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# Interplanetary Program To Optimize Simulated Trajectories (IPOST)

*Volume IV - Sample Cases*

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# 1.0 INTRODUCTION

The Interplanetary Program to Optimize Simulated Trajectories (IPOST) is intended to support many analysis phases, from early interplanetary feasibility studies through spacecraft development and operations. The IPOST output provides information for sizing and understanding mission impacts related to propulsion, guidance, communications, sensor/actuators, payload, and other dynamic and geometric environments.

Much of the overall architecture for IPOST has been derived from the Program to Optimize Simulated Trajectories (POST). Indeed certain POST parameters and capabilities have been incorporated into IPOST to aid in POST-IPOST user compatibility. IPOST has extended trajectory capabilities to target planets and other celestial bodies with intermediate and velocity correction maneuvers. IPOST capabilities and limitations are summarized in Table 1-1.

<b>FEATURE</b>	<b>CAPABILITY</b>
Optimization method	Explicit (Master/subproblems), Implicit (collocation)
Optimization algorithm	NPSOL
Optimization parameter*	$\Delta V$ magnitude, mass, time, . . .
Maximum controls	25 (Master), 45 (subproblems), 1700 (collocation)
Control parameters*	Values of event criteria, $\Delta V$ , arrival conditions, thrust, . . .
Maximum targets	25 (Master), 45 (subproblems), 1700 (collocation)
Target parameters*	Time, position, velocity, orbital conditions, . . .
Targeting method	NPSOL, Newton-Raphson, special Onestep
Sensitivity matrix	Finite differencing, analytic for special interplanetary targeting
Maximum events	100
Event criteria*	Time, distance, speed, closest approach, . . .
Event activities	Info, impulsive $\Delta V$ , launch, orbit insertion, mass jettison
Maximum maneuvers/ subproblems	15
Trajectory propagation	Conic, Onestep, Multiconic, Encke, Cowell, implicit
Planetary bodies	Sun, nine planets, Earth's moon, any user-defined bodies
Ephemeris	Analytic, precision (JPL)
Trajectory perturbations	Central body, perturbing bodies, radiation pressure, $J_2$ , aerodynamics, thrust
Input/Output frames	Ecliptic or planet equator, Mean 1950 or Mean 2000
* User selectable	

Table 1 - 1. IPOST Features/Capabilities

**IPOST, along with members of its family, such as POST and IPREP, can analyze and support almost every activity associated with space exploration (Figure 1- 1).**

