0.06
-37.40	0.0753	0.0723	0.0700	0.0677	0.0662	0.0654	0.0647	0.0648	0.0656	0.06
-38.07	0.0776	0.0745	0.0720	0.0698	0.0681	0.0671	0.0666	0.0664	0.0670	0.06

ATTITUDE SCAN

MINIMUM TRIM FUEL

ANCHOR VECTOR EPOCH
15.HR 14.MIN 43.268SEC

CURRENT ATTITUDE
R.A.= 163.36 DEC.= -14.95

DEC	R.A. 135.1	136.1	137.1	138.1	139.1	140.1	141.1	142.1	143.1	144
-28.74	21.09	20.72	20.36	19.98	19.64	19.28	18.95	18.61	18.31	18.0
-29.40	20.58	20.20	19.82	19.44	19.09m	18.72	[illegible]	18.04	17.74	17.4
-30.07	20.08	19.69	19.30	18.92	18.55	18.18	17.83	17.49	17.16	16.
-30.74	19.60	19.20	18.79	18.40	18.02	17.65	17.29	16.94	16.61	16.2
-31.40	19.13	18.72	18.30	17.90	17.50	17.13	16.76	16.41	16.06	15.
-32.07	18.67	18.25	17.81	17.42	17.00	16.63	16.24	15.90	15.53	15.
-32.74	18.22	17.79	17.35	16.94	16.52	16.14	15.74	15.38	15.02	14.6
-33.40	17.80	17.35	16.90	16.48	16.05	15.65	15.26	14.88	14.53	14.1
-34.07	17.39	16.92	16.47	16.03	15.61	15.19	14.80	14.41	14.06	13.
-34.74	16.99	16.52	16.06	15.61	15.18	14.75	14.36	13.95	13.60	13.
-35.40	16.62	16.13	15.67	15.20	14.77	14.33	13.93	13.52	13.15	12.7
-36.07	16.26	15.76	15.30	14.91	14.38	13.93	13.51	13.11	12.72	12.
-36.74	15.92	15.41	14.93	14.45	14.00	13.55	13.12	12.72	12.32	11.
-37.40	15.59	15.07	14.59	14.10	13.64	13.19	12.75	12.35	11.94	11.5
-38.07	15.29	14.76	14.27	13.78	13.30	12.85	12.40	12.00	11.58	11.

NO MORE DATA, RUN TERMINATED

FIGURE 4.2

RETRO MOTOR DETERMINATION SAMPLE CASE
FIRING TIME ANALYSIS

INPUT CARDS

20	6.	21	10.	22	1973.
23	15.	24	1.	25	3.25
50	6.	51	10.	52	1973.
53	15.	54	14.	55	43.268
1041	1.	1042	1.	1046	1.
1057	1.	1044	2.		

MAESTRO ANALYSIS

DATA CARDS FOR CASE 2

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.100000000D 01	25	0.325000000D 01
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.432680000D 02
1041	0.100000000D 01	1042	0.100000000D 01	1046	0.100000000D 01
1057	0.100000000D 01	1044	0.200000000D 01	0	0.0

LUNAR FIELD, NMOKT) MMOD= 0

INITL JULIAN DATE 2441844.1352

INPUT COMMON

4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.100000000D 01	25	0.325000000D 01	37	0.418441257D 05
38	0.333390000D 03	40	0.105183130D 04	41	0.593204830D 04
42	0.260425590D 04	43	-0.101415680D 02	44	0.303071049D 01
45	-0.280736700D 01	46	0.418441352D 05	47	0.163361728D 03
48	-0.148544276D 02	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.432680000D 02	100	0.216855300D 01	101	0.324835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816503D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.709820000D-04	128	0.175854900D-03	134	0.266169950D-05
170	0.360000000D 04	171	0.180000000D 05	172	0.100000000D 20
180	0.300000000D 03	181	0.180000000D 04	182	0.180000000D 05
197	0.470000000D-04	198	0.210000000D 00	201	0.900000000D 03
202	0.200000000D 05	221	0.190000000D 02	222	0.200000000D 02
260	0.533784000D 02	261	0.266892000D 02	262	0.266892000D 02
280	-0.978500000D 04	281	-0.978500000D 04	321	0.900000000D 03
322	0.200000000D 05	331	0.190000000D 02	332	0.200000000D 02
350	0.240400000D-01	351	0.120200000D-01	352	0.120200000D-01

350	0.353200000D 01	361	0.353200000D 01	380	0.100000000D 21
381	0.100000000D 21	382	0.100000000D 21	[illegible]	[illegible]
384	0.100000000D 21	385	0.100000000D 21	407	0.680000010D 00
408	0.136000000D 09	409	0.400000000D 09	410	[illegible]
411	0.825596028D 00	412	0.199472510D 01	413	0.259978941D 01
414	0.370861390D 01	415	0.483672461D 01	416	0.494202256D 01
417	0.504982198D 01	420	0.283900000D 04	421	0.116500000D 03
422	0.396000000D 06	423	0.620000000D 00	433	0.135600000D 05
434	0.720000000D 04	435	0.700000000D 00	436	0.200000000D-01
437	0.700000000D-01	438	0.300000000D-03	439	0.360000000D 05
440	0.259200000D 06	441	0.226000000D 03	442	0.282500000D 03
443	0.705792000D 02	444	0.283800000D 04	445	0.131436176D 01
446	0.116500000D 03	447	0.600000000D 04	448	0.600000000D 04
450	0.100000000D 21	460	0.180000000D 05	470	0.600000000D 01
471	0.167800000D 00	472	0.204000000D 02	473	0.122377000D 02
474	0.500000000D 01	475	0.200000000D 02	478	0.720000000D 04
479	0.300000000D-03	480	-0.449174131D 00	481	-0.329923498D 00
482	-0.432101757D 00	483	-0.618684470D 00	484	0.113138600D 01
485	0.611106355D 00	486	0.677368671D 00	487	-0.575538602D 00
490	0.100000000D 02	491	0.100000000D 02	492	0.100000000D 02
493	0.100000000D-03	494	0.100000000D-03	495	0.200000000D-01
496	0.500000000D 01	497	0.200000000D 00	501	0.616000000D 06
502	0.925000000D 06	503	0.565000000D 06	504	0.480000000D 08
505	0.540000000D 03	506	0.510000000D 03	507	0.860000000D 08
508	0.330000000D 08	509	0.100000000D 11	510	0.110000000D 06
1003	0.200000000D 01	1010	0.100000000D 01	1011	0.200000000D 01
1014	0.300000000D 01	1015	0.300000000D 01	1017	0.500000000D 01
1018	0.100000000D 01	1019	0.100000000D 01	1023	0.100000000D 01
1031	0.110000000D 02	1032	0.200000000D 01	1035	0.100000000D 01
1036	0.400000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.100000000D 01	1042	0.100000000D 01	1043	0.210000000D 02
1044	0.200000000D 01	1046	0.100000000D 01	1048	0.100000000D 01
1051	0.500000000D 01	1052	0.200000000D 01	1053	0.500000000D 02
1054	0.170000000D 02	1055	0.100000000D 01	1057	0.100000000D 01
1060	0.100000000D 01	1061	0.110000000D 02	1062	0.200000000D 01
1063	0.200000000D 01	1064	0.100000000D 01	1065	0.100000000D 02
1066	0.100000000D 01	1067	0.100000000D 03	1068	0.600000000D 01
1069	0.300000000D 01	1070	0.950000000D 02	1071	0.600000000D 01
1075	0.600000000D 01	1077	0.200000000D 01	1083	0.110000000D 02
1088	0.120000000D 02	1089	0.123456700D 07		

APPROXIMATE APPROACH ANALYSIS

ANCHOR VECTOR EPOCH
15.HR 14.MIN 43.268SEC

DEC.	R.A.
-38.071	135.065

FIRING TIME (HR)	NEXT SHADOW (DAYS)	SHAD FREE TIME (DAYS)	DELTA V TRIM (M/SEC)	TRIM FUEL (KG)	NORMAL VECTOR RT ASC (DEG)	NORMAL VECTOR DEC (DEG)
109.930	63.76	114.10	164.50	17.44	-91.07	-45.24
109.943	63.49	113.47	159.39	16.9	-91.04	-45.26
109.955	63.24	112.89	154.71	16.44	-91.01	-45.29
109.968	63.02	112.36	150.62	16.02	-90.98	-45.32
109.980	62.82	111.87	147.29	15.67	-90.95	-45.35
109.992	62.64	111.44	144.89	15.43	-90.92	-45.37
110.004	62.49	111.05	143.60	15.29	-90.89	-4[illegible].40
110.017	62.37	110.72	143.53	15.29	-90.86	-45.42
110.029	62.26	110.44	144.69	15.40	-90.82	-45.45
110.041	62.19	110.21	146.99	15.64	-90.79	-45.47
110.053	62.14	110.03	150.30	15.98	-90.75	-45.49
110.065	62.11	109.90	154.42	16.40	-90.71	-45.52
110.077	62.11	109.83	159.19	16.89	-90.68	-45.54
110.089	62.13	109.81	[illegible]3.79	17.36	-90.64	-45.56
110.101	62.18	109.84	168.80	17.88	-90.60	-45.58
110.113	62.26	109.93	174.13	18.42	-90.56	-45.61
110.126	62.36	110.07	179.71	18.98	-90.52	-45.63
110.138	62.48	110.26	185.45	19.57	-90.48	-45.65
110.151	62.63	110.51	191.33	20.16	-90.44	-45.67
110.163	62.81	110.81	197.30	20.76	-90.39	-45.68
110.176	63.01	111.15	203.32	21.37	-90.35	-45.70

ORBITAL ELEMENTS OF PRETRIM LUNAR ORBIT

FIRING TIME (HR)	SEM (KM)	ECC	TRUE ANOMALY (DEG)	AOP (DEG)	INCLIN (DEG)	LON (DEG)
109.930	3071.1	0.11786	-38.52	161.69	112.04	-98.54
109.943	3041.3	0.10834	-33.56	158.64	112.06	-98.52
109.955	3014.2	0.09966	-27.76	154.76	112.09	-98.50
109.968	2990.0	0.09203	-21.02	149.93	112.12	-98.47
109.980	2968.3	0.08574	-13.25	144.07	112.14	-98.45
109.992	2949.2	0.08106	-4.50	137.23	112.17	-98.42
110.004	2932.5	0.07829	5.04	129.61	112.19	-98.40
110.017	2918.3	0.07761	14.96	121.61	112.22	-98.37
110.029	2906.4	0.07905	24.76	113.71	112.24	-98.35
110.041	2896.8	0.08250	33.98	106.41	112.26	-98.32
110.053	2889.6	0.08768	42.31	100.00	112.29	-98.29
110.065	2884.5	0.09431	49.62	94.60	112.31	-98.26
110.077	2881.8	0.10207	55.94	90.20	112.33	-98.23
110.089	2881.2	0.11072	61.36	86.69	112.35	-98.20
110.101	2882.9	0.12004	66.02	83.95	112.37	-98.17
110.113	2886.8	0.12988	70.04	81.84	112.39	-98.14
110.126	2892.9	0.14010	73.53	80.27	112.41	-98.11
110.138	2901.2	0.15061	76.59	79.13	112.43	-98.08
110.151	2912.0	0.16135	79.29	78.35	112.45	-98.05
110.163	2925.1	0.17224	81.69	77.97	112.47	-98.03

Section 5

MIDCOURSE ANALYSIS MODE

The midcourse analysis mode is designed to present to the user displays from which he can select the "best" correction according to his needs and constraints. The core of the midcourse analysis mode is a group of subroutines used to determine the correction at a specified place on the transfer trajectory which satisfies input end conditions, see reference 1. Logic was built around those subroutines so that certain control variables can be varied in order to automatically scan the control variable space.

The KTF flag is used to determine the type of scan, and hence, the type of displays to be printed. This flag is defined as follows:

KTF = 0	A one-dimensional scan of midcourse execution time. The initial time is loaded into 478, the increment in 434, and the number of execution times in 1051.
> 0	Two-dimensional scan of midcourse execution times and flight times. Execution scan is defined as above. The flight times are scanned in KTF one-hour steps beginning at the desired flight time in location 422. Fixed time of arrival guidance must also be specified.
< 0	Fixed attitude scan. A two-dimensional scan of midcourse execution times and midcourse impulsive velocities at a fixed attitude input via locations 47 and 48. The impulsive velocity is varied about the velocity input in location 426, in -KTF steps of size equal to the value in location 479. The attitude can be systematically varied about the input attitude if desired. The number of attitude steps are input in 1041 and 1042. The attitude range is input in 474. When this logic is used, the attitude is varied

around a cone whose half angle is input in location 474. The cone is centered at the input attitude.