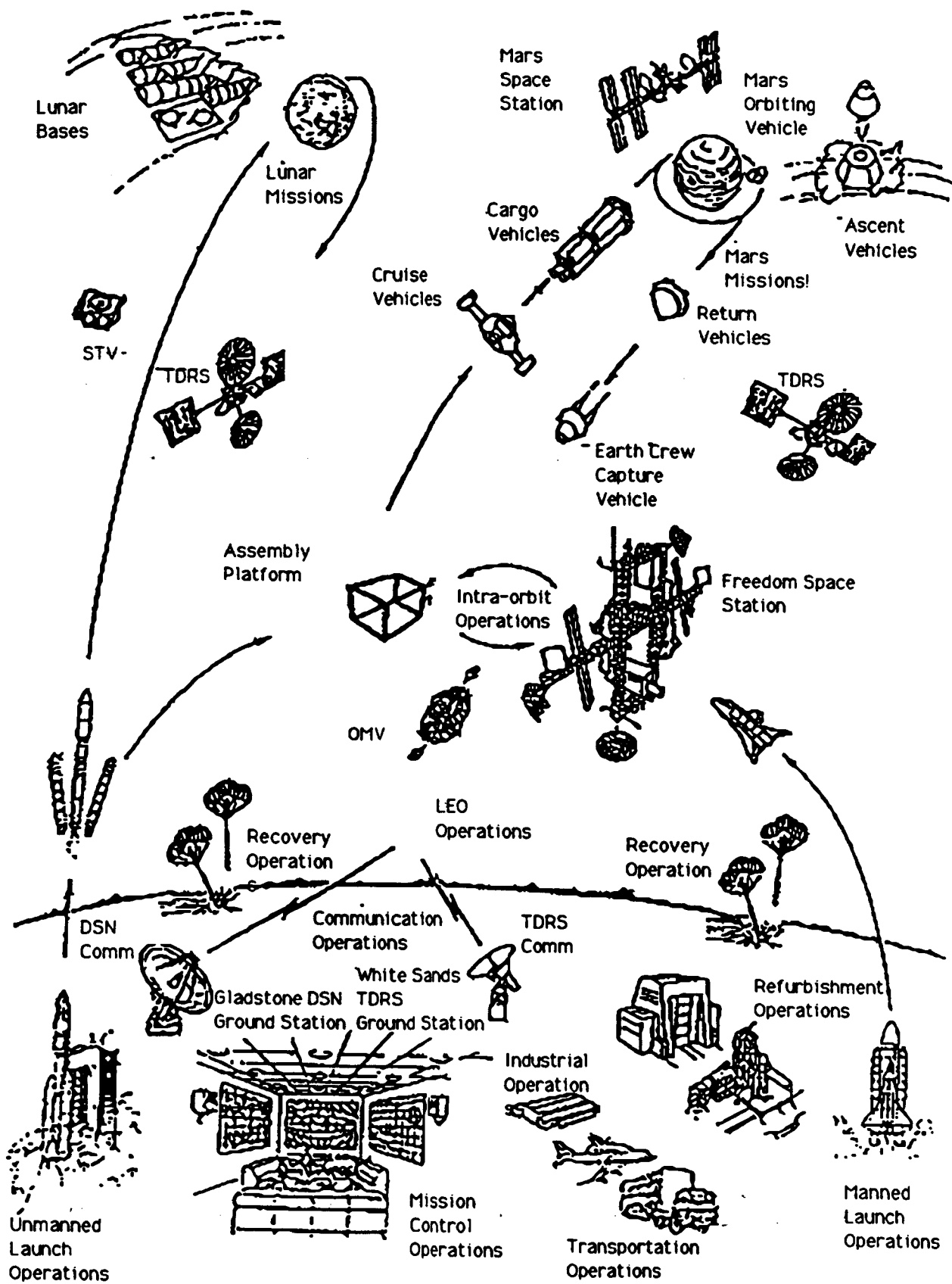


Figure 1-1. Space Exploration Infrastructure

IPOST is event driven. That is, the user defines a sequence of events which are executed in the simulation process. The events can be triggered by different criteria, such as absolute or relative time, distance from a body, or propellant consumption. At the event times, various activities can be initiated or terminated, such as employing a different thrust steering law, changing trajectory propagators or propagation step size, performing an impulsive delta velocity maneuver or jettisoning a probe or stage.

The time period between two contiguous events is called a phase. Trajectory propagation takes place in each phase. Five types of propagators are available (listed in order of increasing accuracy and decreasing computational speed): Conic, Onestep, Multiconic, Encke, Cowell. Propagator selection depends upon user needs, such as simple fast simulations for parametric feasibility analysis, or precision detailed trajectories to support subsystem design.

IPOST can run a single trajectory simulation or it can run multiple simulations. For multiple simulations, one can run a parametric scan and/or an optimization mode. The search mode will vary one parameter, such as planetary arrival time, over a specified interval and increment size, and perform a simulation (or optimization) for each search parameter value.

The optimization mode will optimize a user cost/objective function, such as maximum mass that can be placed in a desired orbit, subject to user-specified constraints. The constraint variables, such as periapsis altitude or orbital inclination, are called dependent variables or target parameters. The parameters which are free to vary, such as maneuver delta velocity ( $\Delta V$ ), are called independent variables or control parameters. As part of, or instead of, optimization, trajectory targeting can be performed. In this case, there is no cost function and the IPOST problem reduces to finding a set of control parameter values that meet specified target parameter conditions.

Generalized targeting and optimization uses the Stanford NPSOL algorithm. For certain types of problems, a trajectory decomposition method is available. There is a master optimization process which requires that the trajectory be divided into legs or sub-problems. Each sub-problem is an optimization problem in itself, containing controls, constraints and an (optional) objective function. A special application of decomposition is the Interplanetary Targeting and Optimization Option (ITOO). This technique uses analytical partials generated during nominal trajectory propagation to determine minimum  $\Delta V$  (or mass) trajectories, usually for gravity assist (swingby) missions.

In addition to the classic method of explicit optimization, there exists an option to perform implicit optimization using the collocation method. In this case, each phase is divided into independent segments which are allowed to vary subject to intersegment continuity and the equations of motion. Optimization using collocation is less sensitive to faulty initial guesses, but requires much greater CP time than explicit optimization to achieve the same level of accuracy.

IPOST input is via three namelists: \$TOP, \$TRAJ and \$TAB. \$TOP contains a description of the targeting and optimization problem. It must be input first. \$TRAJ contains data that describes each mission event/phase. It must follow \$TOP, and there must be one \$TRAJ for each event. \$TAB is used to input tabular data such as thrust vs. time or drag coefficient vs. mach number and angle of attack. Input and output units are metric.

## **2.0 APPLICATIONS**

Examples of mission applications are shown in Table 2 - 1. They illustrate some of the diverse IPOST model capabilities, including lunar, interplanetary, orbital, thrusting (impulsive, low, high), and gravity assist.

The typical IPOST application is usually in the form of run sequences which compare various mission options. These analysis threads build on each other, culminating in a reference mission which is used to support detailed system design and analysis. Table 2 - 2 illustrates representative mission threads which exercise key IPOST capabilities.

For example, in the Comet Rendezvous thread, each case is actually several runs of IPOST to generate parametric data such that mission decisions and refinements can be made. The sequence of multiple runs per case feeds each succeeding case with each case becoming more realistic in terms of model fidelity, and encompassing more system objectives and constraints.

The first step in the Comet Rendezvous thread is to define mission requirements (necessary conditions) and goals (desired conditions), as well as any known constraints, such as technology status. In this thread, a mission requirement would be to successfully rendezvous with a specific comet in a specific time frame. A mission goal might be to collect data on planets or bodies that are encountered during the interplanetary trajectory from Earth to the comet. A mission constraint might be the availability of a Cesium ion thrust engine powered by solar arrays, which provide limits on power/thrust levels and on specific impulse.

The first case is an approximate impulsive  $\Delta V$  solution using a Venus gravity assist. This examines coarse energy requirements, benefits of gravity assist, and optimum mission opportunities (launch-arrival dates with payload/launch mass sensitivities). The mission may be analyzed as separate phases, e.g., Earth to Venus, Venus to comet approach, rendezvous and stationkeeping.

The second case models a low thrust mission using a single thrust segment with variable steering and variable throttle. Implicit optimization (collocation) is used. This recognizes the coarseness of the initial guess, and provides rapid solution searches. A determination is made whether available technology is sufficient to provide the required payload mass at comet rendezvous.

As mission knowledge evolves, the third case introduces multiple coast/thrust segments. These added degrees of freedom provide more flexible, and more realistic, mission solutions. The optimization method can be implicit or explicit (with master-subproblems), depending upon how many, and what level, of mission decisions need to be made. This would include interplanetary and close encounter geometries, flight times, subsystem performance, etc.



TEST CASE	MISSION DURATION	PLANETARY BODIES	ACTIVITIES	SIMULATION	OPTIMIZATION
VOYAGER I	5 years	Earth Jupiter Saturn	Launch, Midcourse $\Delta V$ , Gravity assist	E-J-S, 1 Step, 6 Phases	Minimize to total $\Delta V$ , 2 subproblems
GALILEO	4.2 years	Earth Venus Jupiter	Launch, Midcourse $\Delta V$ , Gravity assist, Probe	E-V-E-E-J, 1 Step, 9 Phases	Minimize total $\Delta V$ , 4 subproblems
LUNAR ORBITER	4 days	Earth Moon (Sun)	Launch, Midcourse $\Delta V$ , Orbit insertion	E-M, 1 Step, 3 Phases	Maximize final mass, Master problem only
VENUS ORBITER WITH SEP	5 months	Earth Venus	Launch, Solar Power, Low Thrust, Orbit Insertion	E-V, 6 Phases	Maximize final mass, Collocation, 5 seg/phase
MANNED MARS	3 years	Earth Mars	Launch (E,M), Midcourse $\Delta V$ , Orbit Insertion	E-M-M-E, 1 Step, Conic, 6 Phases	Minimize initial mass, 3 subproblems
SATURN ORBITER WITH NUCLEAR PROPULSION	4 years	Earth Saturn	Launch, Nuclear Power, Medium Thrust, Orbit Insertion	E-S, 1 Step, Encke, Cowell, 5 Phases	Maximize final mass, 2 subproblems
CRAF	2.3 years	Earth Venus Comet Asteroid	Launch, Midcourse $\Delta V$ , Gravity Assist, Flyby, Rendezvous	E-V-A-C, 7 Phases	Minimize total $\Delta V$ , Collocation, 3 seg/phases

Table 2 - 1 IPOST SAMPLE CASES

The final case provides an end-to-end precision optimized reference trajectory for system analyses and subsystem design support. Science and mission objectives can be assessed with a high degree of confidence.

- **Lunar Mission Thread**
  - L1 Earth departure to lunar orbit with patched conic
  - L2 Space Station to moon with free return
  - L3 Space Station with finite burn escape to libration point
- **Voyager II Thread**
  - V1 EJS portion with ITOO (analytic partials)
  - V2 EJSUN with finite differences partials
- **Comet Rendezvous with Solar Electric Propulsion Thread**
  - C1 Approximate impulsive  $\Delta V$  (DSM) with Venus gravity assist.
  - C2 Single thrust segment, simple collocation
  - C3 Multiple thrust segments, complex collocation
  - C4 Explicit optimization comparison
- **Human Mission to Mars Thread**
  - M1 EM launch/arrival date search, simple aerocapture
  - M2 MVE return leg optimization, Earth orbit capture
  - M3 Mars surface ascent to orbit (MAV design)
  - M4 EMMVE round-trip optimization