Besides the scan option listed above, the user also has the option of selecting one of five guidance laws. The user selects the desired law through the KGLAW input (location 1063) as follows:

KGLAW = 1	Minimum fuel. This is a critical plane maneuver correcting only B·T and B·R (*).
KGLAW = 2	Fixed time of arrival. This corrects B·T, B·R (*) and time of flight to the desired values.
KGLAW = 3	Fixed Target Energy. This corrects B·T, B·R (*) and energy on the mean passage hyperbola to the desired values.
KGLAW = 4	Variable Target Energy. This corrects B·T, B·R (*) and the energy in lunar orbit to a desired value. The lunar orbit is determined by firing a retro motor at the perigee point of the passage hyperbola along the velocity vector.
KGLAW = 5	Minimum Total Fuel. This corrects B·T B·R (*) while minimizing the total midcourse and trim fuel expenditure by optimizing retro orientation and firing time.

The desired end conditions can be adjusted if a retro overburn exists. An overburn occurs when the available retro velocity is greater than the velocity to circularize at the desired radius. When this condition exists, it is necessary to use up the extra velocity in some way to avoid a post-retro maneuver. Two methods are available to the user. They are called the variable inclination procedure and the variable periapsis procedure. These procedures are described in detail in reference 1. Simply, the variable inclination method adjusts the aiming point so that an out-of-plane retro burn at periapsis of the approach hyperbola will result in a circular orbit at the desired radius. In the variable periapsis procedure, the periapsis radius is adjusted so that an in-plane retro firing at the desired radius will result in a circular orbit at the desired radius. The IVTI flag is used to select either of these procedures as follows:

(*) or, alternatively, radius of closest approach and inclination

IVTI = 0	in-plane retro maneuver antiparallel to velocity vector at periapsis.
= ± 1	Variable inclination procedure approaching above or below desired inclination.
= ± 2	Variable periapsis procedure circularizing in-plane before or after periapsis.

It should be noted that none of these options are executed when the NORMIN flag (location 1080) is non-zero. In this case, the retro-maneuver is determined from a steepest ascent optimization procedure. This procedure is explained in reference 1.

The IBURN flag in location 1070 is used to select the method in which the midcourse motor is applied. The number of this flag corresponds to the trajectory propagation method defined in location 1036. Any of the methods may be used except the averaging techniques (input value of 5 or 8). It is suggested that Cowell be used when an accurate simulation is required. When less accurate simulations are required, multi-conic or impulsive velocity can be used. Impulsive velocity is specified by a zero setting of the flag. The midcourse motor's thrust and weight expended histories are input in engine number 1. The values for the RAE-B midcourse motor are pre-initialized in MAESTRO. These values are shown in Table 5.1. The impulsive velocity of the midcourse motor is determined from the standard rocket equation. The mass and specific impulse input via locations 38 and 441 are used in this equation.

The size of the midcourse velocity step in the midcourse determination is limited in order to help ensure convergence. The maximum step is the product of the limiting factor in location 1067 and the partial derivative step in location 479.

Information about the midcourse correction at each execution time is stored on an auxiliary I/O unit. This unit number is input via location 1061. This input must correspond to a unit defined with the proper JCL. This information is retrieved in other analysis modes.

The inputs preset in the Trajectory Propagation Mode are also preset for this mode. A guide for the use of this mode is shown in Table 5.2. This table presents the inputs pertinent to the Midcourse Analysis Mode.

A sample of the Midcourse Analysis is shown in Figure 5.1. The first part of this figure is the input data. For this run, the initial state is loaded as position and velocity vectors in locations 40-45. The initial date is in locations 50-55. The KGLAW flag in 1063 is set for fired time of arrival guidance and the MODE flag in 1044 is set to 3 for Midcourse Analysis. The KTF flag (location 1077) is set to 2 to obtain a scan at two flight times.

The first part of the program output, second part of Figure 5.2, consists of a listing of the input cards followed by a listing of the input array including the preset values. The midcourse analysis output follows the listings of the input array. A line of information is printed for each execution time and flight time. Since it was necessary to abbreviate the titles, a description follows:

MC NO	Midcourse number
TIME	Execution time. Time since liftoff.
MAG	Magnitude of the midcourse correction.
FUEL	Fuel required for the midcourse maneuver.
BURN TIME	Midcourse motor burn time.
R.A. DEC.	Right ascension and declination of the correction velocity in the Earth mean equator and equinox of 1950.
SPIN-SUN	Spin axis-Sun angle. Angle between the Sun and the spin axis when the maneuver is applied.
MIN SUN	Minimum angle between the spin axis and the Sun during the reorientation to the midcourse attitude.
ATT FUEL	Fuel used in the attitude orientation maneuver.
TRACKING VISIBILITY	The rounded off elevation angle for each tracking station. If the elevation angle is between 0.0 and 10.0, a 1 is printed, etc. The station is identified by the first letter of its name.

The Midcourse Analysis output also includes predicted errors in mission objectives due to midcourse maneuver execution errors. The answers are computed by linear propagation of ensemble statistics. The user supplies

Location	Name	
435	SIGAT	1σ pointing error in degrees (actually assumed to be 97% probability on Rayleigh distribution).

436	SIGDV	1σ proportional error in velocity (fraction of midcourse velocity in error).

A 1σ resolution error of .3 meters/ second is built into the program in addition to the input proportional error. The user must also supply the probability (location 1070, in percent) to which he would like the output errors scaled, assuming a Gaussian distribution. The output format lists the following:

MC	Midcourse execution number.
TIME	Execution time.
TFUEL	Total fuel variation relative to errorless execution (primarily caused by trim requirements and assuming no later midcourse)
PERILUNE	closest approach distance error
INCLIN	Inclination error
TFLITE	Flight time error relative to errorless execution.
VINFIN	Hyperbolic excess speed error relative to errorless execution.
VCIRC	Circular excess speed error relative to errorless execution.
MC2	Expected correction velocity requirement at a second midcourse.

The second midcourse correction is presumed to use the same guidance law as the first. The time of the second maneuver is input via location 440 in seconds past liftoff epoch.

Midcourse analysis output also includes lunar orbit insertion information computed from the predicted arrival conditions based on a successful midcourse maneuver execution. The listed output items are:

MC NO	Midcourse execution number
RETRO TIME	Best retro firing time based on minimum trim fuel
RETRO RA	Right ascension of the spin axis for the retro maneuver
ATT DEC	Declination of the spin axis for the retro maneuver
SPIN-SUN	Spin axis-sun angle for the retro maneuver.
TRIM VEL	Trim velocity to achieve desired lunar orbit.

TRIM FUEL	Trim fuel
TOTAL FUEL	Sum of the midcourse and trim fuel expenditures.
TRACKING VISIBILITY	Visibility for the retro maneuver -- same format as for the midcourse maneuver.

This sample case contains two lines of print at each execution time. The first line corresponds to the flight time loaded into location 422 while the second line has a flight time of one hour longer. These times can be verified from the retro firing times in the third block output. More than one flight time was used because the KTF flag in location 1077 was set to two.

A second sample case using the fixed attitude option is shown in Figure 5.2. The data for this case is very similar to the last except for the special inputs pertaining to the fixed attitude mode. The KTF flag is set to minus three to specify 3 velocity increments. The increment in velocity is input in location 479 and its mid-value input in location 426. The center of the attitude scan cone is the spacecraft attitude input via locations 47 and 48. The half cone angle is input via 474. The attitude cone is to be divided in three segments in both right ascension and declination as specified by locations 1041 and 1042.

The MAESTRO output is in the second part of the figure. The input cards followed by the entire input array is presented first. The fixed attitude scan follows. The fixed attitude scan output is divided into blocks pertaining to the midcourse motor firing time. In each block the following information is printed:

DVM	Midcourse impulsive velocity
RTA	right ascension of midcourse velocity
DEC	declination of midcourse velocity
RCA	radius of closest approach at target planet
INC	inclination of approach hyperbola w.r.t. target planet's equator.
TFLT	time of flight, time since liftoff
ROPA	radius at the post-retro apsis opposite approach pericynthian, assuming a pericynthian maneuver opposing the arrival velocity.
FCP	Total fuel, assuming a trim maneuver which circularizes in-plane at approach pericynthian after pericynthian retro maneuver opposite to velocity vector.

TCF	total fuel to trim to a circular orbit with the desired radius. No inclination change made.

Notice that the output consists of a 4-dimensional scan of midcourse control variables - execution time, midcourse velocity, right ascension of midcourse velocity and declination of the velocity.

Table 5.1

Midcourse Motor Thrust/Weight Characteristics

Time since ignition (sec)	Thrust (Newtons)	Mass flow rate (KG/SEC)
0	45.5	0.02404
900	26.6892	0.01202
20000	26.6892	0.01202

Table 5.2

Midcourse Analysis Mode *

MODE = 3

LOCATION	INITIALIZED VALUE	DESCRIPTION
20-25	-	Launch epoch
**30-35 or 40-45	-	initial state
200-386	-	midcourse motor in engine 1
407	.68	retro impulsive velocity
410-419	-	observation site longitudes
**420	2838.	Desired lunar radius
**421	-59.0	Desired lunar inclination
422	396000.	Desired flight time
423	0.62	Desired hyperbolic excess speed
424	0.0	Desired circular excess speeds
434	7200.	Increment in execution time
435	.7	Pointing error
436	.02	Proportional error
440	259200.	Second midcourse time
**441	226.0	midcourse motor ISP
**442	282.5	retro motor ISP
**443	71.11	Mass of retro fuel
**444	2838	desired final orbit radius
**446	59	desired final orbit inclination
447	6000	Desired B · T
448	6000	Desired B · R

LOCATION	INITIALIZED VALUE	DESCRIPTION
473	13.77	retro drop weight
474	5	attitude cone angle used in fixed attitude node
475	20	true anomaly range used in retro determination when 1080 ≠ 0.
**478	7200.	initial execution time
**479	.0003	velocity increment for partials or fixed attitude scan.
480-489	-	observation site latitude
490	10.	Tolerance on B · T
**491	10.	Tolerance on B · R
492	10.	Tolerance on time of flight
493	0.001	Tolerance on hyperbolic excess of speed
494	0.001	Tolerance on circular excess speed
495	.02	Tolerance on minimum total fuel
496	5.	Tolerance on closest approach
497	.2	Tolerance on inclination
1030	-1	Output frequency flag
**1036	6	Trajectory propagator scheme
1041	10	number of right ascension in fixed attitude scan
1042	15	number of declinations in fixed attitude scan

* inputs for trajectory propagation also set
** required inputs

Table 5.2 (Cont'd)

LOCATION	INITIALIZED VALUE	DESCRIPTION
1043	20	number of firings in retro determination. used when 1080≠ 0
1044	-	MODE flag set to 3
1050	0	Auxiliary output flag
1051	10	Number of executions
**1062	2	Miss vector option flag
**1063	1	Guidance law (1 ≡ min. fuel)
1064	1	Number of trials to recompute secant matrix
**1065	10	Number of trials allowed
1066	1	Preliminary targeting done
**1067	100	Limiting factor
1070	95	Output probability
1071	6	Integration type for midcourse burn
**1075	6	Trajectory propagation method when generating partial derivatives
1076	-	element set number of state from GTDS program.
**1077	0	midcourse type flag
**1078	0	overburn option key
1080	0	retro optimization flag
1089	1234567	satellite ID number
1093	-	plot tape unit number

FIGURE 5.1

MIDCOURSE ANALYSIS SAMPLE CASE

EXECUTION AND FLIGHT TIME SCAN

INPUT DATA CARDS

20	6.	21	10.	22	1973.
23	15.	24	1.	25	3.25
50	6.	51	10.	52	1973.
53	15.	54	14.	55	43.268
40	1051.8313	41	5932.0483	42	2604.2559
43	-10.141568	44	3.03071049	45	-2.807367
1044	3.	1063	2.	1077	2.
1051	5.				

MAESTRO OUTPUT

DATA CARDS FOR CASE 1

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.100000000D 01	25	0.325000000D 01
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.432680000D 02
40	0.105183130D 04	41	0.593204830D 04	42	0.260425590D 04
43	-0.101415680D 02	44	0.303071049D 01	45	-0.280736700D 01
1044	0.300000000D 01	1063	0.200000000D 01	1077	0.200000000D 01
1051	0.500000000D 01	0	0.0	0	0.0

LUNAR FIELD, NMOD= 0 MMOD= 0

INITIAL JULIAN DATE 2441844.1352

INPUT COMMON

4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.100000000D 01	25	0.325000000D 01	37	0.418441257D 05
38	0.333390000D 03	40	0.105183130D 04	41	0.593204830D 04
42	0.260425590D 04	43	-0.101415680D 02	44	0.303071049D 01
45	-0.280736700D 01	46	0.418441352D 05	47	0.163361728D 03
48	-0.148544276D 02	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.432680000D 02	100	0.216855300D 01	101	0.324835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816502D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.708820000D-04	128	0.175854900D-03	134	0.266169950D-05
170	0.360000000D 06	171	0.100000000D 20	180	0.180000000D 05
181	0.180000000D 04	197	0.470000000D-04	198	0.210000000D 00
201	0.900000000D 03	202	0.200000000D 05	221	0.190000000D 02
222	0.200000000D 02	260	0.533784000D 02	261	0.266892000D 02
262	0.266892000D 02	280	-0.978500000D 04	281	-0.978500000D 04
321	0.900000000D 03	322	0.200000000D 05	331	0.190000000D 02
332	0.200000000D 02	350	0.240400000D-01	351	0.120200000D-01
352	0.120200000D-01	360	0.353200000D 01	361	0.353200000D 01
380	0.100000000D 21	381	0.100000000D 21	382	0.100000000D 21
383	0.100000000D 21	384	0.100000000D 21	385	0.100000000D 21

407	0.680000000D 00	408	0.136000000D 09	409	0.400000000D 09
410	0.483583260D 00	411	0.825596028D 00	412	0.198472510D 01
413	0.259978941D 01	414	0.370261990D 01	415	0.483672461D 01
416	0.494202256D 01	417	0.504982188D 01	420	0.283800000D 04
421	0.116500000D 03	422	0.396000000D 06	423	0.620000000D 00
433	0.135600000D 05	434	0.720000000D 04	435	0.700000000D 00
436	0.200000000D-01	437	0.700000000D-01	438	0.300000000D-03
439	0.360000000D 05	440	0.259200000D 06	441	0.226000000D 03
442	0.282500000D 03	443	0.705792000D 02	444	0.283800000D 04
445	0.131436176D 01	446	0.116500000D 03	447	0.600000000D 04
448	0.600000000D 04	450	0.100000000D 21	460	0.100000000D 05
470	0.600000000D 01	471	0.167800000D 00	472	0.204000000D 02
473	0.123377000D 02	474	0.500000000D 01	475	0.200000000D 02
478	0.720000000D 04	479	0.300000000D-03	480	-0.449174131D 00
481	-0.329923498D 00	482	-0.432101757D 00	483	-0.618684470D 00
484	0.113138600D 01	485	0.611106355D 00	486	0.677368671D 00
487	-0.575538692D 00	490	0.100000000D 02	491	0.100000000D 02
492	0.100000000D 02	493	0.100000000D-03	494	0.100000000D-03
495	0.200000000D-01	496	0.500000000D 01	497	0.200000000D 00
501	0.616000000D 06	502	0.925000000D 06	503	0.565000000D 06
504	0.480000000D 08	505	0.540000000D 08	506	0.510000000D 08
507	0.860000000D 08	508	0.330000000D 08	509	0.100000000D 11
510	0.110000000D 06	1003	0.200000000D 01	1010	0.100000000D 01
1011	0.200000000D 01	1014	0.300000000D 01	1015	0.300000000D 01
1017	0.500000000D 01	1018	0.100000000D 01	1019	0.100000000D 01
1023	0.100000000D 01	1030	-0.100000000D 01	1031	0.110000000D 02
1032	0.200000000D 01	1035	0.100000000D 01	1036	0.600000000D 01
1039	0.300000000D 01	1040	0.200000000D 01	1041	0.100000000D 02
1042	0.150000000D 02	1043	0.210000000D 02	1044	0.300000000D 01
1048	0.100000000D 01	1051	0.500000000D 01	1052	0.200000000D 01
1053	0.500000000D 02	1054	0.170000000D 02	1055	0.100000000D 01
1060	0.100000000D 01	1061	0.110000000D 02	1062	0.200000000D 01
1063	0.200000000D 01	1064	0.100000000D 01	1065	0.100000000D 02
1066	0.100000000D 01	1067	0.100000000D 03	1068	0.600000000D 01
1069	0.300000000D 01	1070	0.950000000D 02	1071	0.600000000D 01
1075	0.600000000D 01	1077	0.200000000D 01	1083	0.110000000D 02
1088	0.120000000D 02	1089	0.123456700D 07		

NO-MIDCOURSE APPROACH CONDITIONS

RCA (KM)	INC (DEG)	TCA (HRS)	C3 (K2/S2)	TRACKING JTCOFRGS
40014.	175.77	103.33	0.7682	86100002

MIDCOURSE CORRECTION ANALYSIS

ANCHOR VECTOR EPOCH

15.HR 14.MIN 43.268SEC

FIXED TIME OF ARRIVAL GUIDANCE

MC NO	TIME (HR)	MAG. (M/SEC)	FUEL (KG)	BURN TIME (MIN)	R.A. (DEG)	DEC. (DEG)	SPIN-SUN (DEG)	MIN SUN (DEG)	ATT CHNG (DEG)	TRACKING VISIBILITY JTCOFRGS
1	2.00	45.13	6.72	5.09	14.22	26.89	57.69	4.28	148.9	78300000
2	2.00	57.11	8.48	6.61	1.58	16.39	71.83	16.05	162.4	78300000
3	4.00	58.14	8.63	6.74	26.55	28.18	46.76	2.27	137.9	98200000

4	4.00	66.85	9.91	7.91	16.41	22.05	56.87	5.58	147.9	99200000
5	6.00	67.64	10.02	8.02	32.69	28.51	41.42	1.71	122.5	86000002
6	6.00	75.06	11.10	9.07	23.99	24.06	49.70	3.55	140.7	86000002
7	8.00	75.67	11.19	9.16	36.61	28.61	38.05	1.43	129.1	64000004
8	8.00	82.42	12.17	10.16	28.87	25.07	45.24	2.68	126.2	64000004
9	10.00	82.90	12.24	10.23	39.40	28.61	35.67	1.24	126.6	31000227
10	10.00	89.23	13.16	11.22	32.35	25.65	42.12	2.20	133.1	31000227

EXEC ERRORS: 0.10 M/S RES. 0.020 PROP. 0.700 DEG POINT. (ALL 1 SIGMA)

MISS-VECTOR ERROR STATISTICS 95% PROBABILITY

MC	TIME (HR)	TFUEL (KG)	PERILUNE (KM)	INCLIN (DEG)	TFLITE (SEC)	VINFIN (M/S)	VCIPC (M/S)	MC2 (M/S)	FUEL2 (KG)
1	2.00	3.87	531.1	16.878	694.7	3.04	1.77	15.66	2.28
2	2.00	4.64	634.4	19.787	844.8	3.95	2.23	18.02	2.62
3	4.00	4.09	550.5	16.472	714.8	2.99	1.94	15.71	2.27
4	4.00	3.58	616.8	18.072	836.8	3.88	2.38	16.99	2.45
5	6.00	4.58	569.9	16.259	759.0	2.99	2.03	15.36	2.21
6	6.00	4.22	622.7	17.457	876.1	3.71	2.45	16.32	2.35
7	8.00	5.35	589.6	16.125	808.9	3.00	2.20	15.62	2.24
8	8.00	4.99	635.8	17.122	923.8	3.76	2.59	16.40	2.35
9	10.00	6.09	609.2	16.029	859.4	3.03	2.22	15.88	2.27
10	10.00	5.73	651.6	16.904	973.0	3.34	2.72	16.58	2.37

ORBIT INSEPTION INFORMATION

MC NO	RETRO TIME (HR)	RETRO R.A. (DEG)	ATT DEC. (DEG)	SPIN-SUN (DEG)	MIN SUN (DEG)	TRIM VEL (M/SEC)	TRIM FUEL (KG)	TOTAL FUEL (KG)	TRACKING VISIBILITY JTCOFRGS
1	110.00	138.78	-29.57	75.20	26.24	29.46	3.22	9.94	00000338
2	111.00	138.51	-29.52	74.95	45.06	23.95	2.60	11.08	00000337
3	110.00	138.76	-29.53	75.16	20.73	24.37	2.64	11.28	00000338
4	111.00	138.45	-29.46	74.88	31.09	20.40	2.20	12.11	00000337
5	110.00	138.73	-29.53	75.14	18.35	20.58	2.22	12.24	00000338
6	111.00	138.42	-29.50	74.88	26.04	16.74	1.80	12.90	00000337
7	110.00	138.69	-29.52	75.11	16.93	17.29	1.86	13.05	00000338
8	111.00	138.37	-29.53	74.86	23.26	13.45	1.44	13.61	00000337
9	110.00	138.64	-29.52	75.08	15.95	14.25	1.53	13.77	00000338
10	111.00	138.31	-29.54	74.83	21.44	10.38	1.11	14.26	00000337

NO MORE DATA, RUN TERMINATED

FIGURE 5.2

MIDCOURSE ANALYSIS SAMPLE CASE

FIXED ATTITUDE SCAN

INPUT DATA

```
     20 6.                   21 10.                 22 1973.
     23 15.                  24 1.                  25 3.25
     50 6.                   51 10.                 52 1973.
     53 15.                  54 14.                 55 43.268
     40 1051.8313            41 5932.0483           42 2604.2559
     43-10.141568            44 3.03071049          45-2.807367
   1044 3.                  479 .01               1077-3.
   1051 2.                   47 52.                 48 42.
    426 .045               1041 3.              1042 3.
    474 5.
```

MAESTRO OUTPUT

```
DATA CARDS FOR CASE     1
   23    0.150000000D 02    24    0.100000000D 01    25    0.325000000D 01
   50    0.600000000D 01    51    0.100000000D 02    52    0.197300000D 04
   53    0.150000000D 02    54    0.140000000D 02    55    0.432680000D 02
   40    0.105183130D 04    41    0.593204830D 04    42    0.260425590D 04
   43   -0.101415680D 02    44    0.303071049D 01    45   -0.280736700D 01
 1044    0.300000000D 01   479    0.100000000D-01  1077   -0.300000000D 01
 1051    0.200000000D 01    47    0.520000000D 02    48    0.420000000D 02
  426    0.450000000D-01  1041    0.300000000D 01  1042    0.300000000D 01
  474    0.500000000D 01     0    0.0                   0    0.0
LUNAR FIELD, NMOD=***  MMOD=***

INITIAL JULIAN DATE 2441844.1352
   INPUT COMMON
    4    0.540000000D 06     5    0.100000000D 01     6    0.100000000D 01
    8    0.100000000D-10    10    0.100000000D 21    20    0.600000000D 01
   21    0.100000000D 02    22    0.197300000D 04    23    0.150000000D 02
   24    0.100000000D 01    25    0.325000000D 01    37    0.418441257D 05
   38    0.333390000D 03    40    0.105183130D 04    41    0.593204830D 04
   42    0.260425590D 04    43   -0.101415680D 02    44    0.303071049D 01
   45   -0.280736700D 01    46    0.418441352D 05    47    0.520000000D 02
   48    0.420000000D 02    50    0.600000000D 01    51    0.100000000D 02
   52    0.197300000D 04    53    0.150000000D 02    54    0.140000000D 02
   55    0.432680000D 02   100    0.216855300D 01   101    0.324835400D 06
  102    0.398603200D 06   103    0.429155150D 05   104    0.126710600D 09
  105    0.379186900D 08   109    0.132715450D 12   110    0.490277790D 04
  112    0.232981600D 04   113    0.60986300D 04   114.   0.637816503 D 04
```