Case	Bodies	Propagator(s)	Forces	Optimization method
L1	E-Moon	Conic	-	M
L2	SS-Moon-E	1-step	SB, J2	M
L3	E - L1	Multiconic, Cowell	DB, HT	MS(2)
V1	E-J-S	1-step, Conic	SB	MS(3) + ITOO
V2	E-J-S-U-N	1-step	SB	MS(5)
C1	E-V-C	1-step, Conic	SB	MS(2)
C2	E-C	nseg = 1	DB, LT	collocation
C3	E-C	nseg = 6	DB, LT, SP	collocation
C4	E - C	Encke	DB, LT, SP	M
M1	E - M	1-step	SB	Search
M2	M-V-E	1-step	SB	MS(2)
M3	M	Cowell	HT, A	M
M4	E-M-M-V-E	1-step, Encke	SB, J2	MS(3)

A = Aerodynamics    LT = Low thrust    DB = Disturbing body  
 J2 = Zonal (J2)    SP = Solar pressure    M = Master only  
 HT = High thrust    SB = Secondary body    MS = Master + Sub(s)

Table 2 - 2. Example Mission Threads

### **3.0 SAMPLE CASES**

The following sample cases illustrate detailed mission applications of IPOST. These are by no means intended to cover all capabilities nor are they realistic in every detail, but they do provide meaningful examples for constructing and understanding mission applications. There are 8 case discussions, four include both IPOST input and output, and the last four cases include only IPOST input.

The first sample case is a Voyager 2 mission which illustrates a Master-Subproblem formulation. The second sample case is a manned Mars mission that shows a complete round-trip. The third sample case is a Lunar mission which departs from Space Station Freedom and terminates with an insertion into lunar orbit. The fourth sample case illustrates optimization using collocation for an Earth-Jupiter mission.

The fifth case illustrates trajectory simulation with no targeting or optimization. The sixth case is a version of Voyager 2 with subproblem optimization. The seventh case shows a classic Hohmann transfer problem using finite thrust and collocation. The eighth case is a low thrust mission to Jupiter.

### **3.1 VOYAGER 2**

The Voyager 2 case illustrates a master subproblem formulation and multiple planetary encounters. Only the Earth-Jupiter-Saturn phase of Voyager is performed. The simulation has 8 events, starting in Earth park orbit and ending with a Saturn flyby. Total impulsive delta V is minimized in the master problem. The two subproblems target each of two legs, Earth to Jupiter and Jupiter to Saturn.

In setting up an IPOST problem, the trajectory simulation is defined first, as opposed to the optimization process, because it describes the primary mission.

The first \$TRAJ namelist is event 5. This utilizes parameters such as S/C mass and propulsion characteristics. The initial date of July 31, 1977 precedes the actual Voyager launch date. The S/C is placed in a circular orbit about Earth, and trajectory propagation will use conic, or two-body, equations of motion.

The second event (#10) is triggered by a flight time of 20 days. The 1STEP propagator is activated in connection with activation of the LAUNCH mode. Hence, Voyager orbits the Earth for 20 days and then is impulsively injected onto an escape hyperbola. Using flight time as a control parameter would allow variation of initial launch date. For 1STEP, the primary body is the Sun and Earth is the secondary body.

The third event (#15) is initiated after a flight time of 20 days from the launch event. At this point, the S/C is well outside of the Earth's sphere of influence. The secondary body is now defined as Jupiter for 1STEP propagation. The reference body for trajectory calculations is also set to Jupiter.

At event 20, the triggering criteria is mission time. The intended value is Jupiter closest approach time which is not specified explicitly, but indirectly through the optimization process. A conic propagator is used with Jupiter as the primary body.

One day later, at event 23, an impulsive trajectory correction maneuver is executed. 1STEP is reactivated as the propagator as the vehicle flies away from Jupiter. The combination of gravity assist and midcourse correction will set up the trajectory for the flight towards Saturn.

The fifth event (#25) occurs 300 days after the midcourse maneuver. The secondary body for 1STEP is switched to Saturn, as is the reference body. A general rule of thumb is that planetary sphere's of influence for 1STEP (and Multiconic) are about 20 days for small inner planets (Mercury to Mars) and 200 days for large outer planets (Jupiter to Neptune).

The next event (#30) is Saturn's closest approach, on August 25, 1981. It occurs 1467 days after Earth park orbit escape.

A final event (#90) is used as a "dummy" event, and coincides with the previous event. This event is needed because final event computations are done only on the "minus" side of the event. The namelist specification of "NONE" means no more input follows; that is, this is the end of IPOST problem specification.

We now return to the optimization definition, or \$TOP namelist. The NPSOL algorithm is used with finite difference perturbations being calculated internally by NPSOL. This is the normal mode, as opposed to the user specifying perturbations. A maximum of 10 iterations is allowed for master problem optimization and 600 iterations for each subproblem targeting process. A subproblem targeting iteration is typically much shorter than a master problem iteration because the latter must solve all subproblems successfully.