115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
170	0.360000000D 06	171	0.100000000D 20	180	0.180000000D 05
181	0.190000000D 04	197	0.470000000D-04	198	0.210000000D 00
201	0.900000000D 03	202	0.200000000D 05	221	0.190000000D 02
222	0.200000000D 02	260	0.533784000D 02	261	0.266892000D 02
262	0.266892000D 02	280	-0.978500000D 04	281	-0.978500000D 04
321	0.900000000D 03	322	0.200000000D 05	331	0.190000000D 02
332	0.200000000D 02	350	0.240400000D-01	351	0.120200000D-01
352	0.120200000D-01	360	0.353200000D 01	361	0.353200000D 01
380	0.100000000D 21	381	0.100000000D 21	382	0.100000000D 21
383	0.100000000D 21	384	0.100000000D 21	385	0.100000000D 21
407	0.680000000D 00	408	0.136000000D 09	409	0.400000000D 09
410	0.483583263D 00	411	0.825596028D 00	412	0.198472510D 01
413	0.259978941D 01	414	0.370861990D 01	415	0.483672461D 01
416	0.494202256D 01	417	0.504982188D 01	420	0.283800000D 04
421	0.116500000D 03	422	0.396000000D 06	423	0.620000000D 00
426	0.450000000D-01	433	0.135600000D 05	434	0.720000000D 04
435	0.700000000D 00	436	0.200000000D-01	437	0.700000000D-01
438	0.300000000D-03	439	0.360000000D 05	440	0.259200000D 06
441	0.226000000D 03	442	0.282500000D 03	443	0.705792000D 02
444	0.283800000D 04	445	0.131436176D 01	446	0.116500000D 03
447	0.600000000D 04	448	0.600000000D 04	450	0.100000000D 21
460	0.180000000D 05	470	0.600000000D 01	471	0.167800000D 00
472	0.204000000D 02	473	0.123377000D 02	474	0.500000000D 01
475	0.200000000D 02	478	0.720000000D 04	479	0.100000000D-01
480	-0.449174131D 00	481	-0.329923498D 00	482	-0.432101757D 00
483	-0.618684470D 00	484	0.113138600D 01	485	0.611106355D 00
486	0.677368671D 00	487	-0.575538692D 00	490	0.100000000D 02
491	0.100000000D 02	492	0.100000000D 02	493	0.100000000D-03
494	0.100000000D-03	495	0.200000000D-01	496	0.500000000D 01
497	0.200000000D 00	501	0.616000000D 06	502	0.925000000D 06
503	0.565000000D 06	504	0.480000000D 08	505	0.540000000D 08
506	0.510000000D 08	507	0.860000000D 08	508	0.330000000D 08
509	0.100000000D 11	510	0.110000000D 06	1003	0.200000000D 01
1010	0.100000000D 01	1011	0.200000000D 01	1014	0.300000000D 01
1015	0.300000000D 01	1017	0.500000000D 01	1018	0.100000000D 01
1019	0.100000000D 01	1023	0.100000000D 01	1030	-0.100000000D 01
1031	0.110000000D 02	1032	0.200000000D 01	1035	0.100000000D 01
1036	0.600000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.300000000D 01	1042	0.300000000D 01	1043	0.210000000D 02
1044	0.300000000D 01	1048	0.100000000D 01	1051	0.200000000D 01
1052	0.200000000D 01	1053	0.500000000D 02	1054	0.170000000D 02
1055	0.100000000D 01	1060	0.100000000D 01	1061	0.110000000D 02
1062	0.200000000D 01	1063	0.200000000D 01	1064	0.100000000D 01
1065	0.100000000D 02	1066	0.100000000D 01	1067	0.100000000D 03
1068	0.600000000D 01	1069	0.300000000D 01	1070	0.950000000D 02
1071	0.600000000D 01	1075	0.600000000D 01	1077	-0.300000000D 01
1083	0.110000000D 02	1088	0.120000000D 02	1089	0.123456700D 07

FIXED-ATTITUDE SCAN AT 2.00 HOURS

DVM	RTA	DEC	RCA	INC	TELT	ROPA	FCP	TCF
35.000	47.000	37.000	3271.1	133.96	108.59	3370.	6.22	15.93

35.000	47.000	42.000	3896.7	136.24	108.57	3648.	7.28	23.62
35.000	47.000	47.000	4749.3	139.66	108.55	4093.	10.07	31.31
35.000	52.000	37.000	3049.5	132.41	108.46	3268.	7.61	12.63
35.000	52.000	42.000	3673.2	135.03	108.45	3553.	6.29	21.15
35.000	52.000	47.000	4524.9	138.78	108.43	3915.	9.43	29.55
35.000	57.000	37.000	2954.5	132.32	108.31	3224.	8.28	11.12
35.000	57.000	42.000	3578.7	134.99	108.32	3514.	5.82	20.93
35.000	57.000	47.000	4431.8	138.79	108.31	3890.	9.12	28.78

DVM	RTA	DEC	RCA	INC	TFLT	ROPA	FCP	TCF
45.000	47.000	37.000	5900.6	39.62	110.87	4164.	15.59	38.29
45.000	47.000	42.000	5441.9	45.42	110.60	4034.	14.64	35.89
45.000	47.000	47.000	4823.7	53.79	110.23	3847.	13.05	31.96
45.000	52.000	37.000	6148.0	37.77	110.80	4237.	16.01	39.48
45.000	52.000	42.000	5638.3	43.46	110.53	4096.	15.03	36.99
45.000	52.000	47.000	4957.8	51.68	110.17	3892.	13.41	32.91
45.000	57.000	37.000	6152.8	37.02	110.65	4241.	16.01	39.52
45.000	57.000	42.000	5632.9	42.71	110.39	4096.	15.01	36.97
45.000	57.000	47.000	4939.7	50.92	110.03	3888.	13.34	32.80

DVM	RTA	DEC	RCA	INC	TFLT	ROPA	FCP	TCF
55.000	47.000	37.000	18913.4	20.63	113.86	6686.	23.12	59.43
55.000	47.000	42.000	17693.0	23.02	113.58	6506.	23.05	58.98
55.000	47.000	47.000	15951.4	26.20	113.19	6223.	22.91	57.99
55.000	52.000	37.000	19381.8	19.97	113.74	6768.	23.12	59.65
55.000	52.000	42.000	18115.5	22.32	113.47	6582.	23.05	59.11
55.000	52.000	47.000	16321.3	25.44	113.10	6299.	22.91	58.15
55.000	57.000	37.000	19402.1	19.62	113.55	6789.	23.09	59.69
55.000	57.000	42.000	18132.6	21.97	113.30	6591.	23.03	59.13
55.000	57.000	47.000	16335.2	25.09	112.93	6308.	22.89	58.17

FIXED-ATTITUDE SCAN AT 4.00 HOURS

DVM	RTA	DEC	RCA	INC	TFLT	ROPA	FCP	CF
35.000	52.000	37.000	12113.8	165.09	107.93	6895.	15.44	55.52
35.000	52.000	42.000	12771.6	163.99	107.85	7171.	15.43	56.41
35.000	52.000	47.000	13647.3	163.24	107.76	7549.	15.36	57.48
35.000	57.000	37.000	11707.1	165.04	107.78	6749.	15.38	54.97
35.000	57.000	42.000	12391.1	163.92	107.72	7032.	15.38	55.95
35.000	57.000	47.000	13295.7	163.17	107.64	7418.	15.34	57.11

DVM	RTA	DEC	RCA	INC	TFLT	ROPA	FCP	TCF
45.000	47.000	37.000	5349.9	146.35	108.47	4188.	13.24	36.42
45.000	47.000	42.000	6178.3	145.64	108.44	4497.	14.62	40.91
45.000	47.000	47.000	7238.7	146.02	108.39	4883.	15.80	45.31
45.000	52.000	37.000	4770.3	144.40	108.25	3970.	11.87	32.52
45.000	52.000	42.000	5623.5	143.97	108.25	4297.	13.71	38.07
45.000	52.000	47.000	6710.5	144.68	108.22	4700.	15.23	43.31
45.000	57.000	37.000	4371.5	143.05	108.03	3817.	10.68	29.33
45.000	57.000	42.000	5237.6	142.82	108.05	4158.	12.92	35.79
45.000	57.000	47.000	6339.6	143.78	108.04	4572.	14.74	41.75

DVM	RTA	DEC	RCA	INC	TFLT	ROPA	FCP	TCF
55.000	47.000	37.000	2753.9	80.68	109.20	3027.	11.55	11.51
55.000	47.000	42.000	3250.5	88.81	109.12	3253.	8.19	17.43
55.000	47.000	47.000	3866.7	98.22	109.00	3514.	11.13	25.04
55.000	52.000	37.000	2810.0	72.83	109.08	3051.	11.10	11.08
55.000	52.000	42.000	3204.7	82.10	108.98	3232.	9.46	16.76
55.000	52.000	47.000	3713.3	92.78	108.85	3452.	10.47	23.35
55.000	57.000	37.000	2871.3	67.59	108.91	3079.	10.64	11.46

Section 6

MONTE CARLO ANALYSIS MODE

This mode is used to determine the probability of satisfying various mission constraints. The probability is determined by flying many samples along a desired mission flight plan with errors applied at each control point. A typical mission flight plan could consist of the following:

1. Apply tracking errors to anchor vector and fly to first midcourse time.
2. Determine first midcourse correction, apply errors to the correction, and fly to second midcourse execution time.
3. Determine second midcourse correction, apply errors to the correction, and fly to the Moon.
4. Determine retro motor firing time and attitude. Apply errors to retro and burn retro.
5. Determine trim fuel to satisfy mission constraints.

The extent of the mission flight plan is determined through the KMONTE flag in location 1052. This flag is defined as follows:

KMONTE = 3	Two midcourse corrections and retro (as described above)
KMONTE = 2	One midcourse and retro
KMONTE = 1	Retro only

As the mission progresses in real time, a point will be reached where the errors in the tracking data will reach a minimum. At this time, the next correction or retro should be determined for the anchor vector and this correction applied to each sample. The subsequent maneuvers are determined in the usual manner. The KMONTE flag is set negative to use the program in this mode.

The error model is discussed in reference 1. Simply, one sigma errors in the point angle and velocity are input for both the retro motor and midcourse motor. The midcourse motor also includes a .1 meter/sec. resolution error.

The user also has the capability of retrieving the state at the beginning of each sample. When the KMTOUT flag (location 1074) is set to one, the initial state will be output. The output will be position and velocity vectors in the Earth mean equator and equinox of 1950. The random number generator will also be output. A Monte Carlo analysis can be restarted at any sample by the input of the random number generator in location 1054.

The inputs for the Trajectory Propagation mode and the Midcourse Analysis are also preset for this mode. A guide for the use of this mode is presented in Table 6.1. This table presents the preset values of the inputs pertinent to the Monte Carlo Analysis Mode.

A sample of the Monte Carlo Analysis is shown in Figure 6.1. The first part of this figure is the input data. For this run the initial state is loaded as position and velocity vectors in location 40-45. The initial time and liftoff epoch are in locations 50-55 and 20-25, respectively. A covariance matrix is loaded in locations 56-91. This matrix represents the injection errors of the launch vehicle. KMONTE is set to 3 in location 1052, the sample size set to 3 in location 1053, the auxiliary output flag is set to 1 in location 1074, and MODE set to 4 in location 1044.

The first part of the program output consists of a listing of the input cards followed by a listing of the input array including preset values. The Monte Carlo analysis follows the listing of the input array. This output consists of descriptions of the maneuvers and pre-trim orbit for each sample. A map describing the outputs is presented at the beginning of the run. The quantities printed are the fuel, its mean and standard deviation for midcourse 1, midcourse 2, trim 1, trim 2, trim 3, and remaining fuel. The first two trim maneuvers are associated with the Hohmann transfer maneuver to correct radius and eccentricity. The third trim is the plane change maneuver to correct inclination. The spin axis-sun angle, its mean and standard deviation are also presented for midcourse 1, midcourse 2, trim 1, trim 2, trim 3, and the retro. The following lines of output present the pre-trim lunar orbit conditions, their mean values and their standard deviations. The pre-trim orbit conditions printed are apoapsis radius, periapsis radius, eccentricity, argument of perigee, inclination, longitude of the ascending node, true anomaly and time of retro fire.

A statistical summary of the quantities mentioned above is presented at the end of the run. This summary contains the mean value, maximum value encountered on any sample, minimum value encountered and standard deviation.

Table 6.1

Monte Carlo Analysis *

MODE = 4

LOCATION	INITIALIZED VALUE	DESCRIPTION
20-25	-	launch epoch
**30-35 or 40-45	-	initial state
**56-76	-	covariance matrix
**435	.7	midcourse pointing error
**436	.02	midcourse velocity error (percent/100)
**437	.07	retro pointing error
**438	.0003	retro velocity error (percent/100)
439	36000.	first midcourse time
440	324000	second midcourse time
441	226.	midcourse ISP
**442	282.5	retro ISP
**443	71.11	Mass of retro fuel
**444	2838	desired final orbit radius
**446	59	desired final orbit inclination
449	0	tolerance band or inclination correction
**472	20.4	total midcourse fuel available
473	13.77	retro drop weight
475	20	retro firing range when finding retro conditions
**1044	-	Mode set to 4
**1052	2	trajectory profile flag
**1053	50	sample size
**1054	17	random number generator
1074	0	initial state output
1076	-	Element set no. to get initial state from GTDS program
1080	0	retro optimization flag
1085	0	covariance matrix input system
1089	1234567	satellite ID number
1090	0	director's display write

* inputs for a midcourse analysis also set

** required inputs

FIGURE 6.3

MONTE CARLO ANALYSIS SAMPLE CASE

INPUT CARDS

20 6.	21 10.	22 1973.
23 15.	24 40.	25 43.
50 6.	51 10.	52 1973.
53 15.	54 49.	55 51.585
40 1020.52175	41 5938.4128	42 2602.2073
43-10.093822	44 3.01896141	45-2.9309252
56 .21397367 D 01	57 .69581387 D 00	58-.50517885 D-01
59 .78578022 D-02	60 .10068985 D-01	61-.71083883 D-02
62 .16104174 D 01	63-.19448888 D-02	
64 .74400095 D-02	65 .27167241 D-01	66 .24715954 D-02
67 .24969523 D 01		
68-.61726957 D-02	69 .26585233 D-02	70 .28148930 D-01
71 .23410676 D-03	72 .35361370 D-03	73-.34300627 D-03
74 .13113114 D-02	75 .10246022 D-03	
76 .13091829 D-02		
1044 4.	1053 3.	
1052 3.	1066 0.	
1080 1.		

MAESTRO OUTPUT

DATA CARDS FOR CASE 1

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.400000000D 02	25	0.430000000D 02
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.490000000D 02	55	0.515850000D 02
40	0.102052175D 04	41	0.593841280D 04	42	0.260220730D 04
43	-0.100938220D 02	44	0.301896141D 01	45	-0.293092520D 01
56	0.213973670D 01	57	0.695813870D 00	58	-0.505178850D-01
59	0.785780220D-02	60	0.100689850D-01	61	-0.710838830D-02
62	0.161041740D 01	63	-0.194488880D-02	0	0.0
64	0.744000950D-02	65	0.271672410D-01	66	0.247159540D-02
67	0.249695230D 01	0	0.0	0	0.0
68	-0.617269570D-02	69	0.265852330D-02	70	0.281489300D-01
71	0.234106760D-03	72	0.353613700D-03	73	-0.343006270D-03
74	0.131131140D-02	75	0.102460220D-03	0	0.0
76	0.130918290D-02	0	0.0	0	0.0
1044	0.400000000D 01	1053	0.300000000D 01	0	0.0
1052	0.300000000D 01	1066	0.0	0	0.0
1080	0.100000000D 01	0	0.0	0	0.0

LUNAR FIELD, NMOD=*** MMOD=***

INITIAL JULIAN DATE 2441844.1596

INPUT COMMON

4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.400000000D 02	25	0.430000000D 02	37	0.418441533D 05
38	0.333390000D 03	40	0.102052175D 04	41	0.593841280D 04
42	0.260220730D 04	43	-0.100938220D 02	44	0.301896141D 01
45	-0.293092520D 01	46	0.418441596D 05	47	0.163348601D 03
48	-0.155461363D 02	50	0.600000000D 01	51	0.100000000D 02

52	0.197300000D 04	53	0.150000000D03	54	0.140000000D 02
55	0.515850000D 02	56	0.213973670D 01	57	0.685913870D 00
58	-0.505178850D-01	59	0.78580220D-02	60	0.100699850D-01
61	-0.710838830D-02	62	0.161041740D 01	63	-0.194488890D-02
64	0.744000950D-02	65	0.271672410D-01	66	0.247159540D-02
67	0.249695230D 01	68	-0.617269570D-02	69	0.265852330D-02
70	0.281489300D-01	71	0.234106760D-03	72	0.353613700D-03
73	-0.343006270D-03	74	0.131131140D-02	75	0.102460220D-03
76	0.130918290D-02	100	0.216855300D 01	101	0.324835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816503D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.708820000D-04	128	0.175854900D-03	134	0.266169950D-05
170	0.360000000D 06	171	0.100000000D 20	180	0.180000000D 05
181	0.180000000D 04	197	0.470000000D-04	198	0.210000000D 00
201	0.900000000D 03	202	0.200000000D 05	221	0.190000000D 02
222	0.200000000D 02	260	0.533784000D 02	261	0.266892000D 02
262	0.266892000D 02	280	-0.978500000D 04	281	-0.978500000D 04
321	0.900000000D 03	322	0.200000000D 05	331	0.190000000D 02
332	0.200000000D 02	350	0.240400000D-01	351	0.120200000D-01
352	0.120200000D-01	360	0.332000000D 01	361	0.353200000D 01
380	0.100000000D 21	381	0.100000000D 21	382	0.100000000D 21
383	0.100000000D 21	384	0.100000000D 21	385	0.100000000D 21
407	0.680000000D 00	408	0.136000000D 09	409	0.400000000D 09
410	0.483583263D 00	411	0.825596028D 00	412	0.198472510D 01
413	0.259978941D 01	414	0.370861990D 01	415	0.483672461D 01
416	0.494202256D 01	417	0.504982188D 01	420	0.283800000D 04
421	0.116500000D 03	422	0.396000000D 06	423	0.620000000D 00
433	0.135600000D 05	434	0.720000000D 04	435	0.700000000D 00
436	0.200000000D-01	437	0.700000000D-01	438	0.300000000D-03
439	0.360000000D 05	440	0.259200000D 06	441	0.226000000D 03
442	0.282500000D 03	443	0.705792000D 02	444	0.283800000D 04
445	0.131436176D 01	446	0.116500000D 03	447	0.600000000D 04
448	0.600000000D 04	450	0.100000000D 21	460	0.180000000D 05
470	0.600000000D 01	471	0.167800000D 00	472	0.204000000D 02
473	0.123377000D 02	474	0.500000000D 01	475	0.300000000D 02
478	0.720000000D 04	479	0.300000000D-03	480	-0.449174131D 00
481	-0.329923498D 00	482	-0.432101757D 00	483	-0.618684470D 00
484	0.113138600D 01	485	0.611106355D 00	486	0.677368671D 00
487	-0.575538692D 00	490	0.100000000D 02	491	0.100000000D 02
492	0.100000000D 02	493	0.100000000D-03	494	0.100000000D-03
495	0.200000000D-01	496	0.500000000D 01	497	0.200000000D 00
501	0.616000000D 06	502	0.925000000D 06	503	0.565000000D 06
504	0.480000000D 08	505	0.540000000D 08	506	0.510000000D 08
507	0.860000000D 08	508	0.330000000D 08	509	0.100000000D 11
510	0.110000000D 06	1003	0.200000000D 01	1010	0.100000000D 01
1011	0.200000000D 01	1014	0.300000000D 01	1015	0.300000000D 01
1017	0.500000000D 01	1018	0.100000000D 01	1019	0.100000000D 01
1023	0.100000000D 01	1030	-0.100000000D 01	1031	0.110000000D 02
1032	0.200000000D 01	1035	0.100000000D 01	1036	0.600000000D 01
1039	0.300000000D 01	1040	0.200000000D 01	1041	0.100000000D 02
1042	0.150000000D 02	1043	0.210000000D 02	1044	0.400000000D 01
1048	0.100000000D 01	1051	0.100000000D 02	1052	0.300000000D 01
1053	0.300000000D 01	1054	0.170000000D 02	1055	0.100000000D 01
1060	0.100000000D 01	1061	0.110000000D 02	1062	0.200000000D 01
1063	0.200000000D 01	1064	0.100000000D 01	1065	0.100000000D 02
1067	0.100000000D 03	1068	0.600000000D 01	1069	0.300000000D 01

```
1070    0.950000000D 02 1071    0.600000000D 01 1075    0.600000000D 01
1080    0.100000000D 01 1083    0.110000000D 02 1088    0.120000000D 02
1089    0.123456700D 07
```

MONTECARLO ANALYSIS

ANCHOR VECTOR EPOCH
15.HR 49.MIN 51.585SEC

SAMPLE SIZE = 3

FIRST MIDCOURSE AT 10.00HRS
SECOND MIDCOURSE AT 72.00HRS
MIDCOURSE GUIDANCE LAW = 2
1 SIGMA MIDCOURSE POINTING ERROR = 0.70 DEGREES
1 SIGMA MIDCOURSE VELOCITY ERROR = 2.00 PERCENT
1 SIGMA RETRO POINTING ERROR = 0.07 DEGREES
1 SIGMA RETRO VELOCITY ERROR = 0.03 PERCENT

TRACKING COVARIANCE MATRIX

```
 0.21397D 01 0.68581D 00-0.50518D-01 0.78578D-02 0.10069D-01-0.71084D-02
 0.68581D 00 0.16104D 01-0.19449D-02 0.74400D-02 0.27167D-01 0.24716D-02
-0.50518D-01-0.19449D-02 0.24970D 01-0.61727D-02 0.26585D-02 0.28149D-01
 0.78578D-02 0.74400D-02-0.61727D-02 0.23411D-03 0.35361D-03-0.34301D-03
 0.10069D-01 0.27167D-01 0.26585D-02 0.35361D-03 0.13113D-02 0.10246D-03
-0.71084D-02 0.24716D-02 0.28149D-01-0.34301D-03 0.10246D-03 0.13092D-02
```

OUTPUT FORMAT

MC1 FUEL (KG)	MC2 FUEL (KG)	TRIM1 FUEL (KG)	TRIM2 FUEL (KG)	TRIM3 FUEL (KG)	FUEL REMAINING (KG)
MEAN MC1 FUEL	MEAN MC2 FUEL	MEAN TRIM1 FUEL	MEAN TRIM2 FUEL	MEAN TRIM3 FUEL	MEAN FUEL REMAINING
SIGMA MC1 FUEL	SIGMA MC2 FUEL	SIGMA TRIM1 FUEL	SIGMA TRIM2 FUEL	SIGMA TRIM3 FUEL	SIGMA FUEL REMAINING
MC1 SPIN-SUN (DEG)	MC2 SPIN-SUN (DEG)	TRIM1 SPIN-SUN (DEG)	TRIM2 SPIN-SUN (DEG)	TRIM3 SPIN-SUN (DEG)	RETRO SPIN-SUN (DEG)
MEAN MC1 SPIN-SUN	MEAN MC2 SPIN-SUN	MEAN TRIM1 SPIN-SUN	MEAN TRIM2 SPIN-SUN	MEAN TRIM3 SPIN-SUN	MEAN RETRO SPIN-SUN
SIGMA MC1 SPIN-SUN	SIGMA MC2 SPIN-SUN	SIGMA TRIM1 SPIN-SUN	SIGMA TRIM2 SPIN-SUN	SIGMA TRIM3 SPIN-SUN	SIGMA RETRO SPIN-SUN

PRE-TRIM LUNAR ORBIT

	RA (KM)	RP (KM)	ECCEN	AOP (DEG)	INCLIN (DEG)	LAN (DEG)
	MEAN RA	MEAN RP	MEAN ECCEN	MEAN AOP	MEAN INCLIN	MEAN LAN
	SIGMA RA	SIGMA RP	SIGMA ECCEN	SIGMA AOP	SIGMA INCLIN	SIGMA LAN
	TRUE ANOM (DEG)	RETRO FIRE (HR)				
	MEAN TRUE (DEG)	MEAN RETRO (HR)				
	SIGMA TRUE (DEG)	SIGMA RETRO (HR)				
SAMPLE 1						
	2.181	0.084	0.018	4.529	0.054	13.534
	2.181	0.084	0.018	4.529	0.054	13.534
	0.0	0.0	0.0	0.0	0.0	0.0
	138.186	11.304	112.142	112.132	119.138	67.666
	138.186	11.304	112.142	112.132	119.138	67.666
	0.0	0.0	0.0	0.0	0.0	0.0
	3216.3	2836.6	0.06274	141.270	116.523	-74.747
	3216.3	2836.6	0.06274	141.270	116.523	-74.747
	0.0	0.0	0.0	0.0	0.0	0.0
	-0.340	109.848				
	-0.340	109.848				
	0.0	0.0				
SAMPLE 2						
	9.121	0.180	0.006	2.868	0.041	8.183
	5.651	0.132	0.012	3.699	0.047	10.859
	3.470	0.048	0.006	0.830	0.006	2.675
	142.350	135.398	68.023	111.977	60.738	67.424
	140.268	73.351	90.082	112.055	89.938	67.545
	2.082	62.047	22.059	0.077	29.200	0.121
	3069.7	2838.5	0.03913	141.467	116.483	-74.589
	3143.0	2837.5	0.05094	141.368	116.503	-74.668
	73.3	1.0	0.01180	0.099	0.020	0.079
	-0.710	109.846				
	-0.525	109.847				
	0.185	0.004				

SAMPLE 3

4.476	0.475	0.082	3.845	0.001	11.522
5.260	0.246	0.035	3.747	0.032	11.080
2.887	0.166	0.033	0.682	0.023	2.207
25.714	153.209	68.197	111.813	60.687	67.436
102.093	99.970	82.784	111.974	80.188	67.509
54.028	63.117	20.759	0.130	27.542	0.111
3154.8	2844.4	0.05174	141.666	116.500	-74.537
3146.9	2839.8	0.05120	141.468	116.502	-74.624
60.1	3.4	0.00965	0.162	0.017	0.089
-0.718	109.846				
-0.589	109.847				
0.176	0.004				

PROBABILITY OF SATISFYING

SUFFICIENT MANEUVER FUEL = 100.00 PERCENT

STATISTICAL SUMMARY

	MEAN	MAX	MIN	SIGMA
MC1 FUEL	5.26	9.12	2.18	2.99
MC1 SPIN-S	102.09	142.35	25.71	54.03
MC2 FUEL	0.25	0.47	0.08	0.17
MC2 SPIN-S	99.97	153.21	11.30	63.12
TRIM1 FUEL	0.04	0.08	0.01	0.03
TRIM1 SPIN-S	82.78	112.14	63.02	20.76
TRIM2 FUEL	3.75	4.53	2.97	0.68
TRIM2 SPIN-S	111.97	112.13	111.81	0.13
TRIM3 FUEL	0.03	0.05	0.00	0.02
TRIM3 SPIN-S	80.19	119.14	60.69	27.54
FUEL REMAINING	11.08	12.53	8.18	2.21
RETRO SPIN-S	67.51	67.67	67.42	0.11
	PRE-TRIM LUNAR ORBIT			
RA	3146.9	3216.3	3069.7	60.1
RP	2839.8	2844.4	2836.6	3.4
ECCEN	0.0512	0.0627	0.0391	0.0096
AOP	141.47	141.67	141.27	0.16
INCLIN	116.50	116.52	116.48	0.02
LAN	-74.62	-74.54	-74.75	0.09
TRUE	-0.59	-0.72	-0.34	0.18
RETRO TIME	109.85	109.85	109.85	0.00

NO MORE DATA, RUN TERMINATED

Section 7

MIDCOURSE VERIFICATION MODE

This mode is a complete numerical integration of the midcourse correction. The state is propagated from anchor vector epoch to the desired midcourse execution time, then the midcourse motor burn is simulated,and the state propagated to closest approach to the Moon. This mode also presents an extensive tracking station summary and a history of the midcourse burn.