The master problem controls are Jupiter closest approach time (defined as the criterion of event 20),  $B \cdot T$  and  $B \cdot R$  of the Jupiter approach, or incoming, hyperbola (defined as the 2nd and 3rd dependent variables of subproblem 1). In addition to the initial guesses for control values, the upper and lower bounds, and weighting values are important inputs. These define the performance manifold and often mean the difference between problem convergence and divergence. The objective function is the sum of all  $\Delta V$  magnitudes, which in this case corresponds to the launch/escape maneuver at Earth plus the Jupiter midcourse correction.

The two subproblems are defined next. The first subproblem ends at event 20 (Jupiter closest approach) and the second subproblem ends at event 30 (Saturn closest approach). IPOST automatically assumes that subproblems are non-overlapping. Both subproblems use a Newton-Raphson targeting technique, as opposed to subproblem optimization with NPSOL.

The control variables for subproblem 1 are the  $V$ -infinity vector of the Earth departure hyperbola. Controls for subproblem 2 are the  $\Delta V$  components after Jupiter flyby. As in the master problem, important inputs are the control initial guesses (USUB), bounds (INDSL and INDSUB), and weightings (WGTS).

The constraint or target variables for subproblem 1 are time from periapsis,  $B \cdot T$  and  $B \cdot R$  at Jupiter. For subproblem 2 the constraints are time from periapsis,  $B \cdot T$  and closest approach distance at Saturn. The use of  $B \cdot T$  as a control parameter (with loose bounds) at Saturn affects orbit inclination as well as which side of Saturn the S/C flies by.  $B \cdot T$  and  $B \cdot R$  are often used because of their stability in the targeting and optimization process. The choice of constraint parameters for subproblem 2 reflect termination of the mission at Saturn flyby. For the actual Voyager mission, which continues on to Uranus and Neptune, the constraint parameter types at Saturn would have been identical to those at Jupiter.

Because IPRINT was not input, the default value of IPRINT = 0 is used. This will result in only summary information of the master problem, plus the final trajectory, being output. Except for well tested production runs, it is recommended that more detailed levels of print be exercised.

The first page of output, after the Namelist echo, summarizes IPOST input, including initial conditions, event summary, targeting and optimization definition, master-subproblem structure, and NPSOL options.

The next page of output completes NPSOL parameter definition and then prints an iteration summary for each major (master level) iteration. This includes the objective function value (sum of delta V) and other conditions of the optimization process. Of some interest are the number of objective function evaluations (NFUN) and the condition number of the Jacobian (COND T). This problem does not have any nonlinear constraints, only control bounds, but if it did, the value of the nonlinear constraint norm is displayed, as well as the constraint values.

As the iterations progress, certain key parameters should be monitored. These are the objective function value (which should decrease), the condition numbers of the Hessian and Jacobian (which should remain small), and the value of the nonlinear constraint norm (which should decrease). Also of interest are the convergence indicators at the right side of the summary. When all these flags are "T", then successful optimization has been achieved (according to NPSOL). One cautionary note is that reliance on a few indicators, such as the convergence flags, can be misleading. It is important to examine all measures, including the final solution.

The iteration summary continues until page 4 of the output, where a maximum iteration limit has been reached (INFORM = 4). NPSOL is exited, and the final trajectory is displayed. Conditions at each event are output, including the minus and plus sides of each impulsive maneuver. At the end of each subproblem, a final iteration summary is displayed. In this case, Subproblem 1 convergence is summarized between trajectory blocks for event 15 and event 20 (Jupiter closest approach), and Subproblem 2 is summarized just before event 30 (Saturn closest approach).

The last solution has a total  $\Delta V$  of 7.27 km/s, reduced from the initial solution of 7.67 km/s. Jupiter closest approach time is 711.9 days from launch, and B dot T, B dot R were selected as 1898747 km, 130453 km.

Finally, a master problem summary output is given which includes the number of iterations and CPU time. A valid solution may or may not meet all convergence criteria. Only the user, with adequate engineering experience, can make that judgment.

i p o s t - interplanetary post simulation. version 2.18 , dated 03-05-90.