The velocity away from each of the visible tracking stations is computed during the midcourse motor burn in subroutine DOPLER. This data could be compared to real-time telemetry data to determine if a non-nominal burn is taking place. Any of the trajectory propagation techniques except the averaging and multiconic techniques may be used.

This mode has the capability of obtaining the initial spacecraft state from a previous midcourse analysis. This option is specified by setting the KREAD flag to the desired midcourse correction number. If this option is not used, the initial state, midcourse execution time, burn time, and attitude must be input.

Table 7.1 presents the inputs to run this mode plus their preset values.

A sample of this mode is shown in Figure 7.1. The first part of this figure presents the input data. This consists of the initial date in locations 50-55 and KREAD set to 1. This means that the initial state will be obtained from the first midcourse firing time.

The MAESTRO output consists of three parts. The first part is the input data. The input array is listed after the input cards and includes the preset values. The second part presents histories of the thrust,weight, and velocity away from the visible tracking stations while the midcourse motor is burning. The third part of the program output is a summary of the midcourse correction maneuver. Pertinent information is presented about the midcourse maneuver, tracking stations, and the state at closest approach to the Moon after the maneuver is applied.

Table 7.1

Midcourse Verification Analysis *

MODE = 5

LOCATION	INITIALIZED VALUE	DESCRIPTION
20-25	-	launch epoch
**30-35, 1057 or 40-45	-	initial state
47, 48		spacecraft attitude (used when 1057 $\neq$ 0)
**50-55	-	state epoch
200-379		midcourse motor in engine 1
380	-	ignition time when 1057 = 0
408	4.0095D8	Telemetry carrier frequency # 1
409	4.0D8	Telemetry carrier frequency # 2
410-419	-	observation site longitudes
476	-	midcourse burntime when 1057=0
480-489	-	observation site latitudes
**1036	-	trajectory propagator
1045	1	doppler analysis flag
1076	-	Element set number when initial state from GTDS program
1087	-	Element set number when attitude input from ADP
1088	12	unit number of 1087 read
1089	1234567	satellite ID number
1090	-	director's write
1092	-	Element set number when state transfered to GTDS

FIGURE 7.1

MIDCOURSE VERIFICATION ANALYSIS SAMPLE CASE

INPUT CARDS

20 6.	21 10.	22 1973.
23 15.	24 1.	25 3.25
50 6.	51 10.	52 1973.
53 15.	54 14.	55 43.268
1057 1.	1044 5.	

MAESTRO OUTPUT

DATA CARDS FOR CASE 2

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.100000000D 01	25	0.325000000D 01
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.432680000D 02
1057	0.100000000D 01	1044	0.500000000D 01	0	0.0

LUNAR FIELD, NMOD= 0 MMOD= 0

INITIAL JULIAN DATE 2441844.1352

INPUT COMMON

4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.100000000D 01	25	0.325000000D 01	37	0.418441257D 05
38	0.333390000D 03	40	0.105183130D 04	41	0.592204830D 04
42	0.260425590D 04	43	-0.101415680D 02	44	0.203071049D 01
45	-0.280736700D 01	46	0.418441352D 05	47	0.163361728D 03
48	-0.148544276D 02	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.432680000D 02	100	0.216855390D 01	101	0.224835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816503D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.708820000D-04	128	0.175854000D-03	124	0.266169950D-05
170	0.360000000D 04	171	0.180000000D 05	172	0.100000000D 20
180	0.300000000D 03	181	0.180000000D 04	18	0.180000000D 05
197	0.470000000D-04	198	0.210000000D 00	201	0.900000000D 03
202	0.200000000D 05	221	0.190000000D 02	222	0.200000000D 02
260	0.533784000D 02	261	0.266892000D 02	262	0.266892000D 02
280	-0.978500000D 04	281	-0.978500000D 04	321	0.900000000D 03
322	0.200000000D 05	331	0.190000000D 02	332	0.200000000D 02
350	0.240400000D-01	351	0.120200000D-01	352	0.120200000D-01
360	0.353200000D 01	361	0.353200000D 01	380	0.100000000D 21
381	0.100000000D 21	382	0.100000000D 21	383	0.100000000D 21
384	0.100000000D 21	385	0.100000000D 21	407	0.680000000D 00
408	0.136000000D 09	409	0.400000000D 09	410	0.483583263D 00

411	0.825596028D 00	412	0.198472510D 01	413	0.259978941D 01
414	0.370861990D 01	415	0.493672461D 01	416	0.494202256D 01
417	0.504982188D 01	420	0.283800000D 04	421	0.115500000D 02
422	0.396000000D 06	423	0.620000000D 00	433	0.135600000D 05
434	0.720000000D 04	435	0.700000000D 00	436	0.200000000D-01
437	0.700000000D-01	438	0.300000000D-03	439	0.260000000D 05
440	0.259200000D 06	441	0.226000000D 03	442	0.282500000D 03
443	0.705792000D 02	444	0.283800000D 04	445	0.131436176D 01
446	0.116500000D 03	447	0.600000000D 04	448	0.600000000D 04
450	0.100000000D 21	460	0.180000000D 05	470	0.600000000D 01
471	0.167800000D 00	472	0.204000000D 02	473	0.123377000D 02
474	0.500000000D 01	475	0.200000000D 02	478	0.720000000D 04
479	0.300000000D-03	480	-0.449174131D 00	481	-0.329923498D 00
482	-0.432101757D 00	483	-0.618684470D 00	484	0.113138600D 01
485	0.611106355D 00	486	0.677369671D 00	487	-0.575538692D 00
490	0.100000000D 02	491	0.100000000D 02	492	0.100000000D 02
493	0.100000000D-03	494	0.100000000D-03	495	0.200000000D-01
496	0.500000000D 01	497	0.200000000D 00	501	0.616000000D 06
502	0.925000000D 06	503	0.565000000D 06	504	0.481000000D 02
505	0.540000000D 08	506	0.510000000D 09	507	0.860000000D 08
508	0.330000000D 08	509	0.100000000D 11	510	0.110000000D 06
1003	0.200000000D 01	1010	0.100000000D 01	1011	0.200000000D 01
1014	0.300000000D 01	1015	0.300000000D 01	1017	0.500000000D 01
1018	0.100000000D 01	1019	0.100000000D 01	1023	0.100000000D 01
1031	0.110000000D 02	1032	0.200000000D 01	1035	0.100000000D 01
1036	0.400000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.100000000D 02	1042	0.150000000D 02	1043	0.210000000D 02
1044	0.500000000D 01	1045	0.100000000D 01	1048	0.100000000D 01
1051	0.500000000D 01	1052	0.200000000D 01	1053	0.500000000D 02
1054	0.170000000D 02	1055	0.100000000D 01	1057	0.100000000D 01
1060	0.100000000D 01	1061	0.110000000D 02	1062	0.200000000D 01
1063	0.200000000D 01	1064	0.100000000D 01	1065	0.100000000D 02
1066	0.100000000D 01	1067	0.100000000D 03	1068	0.600000000D 01
1069	0.300000000D 01	1070	0.950000000D 02	1071	0.600000000D 01
1075	0.600000000D 01	1077	0.200000000D 01	1083	0.110000000D 02
1088	0.120000000D 02	1089	0.123456700D 07		

REAL TIME THRUSTING INFORMATION

ANCHOR VECTOR EPOCH
15.HRS 14.MINS 43.268SEC
IGNITION TIME = 2.00HRS

TIME (MIN)	THRUST (NEWTON)	WEIGHT (KG)	VELOCITY AWAY FROM TRACKING STATION JOBURG	TANANARI	CARNARVN
0.17	53.09	333.15	4.04904	4.08896	4.07335
0.33	52.79	332.91	4.04523	4.08532	4.07066
0.50	52.49	332.67	4.04143	4.08169	4.06797
0.67	52.19	332.44	4.03765	4.07808	4.06530
0.83	51.90	332.20	4.03388	4.07447	4.06263
1.00	51.60	331.97	4.03012	4.07088	4.05997
1.17	51.30	331.74	4.02638	4.06730	4.05731
1.33	51.01	331.51	4.02265	4.06373	4.05467
1.50	50.71	331.28	4.01893	4.06018	4.05203
1.67	50.41	331.05	4.01523	4.05663	4.04940
1.83	50.12	330.83	4.01153	4.05310	4.04678
2.00	49.82	330.60	4.00785	4.04959	4.04416
2.17	49.52	330.38	4.00418	4.04607	4.04155
2.33	49.23	330.16	4.00053	4.04258	4.03895
2.50	48.93	329.93	3.99689	4.03909	4.03636
2.67	48.63	329.71	3.99326	4.03562	4.03377
2.83	48.34	329.50	3.98964	4.03216	4.03120
3.00	48.04	329.28	3.98603	4.02872	4.02863
3.17	47.74	329.06	3.98244	4.02528	4.02607
3.33	47.45	328.85	3.97886	4.02186	4.02351
3.50	47.15	328.64	3.97530	4.01845	4.02097
3.67	46.85	328.42	3.97174	4.01505	4.01843
3.83	46.56	328.21	3.96820	4.01166	4.01590
4.00	46.26	328.01	3.96467	4.00829	4.01338
4.17	45.96	327.80	3.96116	4.00492	4.01086
4.33	45.67	327.59	3.95765	4.0157	4.00836
4.50	45.37	327.39	3.95416	3.99823	4.00586
4.67	45.09	327.18	3.95069	3.99491	4.00337
4.83	44.78	326.98	3.94722	3.99159	4.00089
5.00	44.48	326.78	3.94377	3.98829	3.99842
5.09	44.32	326.67	3.94189	3.98649	3.99707

MIDCOURSE VERIFICATION MODE

ANCHOR VECTOR EPOCH
6./10./1973.
15.HR 14.MIN 43.268SEC

MIDCOURSE CORRECTION SUMMARY

TIME (HR)	MAGNITUDE (M/SEC)	RT.ASC. (DEG)	DEC. (DEG)	FUEL (KG)	BURN TIME (MIN)
2.00	45.13	14.22	26.89	6.72	5.091

ATTITUDE MANEUVER (DEG)	ATTITUDE FUEL (KG)	SPIN AXIS SUN ANGLE (DEG)
148.87	148.870	57.69

TRACKING STATION SUMMARY

STATION	LOCAL TIME (HRS)	ELEVATION ANGLE (DEG)	AZIMUTH ANGLE (DEG)
JOHANNESBURG	18.02	64.21	93.94
TANANARIVE	20.02	78.39	155.51
CARNARVON	0.02	25.26	-106.93
ORRORAL	2.02	-9.52	-116.39
FAIRBANKS	7.02	-56.10	-27.05
GREENBELT	11.02	-52.04	90.71
SANTIAGO	12.02	-18.49	130.34

END CONDITIONS AT CLOSEST APPROACH TO MOON

TIME (HR)	RADIUS (KM)	INCLIN (DEG)	C3 (KM2/SEC2)
110.01	2820.57	115.13	0.6169

NO MORE DATA, RUN TERMINATED

Section 8

ORBIT LIFETIME MODE

This mode is used to integrate the spacecraft while in orbit about the target planet. There are no special analysis techniques associated with this mode. The MAESTRO trajectory propagation mode is used with this mode. The orbit lifetime was included as a separate mode because many of the trajectory propagation inputs that are preset for the trajectory propagation mode must be modified for the orbit lifetime mode. The trajectory propagation inputs modified for this mode are shown in Table 8.1

This mode is preset to fly the lunar orbit using the averaging technique. Thus, the compute interval and print table are set to appropriately large values (two days). If the user changes the trajectory propagator to a scheme other than the averaging, he must also change the compute interval. The multiconic method should not be used with this mode.

A sample of this mode is presented in Figure 8.1. The inputs used in this run were the orbital elements in locations 30-35 and the initial date in locations 50-55. The flight time was set to 20 days for this run. Normally it is 200 days. The shadow flag in 1049 and the flag in location 1018 to determine averaged elements from input osculating elements are set. The output first consists of listings of the input cards array and the entire input with the preset values. The trajectory output shown is obtained from the auxiliary output unit. The KOUT9 flag in location 1058 is preset to 9; thus, the output is obtained from the output unit nine. This output is much more condensed and easier to read for a lifetime case than the normal unit 6 output. The unit 6 output is not lost and is available if desired. The output in the condensed form is labeled. The only output which might cause confusion is FRAME. In this column two integer values are printed. The first integer corresponds to the planet number while the second integer defines the coordinate system. The coordinate system number corresponds to the definition in locations 1039 and 1040. The output times shown in unit 9 are shifted from the values in the print table because the averaged element start-up procedure was used.

Table 8.1

Lunar Lifetime Mode *

MODE = 6

LOCATION	INITIALIZED VALUE	DESCRIPTION
4	.1728D8	Final time
30-35 or 40-45	-	initial state
50-55	-	Initial date
170	1.D20	First switching time
180	.1728D6	First compute time
450	1.D20	Switching time for printing
460	.1728D6	Printing interval
1015	11	Launch planet
1018	0	Earth oblateness flag
1019	4	Input coordinate system
1029	1	Lunar oblateness flag
1030	1	Output frequency flag
1032	0	Closest approach test flag
1035	1	Lunar gravity model
1036	8	Trajectory propagator scheme
1039	5	Earth output coordinate system
1040	2	Moon output system
1044	-	Mode flag set to 6
1058	9	Auxiliary output unit number
1068	6	Number of ordinates per interval in Quadrature integration
1069	3	Number of intervals in the Gaussian Quadrature integration
1098	0	Flag to obtain average elements from osculating elements.

* Inputs to trajectory propagator also set, however many locations are modified

FIGURE 8.1

ORBIT LIFETIME SAMPLE CASE

INPUT CARDS

```
  30 2838.          31 .004                32 0.0
  33 95.            34 116.                35-63.
1044 6.             50 6.                  51 10.
  52 1973.          53 15.                 54 14.
  55 43.             4 .1728      E 07 1049 2.
1098 1.
```

%

MAESTRO OUTPUT

DATA CARDS FOR CASE 1

30	0.283800000D 04	31	0.400000000D-02	32	0.0
33	0.950000000D 02	34	0.116000000D 03	35	-0.630000000D 02
1044	0.600000000D 01	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.430000000D 02	4	0.172800000D 07	1049	0.200000000D 01
1098	0.100000000D 01	0	0.0	0	0.0

LUNAR FIELD, NMOD= 3 MMOD= 3

INITIAL JULIAN DATE 2441844.1352

INPUT COMMON

4	0.172800000D 07	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	23	0.150000000D 02
24	0.140000000D 02	25	0.430000000D 02	30	0.283800000D 04
31	0.400000000D-02	33	0.950000000D 02	34	0.116000000D 03
35	-0.630000000D 02	37	0.418441352D 05	38	0.333390000D 03
46	0.418441352D 05	47	0.131876221D 03	48	0.141009832D 02
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.430000000D 02
100	0.216855300D 01	101	0.324835400D 06	102	0.398603200D 06
103	0.429155150D 05	104	0.126710600D 09	105	0.379186900D 08
109	0.132715450D 12	110	0.490277790D 04	112	0.232981600D 04
113	0.609863600D 04	114	0.637816503D 04	115	0.340953000D 04
116	0.714220000D 05	117	0.575050000D 05	118	0.254840000D 05
119	0.249830000D 05	120	0.634500000D 04	121	0.706000000D 06
122	0.173800000D 04	126	0.729212361D-04	127	0.708820000D-04
128	0.175854900D-03	134	0.266169950D-05	170	0.100000000D 21
180	0.172800000D 06	197	0.470000000D-04	198	0.210000000D 00
201	0.900000000D 03	202	0.200000000D 05	221	0.190000000D 02
222	0.200000000D 02	260	0.533784000D 02	261	0.266892000D 02
262	0.266892000D 02	280	-0.978500000D 04	281	-0.978500000D 04
321	0.900000000D 03	322	0.200000000D 05	331	0.190000000D 02
332	0.200000000D 02	350	0.240400000D-01	351	0.120200000D-01
352	0.120200000D-01	360	0.353200000D 01	361	0.353200000D 01
380	0.100000000D 21	381	0.100000000D 21	382	0.100000000D 21
383	0.100000000D 21	384	0.100000000D 21	385	0.100000000D 21
407	0.680000000D 00	408	0.136000000D 09	409	0.400000000D 09
410	0.483583263D 00	411	0.825596028D 00	412	0.198472510D 01
413	0.259978941D 01	414	0.370861990D 01	415	0.483672461D 01
416	0.494202256D 01	417	0.504982198D 01	420	0.283800000D 04
421	0.116500000D 03	422	0.396000000D 06	423	0.620000000D 00
433	0.135600000D 05	434	0.720000000D 04	435	0.700000000D 00
436	0.200000000D-01	437	0.700000000D-01	438	0.300000000D-03

```
 439   0.360000000D 05   440   0.259200000D 06   441    0.226000000D 03
 442   0.282500000D 03   443   0.705792000D 02   444    0.223800000D 04
 445   0.131436176D 01   446   0.116500000D 03   447    0.600000000D 04
 448   0.600000000D 04   450   0.100000000D 21   460    0.172800000D 06
 470   0.600000000D 01   471   0.167800000D 00   472    0.204000000D 02
 473   0.123377000D 02   474   0.500000000D 01   475    0.200000000D 02
 478   0.720000000D 04   479   0.300000000D-03   480   -0.449174131D 00
 481  -0.329923498D 00   482  -0.432101757D 00   483   -0.618694470D 00
 484   0.113138500D 01   485   0.611105355D 00   486    0.677363671D 00
 487  -0.575538692D 00   490   0.100000000D 02   491    0.100000000D 02
 492   0.100000000D 02   493   0.100000000D-03   494    0.100000000D-03
 495   0.200000000D-01   496   0.500000000D 01   497    0.200000000D 00
 501   0.616000000D 06   502   0.925000000D 06   503    0.565000000D 06
 504   0.480000000D 08   505   0.540000000D 08   506    0.510000000D 08
 507   0.860000000D 08   508   0.330000000D 08   509    0.100000000D 11
 510   0.110000000D 06  1003   0.200000000D 01  1010    0.100000000D 01
1011   0.200000000D 01  1014   0.300000000D 01  1015    0.110000000D 02
1017   0.500000000D 01  1019   0.400000000D 01  1023    0.100000000D 01
1029   0.110000000D 02  1030   0.100000000D 01  1031    0.110000000D 02
1033   0.100000000D 01  1035   0.100000000D 01  1036    0.800000000D 01
1039   0.500000000D 01  1040   0.200000000D 01  1041    0.100000000D 02
1042   0.150000000D 02  1043   0.210000000D 02  1044    0.600000000D 01
1048   0.100000000D 01  1049   0.200000000D 01  1051    0.100000000D 02
1052   0.200000000D 01  1053   0.500000000D 02  1054    0.170000000D 02
1055   0.100000000D 01  1058   0.900000000D 01  1060    0.100000000D 01
1061   0.110000000D 02  1062   0.200000000D 01  1063    0.200000000D 01
1064   0.100000000D 01  1065   0.100000000D 02  1066    0.100000000D 01
1067   0.100000000D 01  1068   0.600000000D 01  1069    0.300000000D 01
1070   0.950000000D 02  1071   0.600000000D 01  1075    0.600000000D 01
1083   0.110000000D 02  1088   0.120000000D 02  1089    0.123456700D 07
1098   0.100000000D 01
```

```
                 RAE-B LUNAR ORBIT TIME HISTORY
              INITIAL JULIAN DATE = 2441944.135
                  TRAJECTORY PROPAGATOR = 7
              ORDINATES =   6    INTERVALS =   3
               COMPUTE INTERVAL =   2.00DAYS

  TIME     SMA      ECCEN      TRUE       AOP       INCLIN      LAN  FRAME   SHAD T
RESTART WITH AVERAGED ELEMENTS AT T =      6784.4 SEC.
  2838.3 0.004087 -179.635   71.433   128.762   -59.743 MEAN OF 50
   0.08   2838.3 0.004087 -179.635    94.635   115.993   -64.021 11   2    0.0
   2.08   2838.3 0.003842   95.247    84.703   115.935   -90.033 11   2    0.0
   4.08   2838.3 0.004191    8.417    75.625   116.026 -116.048 11   2    0.0
   6.08   2838.3 0.004762  -80.031    68.043   116.199 -142.113 11   2    0.0
   8.08   2838.3 0.004909 -169.038    61.992   116.335 -168.243 11   2    0.0
  10.08   2838.3 0.004600   98.089    60.092   116.332  165.595 11   2    0.0
  12.08   2838.3 0.004336   -3.902    66.062   116.182  139.453 11   2    0.0
  14.08   2838.3 0.004432 -110.300    76.520   115.980  113.301 11   2    0.184
  16.08   2838.3 0.004492  146.158    85.369   115.875   87.294 11   2    0.289
  18.08   2838.3 0.004226   41.471    94.672   115.959   61.414 11   2    0.350
  20.00   2838.4 0.004064  116.797   103.943   116.156   35.398 11   2    0.405
```

Section 9

POST-INJECTION TRIM MODE

This mode is used to determine the trim maneuvers required to adjust the post-retro orbit to the desired quantities. The desired orbit is defined as a circular orbit of the radius input in location 444 and inclination with respect to the equator input in location 446. This mode presents two different trim maneuvers. The first is a two-impulse plane change maneuver determined from a method developed by F.T. SUN. This method is described in reference 1. The second maneuver shown is a two-impulse Hohmann transfer maneuver. This maneuver corrects only the radius and eccentricity. The inclination is not changed.

To use this mode, the initial spacecraft state is input in the normal manner, the final orbit conditions in locations 444 and 446,and the MODE flag set to seven. The input in location 449 is used to control the analysis to some extent. If the difference between the inclination of the pre-trim orbit and the desired orbit is less than the value loaded in 449, the plane change maneuver will not be determined. There are no other special inputs for this mode.

The output of this mode is shown in Figure 9.1. The first part of this figure is the input data cards. The second part is the program output. The analysis appears after the input array. This output presents a description of the initial, transfer, and final orbits in the target planet's equator and prime meridian. The second part describes the trim impulses. The attitude of the maneuver is in the Earth mean equator and the ecliptic of 1950. The times are shown assuming the impulses are performed at the earliest possible times. In actuality, the maneuver can be applied at the indicated time plus any integer times the orbit period. These times are relative to launch epoch.

The same output is presented for the Hohmann transfer maneuver. The post-trim state is presented in the Earth mean equinox and equator of 1950.

The precise post-injection trim maneuver is determined by the targeting portion of the post-injection trim analysis. This analysis uses the midcourse logic to determine the trim motor's firing time, attitude, and burntime which will result in some desired post-trim orbit. The desired end conditions could be obtained from the post-injection trim analysis discussed above. The midcourse logic uses secant partials to determine the motor's attitude and burntime at some fixed ignition time. However, the analysis automatically scans through a range of ignition times so that the characteristics as a function of ignition time can be readily accessed.

To use this mode, the MODE flag is set to seven and the targeting flag in location 1091 is set to 1. The flags pertaining to the midcourse analysis are not automatically set, thus the user should exercise some care when using this mode. Table 9.1 describes the inputs required to run this analysis. The orbital elements at the final time defined by location 4 are the dependent variables used in the iteration scheme. If the final time is input zero or less than the required motor burntime, the final time is automatically set to the burnout time. A finite burn of the motor (location 1071) will initiate a two-step iteration process. The first step determines the burntime using the impulsive velocity approximation. The impulsive velocity approximation is used as a first guess in the finite burn step except that the ignition time is decreased by half the burn time so that the motor burn is centered about the desired ignition time.