problem no. 1

```

c... voyager ii earth-jupiter-saturn
srchm = 'npsol',
iprint = 0,
ideb = 0,
iephem = 1,
fesn = 90,
istm = 'autopert',
npad(1) = 0,
mxitop = 30,
mxtar = 600,
ftol = 1.d-6,
c
c master controls are jupiter tca, arrival bdt, arrival bdr,
c
indxi = 1,2,3,
indvr = 'critr','depsv102','depsv103',
indph = 3*20,
u = 708.,.180849d7,.129268d6,
indplb = 700., 0.d0,0.d0,
indpub = 720.,3.d7,2.d6,
pert = .01,1000.,1000.,
wvu = 10.,.180849d7,.129268d6,
c
c minimize delta-v at swingby
c
optvar = 5hdvsum,
opt = -1,
optph = 90,
wopt = 1.,
etanl = .5,
c
c subproblem setup
c
modelt = 'nraph','nraph',
spfesn = 20.30,
tolf = 1.0d0,
tolu = 1.0d0,
npi = 10,
c
c controls
c
indxsi = 1,1,1, 2,2,2,
indsvr = 'vinfxo','vinfyo','vinfzo', 'dvx','dvy','dvz',
indspk = 3*10, 3*23,
usub = 2.26374, 9.45391, 3.16241, 0.d0,0.d0,0.d0,
indslb = -20., -20., -20.,-10.,-10.,-10.,
indsub = 20., 20., 20., 10., 10., 10.,
wvus = 20., 20., 20., 10., 10., 10.,
pertsb = .00001,.00001,.00001, 3*-.00001,
wgts = .01,.180849d7,.129268d6,15.,.01,.206130d6,.2d6,
c
c targets
c
indxsd = 1,1,1, 2,2,2,
depsvr = 'tfp','bdti','bdri', 'tfp','bdti','rperi',
depsph = 3*20, 3*30,

```

```

dpsvl      = -.0001,.180849d7,.129268d6, -.0001,.206130d6,200000.d0,
dpslb      = -.0001,.180849d7,.129268d6, -.0001,.206130d6,199999.d0,
dpsub      = -.0001,.180849d7,.129268d6, -.0001,.206130d6,200001.d0,
depstl     = .00005,1,.1,.00005,100.,100.,
wvsnlc     = 1.,.180849d7,.129268d6, 1.,.206130d6,

```

```

c objective
c

```

```

optsvr     = 'target','dvmag',
opts       = -1,-1,
optsph     = 20,23,
wopts      = .10,.10,

```

```

$

```

```

p$traj
event      = 5,
lePOCH     = 'calend',
date       = 1977,7,31,

ldfram     = 'ecliptic','mean2000',
ipbody     = 3,
ibody      = 3,
iprop      = 'conic',

```

```

scmass     = 1.d6,
thrust     = 2.d5,
spi        = 480.,

```

```

inputx     = 'conic',
x          = 6563.,0.,0.,0.,0.,0.,

```

```

$

```

```

p$traj
c earth escape
c

```

```

event      = 10,
critr      = 'timrf1',
value      = 20.,

```

```

iprop      = '1step',
ipbody     = 0,3,

```

```

mantyp     = 'launch',
flnch      = 2,

```

```

rperi      = 6563.,
rapoap     = 6563.,
inc        = -1.,

```

```

$

```

```

p$traj
c change ibody
c

```

```

event      = 15,
critr      = 'tdurp',
value      = 20.,
ipbody     = 0,5,
ibody      = 5,

```



```

$
p$traj
c jupiter tca
c 7/9/1979
c

```

```

event = 20,
critr = 'timrf1',
iprop = 'conic',
ipbody = 5,0,

```

```
$
```

```

p$traj
c powered swingby
c

```

```

event = 23,
critr = 'tdurp',
value = 1.,
mantyp = 'impuls',
iprop = '1step',
ipbody = 0,5,

```

```
$
```

```

p$traj
c change idbody
c

```

```

event = 25,
critr = 'tdurp',
value = 300.,
ipbody = 0,6,
idbody = 6,

```

```
$
```

```

p$traj
c saturn tca
c 8/25/1981
c

```

```

event = 30,
critr = 'timrf1',
value = 1487.,

```

```
$
```

```

p$traj
c this is the end
c

```

```

event = 90,
critr = 'tdurp',
value = 0.,
namlst = 'none',
$

```

\*\*\* core requirements for problem 1 are \*\*\*

parameter	octal	decimal
event criteria data -	531b	345
general data	- 224b	148

execution date and time Fri Oct 23

\*\*\*\* ipost input summary \*\*\*\*

\*\*\* trajectory inputs \*\*\*

initial epoch

julian date ...2443355.5000

calendar date ...1977 jul 31, 0 hr 0 min 0.0000 secs

initial body and frame of reference 3 , earth , ecliptic, mean2000

initial state

cartesian 6.56300000000D+03 0.0000000000D+00 0.0000000000D+00

0.0000000000D+00 7.79323386922D+00 0.0000000000D+00

6.56300000000D+03 0.0000000000D+00 0.0000000000D+00

0.0000000000D+00 0.0000000000D+00 0.0000000000D+00

initial state, heliocentric, ecliptic

9.34871650060D+07 -1.19661308795D+08 -5.77793013208D+03

2.29812686681D+01 2.60127502765D+01 1.48462231329D-03

input units - metric, output units - metric

event summary

number	trigger	value	type	propagator
5.000	time	1.0000000000D+10	none	conic
10.000	timrf1	2.0000000000D+01	launch	lstep
15.000	tdurp	2.0000000000D+01	none	lstep
20.000	timrf1	2.0000000000D+01	none	conic
23.000	tdurp	1.0000000000D+00	impuls	lstep
25.000	tdurp	3.0000000000D+02	none	lstep
30.000	timrf1	1.4870000000D+03	none	lstep
90.000	tdurp	0.0000000000D+00	none	lstep