A sample of this mode is shown in Figure 9.2. The inputs indicate that three firings are desired beginning at 2735.8 seconds, spaced at 10 minute intervals. The final time is input zero to indicate that the elements at burnout are the dependent variables. The desired end conditions are input in locations 420 - 422 and the tolerances on those elements input in locations 490 - 492. A finite burn using Cowell's method is indicated through the flag in location 1071.

The MAESTRO output is shown in the second part of the figure. The post-injection targeting appears after the input common listing. The output presents the motor firing conditions as a function of ignition time. A second block presents the post-firing orbital elements. A solution for the second firing time is not attempted because the radius at the desired ignition time did not fall between the apo-apsis or peri-apsis defined by the desired orbit.

Table 9.1

Post-Injection Trim Targeting

MODE = 7

LOCATION	INITIALIZED VALUE	DESCRIPTION
4	540000.	Initial time. Should reset to zero.
20-25	-	liftoff epoch
30-35 40-45	-	initial state
50-55	-	State epoch
410-419	-	observation site longitude
420	-	desired semi-major axis
421	-	desired inclination
422	-	desired eccentricity
434	7200	Increment in execution time.
478	7200	First execution time. Should reset.
490	10.	Tolerance on semi-major axis.
491	10.	Tolerance on eccentricity. Should reset to small number.
492	10.	Tolerance on inclination. Should reset smaller.
1015	3	Launch planet. Should reset to 11.
1019	1	Input coordinate system
1030	0	Output frequency flag. Set to -1.
1044	-	Mode set to 7.
1051	10	Number of execution times.
1063	1	Targeting law set to 2.
1064	1	Number of times to recompute partials. Should be set to 10.
1066	0	Pre-targeting flag should be set to zero.
1071	0	Trajectory propagator used when burning motor. Do not use 6.
1075	6	Propagator used to generate partials. Do not use 6.
1091	0	Targeting flag set to 1.

FIGURE 9.1

POST-INJECTION TRIM ANALYSIS SAMPLE CASE

INPUT DATA CARDS

20	6.	21	10.	22	1973.
23	15.	24	1.	25	3.25
50	6.	51	10.	52	1973.
53	15.	54	14.	55	43.268
30	3007.6	31	.13584	32	83.87
33	77.29	34	114.67	35	-97.53
1044	7.	1019	4.	444	3500.
1015	11.				

MAESTRO OUTPUT
DATA CARDS FOR CASE 1

20	0.600000000D 01	21	0.100000000D 02	22	0.197300000D 04
23	0.150000000D 02	24	0.100000000D 01	25	0.325000000D 01
50	0.600000000D 01	51	0.100000000D 02	52	0.197300000D 04
53	0.150000000D 02	54	0.140000000D 02	55	0.432680000D 02
30	0.300760000D 04	31	0.135840000D 00	32	0.838700000D 02
33	0.772900000D 02	34	0.114670000D 03	35	-0.975300000D 02
1044	0.700000000D 01	1019	0.400000000D 01	444	0.350000000D 04
1015	0.110000000D 02	0	0.0	0	0.0

LUNAR FIELD, NMOD= 3 MMOD= 3

INITIAL JULIAN DATE 2441344.1352
INPUT COMMON

4	0.540000000D 06	5	0.100000000D 01	6	0.100000000D 01
8	0.100000000D-10	10	0.100000000D 21	20	0.600000000D 01
21	0.100000000D 02	22	0.197300000D 04	23	0.150000000D 02
24	0.100000000D 01	25	0.325000000D 01	30	0.300760000D 04
31	0.135840000D 00	32	0.838700000D 02	33	0.772900000D 02
34	0.114670000D 03	35	-0.975300000D 02	37	0.418441257D 05
38	0.333390000D 03	46	0.418441352D 05	47	0.713556478D 02
48	-0.317648987D 02	50	0.600000000D 01	51	0.100000000D 02
52	0.197300000D 04	53	0.150000000D 02	54	0.140000000D 02
55	0.432680000D 02	100	0.216855300D 01	101	0.324835400D 06
102	0.398603200D 06	103	0.429155150D 05	104	0.126710600D 09
105	0.379186900D 08	109	0.132715450D 12	110	0.490277790D 04
112	0.232981600D 04	113	0.609863600D 04	114	0.637816502D 04
115	0.340953000D 04	116	0.714220000D 05	117	0.575050000D 05
118	0.254840000D 05	119	0.249830000D 05	120	0.634500000D 04
121	0.706000000D 06	122	0.173800000D 04	126	0.729212361D-04
127	0.708820000D-04	128	0.175354900D-03	134	0.266169950D-05
170	0.360000000D 04	171	0.180000000D 05	172	0.100000000D 20
180	0.300000000D 03	181	0.180000000D 04	182	0.180000000D 05
197	0.470000000D-04	198	0.210000000D 00	201	0.900000000D 03
202	0.200000000D 05	221	0.190000000D 02	222	0.200000000D 02
260	0.533784000D 02	261	0.266892000D 02	262	0.266892000D 02
280	-0.978500000D 04	281	-0.978500000D 04	321	0.900000000D 03
322	0.200000000D 05	331	0.190000000D 02	332	0.200000000D 02
350	0.240400000D-01	351	0.120200000D-01	352	0.120200000D-01
360	0.353200000D 01	361	0.353200000D 01	380	0.100000000D 21
381	0.100000000D 21	382	0.100000000D 21	383	0.100000000D 21
384	0.100000000D 21	385	0.100000000D 21	407	0.630000000D 00
408	0.136000000D 09	409	0.400000000D 09	410	0.483583263D 00
411	0.325596028D 00	412	0.198472510D 01	413	0.259978941D 01
414	0.370861990D 01	415	0.483672461D 01	416	0.494290256D 01
417	0.504982183D 01	420	0.283800000D 04	421	0.116500000D 03

422	0.396000000D 06	423	0.620000000D 00	433	0.125000000D 05
434	0.720000000D 04	435	0.700000000D 00	436	0.200000000D-01
437	0.700000000D-01	438	0.200000000D-03	439	0.260000000D 05
440	0.259200000D 06	441	0.226000000D 03	442	0.282500000D 03
443	0.705792000D 02	444	0.350000000D 04	445	0.118355130D 01
446	0.116500000D 03	447	0.600000000D 04	448	0.600000000D 04
450	0.100000000D 21	460	0.180000000D 05	470	0.600000000D 01
471	0.167800000D 00	472	0.204000000D 02	473	0.123377000D 02
474	0.500000000D 01	475	0.200000000D 02	478	0.720000000D 04
479	0.300000000D-03	480	-0.449174131D 00	481	-0.329923498D 00
482	-0.432101757D 00	483	-0.613684470D 00	484	0.113133600D 01
485	0.611106355D 00	486	0.677368671D 00	487	-0.575538692D 00
490	0.100000000D 02	491	0.100000000D 02	492	0.100000000D 02
493	0.100000000D-03	494	0.100000000D-03	495	0.200000000D-01
496	0.500000000D 01	497	0.200000000D 00	501	0.616000000D 06
502	0.925000000D 06	503	0.565000000D 06	504	0.480000000D 08
505	0.540000000D 02	506	0.510000000D 08	507	0.960000000D 02
508	0.330000000D 08	509	0.100000000D 11	510	0.110000000D 06
1003	0.200000000D 01	1010	0.100000000D 01	1011	0.200000000D 01
1014	0.300000000D 01	1015	0.110000000D 02	1017	0.500000000D 01
1018	0.100000000D 01	1019	0.400000000D 01	1023	0.100000000D 01
1029	0.110000000t02	1030	0.100000000D 01	1031	0.110000000D 02
1032	0.200000000D 01	1033	0.100000000D 01	1035	0.100000000D 01
1036	0.400000000D 01	1039	0.300000000D 01	1040	0.200000000D 01
1041	0.100000000D 02	1042	0.150000000D 02	1043	0.210000000D 02
1044	0.700000000D 01	1048	0.100000000D 01	1051	0.100000000D 02
1052	0.200000000D 01	1053	0.500000000D 02	1054	0.170000000D 02
1055	0.100000000D 01	1060	0.100000000D 01	1061	0.110000000D 02
1062	0.200000000D 01	1063	0.200000000D 01	1064	0.100000000D 01
1065	0.100000000D 02	1066	0.100000000D 01	1067	0.100000000D 03
1068	0.600000000D 01	1069	0.200000000D 01	1070	0.350000000D 02
1071	0.600000000D 01	1075	0.600000000D 01	1083	0.110000000D 02
1088	0.120000000D 02	1089	0.123456700D 07		

RAE-B POST-INJECTION TRIM ANALYSIS

TWO IMPULSE PLANE CHANGE MANEUVER

ORBITAL ELEMENTS OF PERTINENT ORBITS
IN TRUE SELENOGRAPHIC SYSTEM

	SEM (KM)	ECC	INCLIN (DEG)	PERIOD (HR)	LON (DEG)
INITIAL ORBIT	3007.6	0.18584	114.67	4.111	-97.53
TRANSFER ORBIT	3518.8	0.00554	116.46	5.202	-93.57
FINAL ORBIT	3500.0	0.00000	116.50	5.161	-93.59

	TIME (HR)	MAG (M/SEC)	R.A. (DEG)	DEC (DEG)	SPIN-SUN (DEG)
FIRST IMPULSE	1.08	145.90	-52.89	-4.09	122.14
SECOND IMPULSE	3.69	3.99	-104.23	-31.89	179.28

POST TRIM STATE IN EARTH MEAN EQUATOR OF 1950
JULIAN DATE = 2441844.2890

X	Y	Z
-0.970809033D 03	-0.278180410D 04	0.188920485D 04

XDOT	YDOT	ZDOT
-0.436521161D 00	0.718247630D 00	0.833284630D 00

HOHMANN TRANSFER MANEUVER

ORBITAL ELEMENTS OF PERTINENT ORBITS IN TRUE SELENOGRAPHIC SYSTEM

	SEM (KM)	ECC	INCLIN (DEG)	PERIOD (HR)	LON (DEG)
INITIAL ORBIT	3007.6	0.18584	114.67	4.111	-97.53
TRANSFER ORBIT	3533.3	0.00942	114.67	5.25	-97.53
FINAL ORBIT	3500.0	0.00000	114.67	5.161	-97.53

	TIME (HR)	MAG (M/SEC)	R.A. (DEG)	DEC (DEG)	SPIN-SUN (DEG)
FIRST IMPULSE	1.33	109.01	-74.42	-34.42	153.52
SECOND IMPULSE	3.95	5.56	-74.42	-34.42	153.52

POST TRIM STATE IN EARTH MEAN EQUATOR OF 1950

JULIAN DATE = 2441844.2999

X	Y	Z
-0.121996144D 04	-0.212066578D 04	0.250289227D 04

XDOT	YDOT	ZDOT
-0.262304050D 00	0.940454258D 00	0.668981354D 00

POST INJECTION TRIM TARGETING

MOTOR SIMULATED USING METHOD 1

INITIAL ORBIT

SEM (KM)	ECC	TRUE (DEG)	AOP (DEG)	INCLIN (DEG)	LAN (DEG)
3023.57	0.03404	1.81	357.90	37.56	156.53

IGN TIME (HR)	DATE	GMT TIME (HR)	BURN TIME (MIN)	VEL MAG (M/S)	FUEL (KG)	RA (DEG)	DEC (DEG)	SPIN-S (DEG)	TRUE ANOM (DEG)	TRACKING VISIBILITY JFCOFRGS
185.97	17	7.41	2.98	34.91	3.76	295.19	26.73	122.16	-62.95	00000437
186.13	17	7.58	3.19	37.23	4.01	309.45	19.06	119.54	-53.90	00000337
186.30	17	7.74	3.52	40.90	4.41	322.46	20.33	114.75	-38.85	00000337

ORBITAL ELEMENTS OF POST-TRIM LUNAR ORBIT

FIRING TIME (HR)	SEM (KM)	ECC	TRUE ANOM (DEG)	AOP (DEG)	INCLIN (DEG)	LON (DEG)
185.969	2982.2	0.04837	-77.22	19.38	59.04	60.97
186.134	2982.2	0.04837	-70.86	28.37	59.04	60.87
186.298	2982.2	0.04837	-65.40	38.50	59.04	60.78

REFERENCES

1. Final Report for the Development of a Trajectory Control Program and Midcourse Guidance Program on the RAE-B Lunar Orbiting Mission, Contract No. NAS 5-11900, Analytical Mechanics Report No. 73-8, March 1973.

2. Final Report for Radio Astronomy Explorer-B In-Flight Mission Control System Design Study, Contract No. NAS 5-11796, Analytical Mechanics Report No. 71-23, April 1971.