\*\*\*targeting/optimization inputs\*\*\*

master problem optimization parameter dvsum at event 90

master prob. control/indep parameters

evtnum name  
 20.000 critr  
 20.000 depsv102  
 20.000 depsv103

master problem target/dep parameters

evtnum	name	value	at event
total number of subproblems	is	2	
subproblem number	i		
subproblem controls	at event	vinfxo	vinfzo
subproblem targets	tfp	10	10
at events	20	bdti	bdri
subproblem values	-0.10000E-03	0.18085E+07	0.12927E+06
with tolerance	0.50000E-04	0.10000E+00	0.10000E+00
subproblem number	2		
subproblem controls	at event	dvx	dvz
subproblem targets	tfp	23	23
at events	30	bdti	rperi
subproblem values	-0.10000E-03	0.20613E+06	0.20000E+06
with tolerance	0.50000E-04	0.10000E+03	0.10000E+03

OPTIONS file  
-----

BEGIN OPTIONS FOR NPSOL 4.0

VERIFY LEVEL 0  
 DERIV LEVEL 0  
 DIFFERENCE INTERVAL 1.0E-4  
 MAJOR ITERATIONS LIMIT 30  
 MAJOR PRINT LEVEL 20  
 NONLINEAR FEASIBILITY TOLERANCE 3.E-7  
 OPTIMALITY TOLERANCE 1.E-6  
 HESSIAN NO  
 COLD START  
 END

Calls to NPOPTN  
-----

major iteration limit = 30

NPSOL --- Version 4.05 Nov 1989  
 =====

Parameters  
-----

Linear constraints.....	0	Linear feasibility.....	5.96E-08
Variables.....	3	Infinite bound size.....	1.00E+20
Step limit.....	2.00E+00	Infinite step size.....	1.00E+20
Nonlinear constraints..	0	Optimality tolerance...	1.00E-06
Nonlinear Jacobian vars	3	Nonlinear feasibility..	3.00E-07
Nonlinear objectiv vars	3	Linesearch tolerance...	9.00E-01
EPS (machine precision)	3.55E-15	Derivative level.....	0
Major iterations limit.	30	Major print level.....	20
Minor iterations limit.	50	Minor print level.....	0
RUN loaded from file...	0	RUN to be saved on file	0
Difference interval....	1.00E-04	Central diffee interval	5.11E-05

Workspace provided is IW( 2500), W( 770500).  
 To solve problem we need IW( 9), W( 60).

The user sets 0 out of 3 objective gradient elements.  
 Each iteration, 3 gradient elements will be estimated numerically.

```

Major iteration 0
=====
Itn ItQP Step Nfun Objective Bnd Lin Nz Norm Gf Norm Gz Cond H Cond Hz Cond T Cony
0 1 0.0E+00 1 7.672923E+00 0 0 3 1.1E+01 1.1E+01 1.E+00 1.E+00 0.E+00 0.E+00 F FT
Nonlinear objective value = 7.672923E+00
Values of the constraints and their predicted status
-----
Variables
7.080000E+01 0 1.000000E+00 0 1.000000E+00 0
=====

```

```

Major iteration 1
=====
1 1 3.7E-03 8 7.308022E+00 0 0 3 2.8E+00 2.8E+00 2.E+02 2.E+02 0.E+00 0.E+00 T FT
Nonlinear objective value = 7.308022E+00
Values of the constraints and their predicted status
-----
Variables
7.079876E+01 0 1.040315E+00 0 1.000052E+00 0
=====

```

```

Major iteration 2
=====
2 1 2.3E-01 10 7.304856E+00 0 0 3 2.9E-01 2.9E-01 4.E+02 4.E+02 0.E+00 0.E+00 T FT
Nonlinear objective value = 7.304856E+00
Values of the constraints and their predicted status
-----
Variables
7.081255E+01 0 1.039087E+00 0 9.825305E-01 0
=====

```

```

Major iteration 3

```

```

=====
3 1 3.7E-01 12 7.302548E+00 0 0 3 2.3E+00 2.3E+00 2.E+02 2.E+02 0.E+00 T FT
Nonlinear objective value = 7.302548E+00
Values of the constraints and their predicted status
-----
Variables
7.085144E+01 0 1.039036E+00 0 1.001594E+00 0
=====

```

```

Major iteration 4
=====
4 1 2.1E-01 14 7.297528E+00 0 0 3 4.1E+00 4.1E+00 4.E+01 4.E+01 0.E+00 F FT
Nonlinear objective value = 7.297528E+00
Values of the constraints and their predicted status
-----

```

```

Variables
7.093058E+01 0 1.040861E+00 0 1.023273E+00 0
=====
Major iteration 5
=====
5 1 5.2E-01 18 7.275443E+00 0 0 3 7.4E-01 7.4E-01 5.E+01 5.E+01 0.E+00 F FT
Nonlinear objective value = 7.275443E+00
Values of the constraints and their predicted status
-----
Variables
7.116154E+01 0 1.048950E+00 0 1.017611E+00 0
=====

```

```

Major iteration 6
=====
6 1 3.8E-02 21 7.273502E+00 0 0 3 4.6E+00 4.6E+00 3.E+02 3.E+02 0.E+00 T FT
Nonlinear objective value = 7.273502E+00

```

-----  
Values of the constraints and their predicted status  
-----

Variables  
7.118782E+01 0 1.049873E+00 0 1.014660E+00 0  
-----

Major iteration 7  
-----  
7 1 1.5E-01 24 7.271064E+00 0 0 3 1.0E+01 1.0E+01 1.E+02 1.E+02 0.E+00 T FT

Nonlinear objective value = 7.271064E+00

-----  
Values of the constraints and their predicted status  
-----

Variables  
7.119375E+01 0 1.050102E+00 0 1.009663E+00 0  
-----

Major iteration 8  
-----  
8 1 7.4E-02 27 7.270613E+00 0 0 3 1.0E+01 1.0E+01 3.E+02 3.E+02 0.E+00 T FT

Nonlinear objective value = 7.270613E+00

-----  
Values of the constraints and their predicted status  
-----

Variables  
7.119852E+01 0 1.050158E+00 0 1.008869E+00 0  
-----

Major iteration 9  
-----  
9 1 3.1E-01 29 7.270559E+00 0 0 3 1.5E+00 1.5E+00 2.E+02 2.E+02 0.E+00 T FT

Nonlinear objective value = 7.270559E+00

-----  
Values of the constraints and their predicted status  
-----

```

Variables
7.119208E+01 0 1.049746E+00 0 1.007911E+00 0
=====
Major iteration 10
=====
10 1 0.0E+00 31 7.270559E+00 0 0 3 1.1E+01 1.1E+01 2.E+02 2.E+02 0.E+00 T FT C
Nonlinear objective value = 7.270559E+00
Values of the constraints and their predicted status
-----
Variables
7.119208E+01 0 1.049746E+00 0 1.007911E+00 0
=====
Major iteration 11
=====
11 1 4.0E-01 33 7.269980E+00 0 0 3 3.0E+00 3.0E+00 6.E+01 6.E+01 0.E+00 T FT C
Nonlinear objective value = 7.269980E+00
Values of the constraints and their predicted status
-----
Variables
7.118672E+01 0 1.049732E+00 0 1.008100E+00 0
=====
Major iteration 12
=====
12 1 3.6E-01 36 7.269251E+00 0 0 3 9.4E+00 9.4E+00 1.E+02 1.E+02 0.E+00 T FT C
Nonlinear objective value = 7.269251E+00
Values of the constraints and their predicted status
-----
Variables
7.119253E+01 0 1.049898E+00 0 1.009001E+00 0
=====

```

Major iteration 13  
 =====  
 13 1 2.2E-01 38 7.269194E+00 0 0 3 7.7E+00 7.7E+02 2.E+02 2.E+02 0.E+00 T FT C

Nonlinear objective value = 7.269194E+00  
 Values of the constraints and their predicted status  
 -----

Variables  
 7.119363E+01 0 1.049907E+00 0 1.009167E+00 0  
 =====

Exit NP phase. INFORM = 6 MAJITS = 14 NFUN = 53 NGRAD = 13

Variable	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
VARBL 1	FR	71.19363	70.00000	72.00000	0.0000000E+00	0.8064
VARBL 2	FR	1.049907	0.000000E+00	16.58842	0.000000E+00	1.050
VARBL 3	FR	1.009167	0.000000E+00	15.47173	0.000000E+00	1.009

Exit NPSOL - Current point cannot be improved upon.

Final nonlinear objective value = 7.269194

date = 7 31 1977 0.00 julian =2443355.500000000 tdurp = 0.000000000 critr = time propid = conic  
 primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000  
 timrfl = 0.00000000E+00  
 state relative to idbody: earth  
 x = 0.656300000E+04 y = 0.000000000E+00 z = 0.000000000E+00 radius = 0.656300000E+04 scmass = 0.100000000E+07  
 vx = 0.000000000E+00 vy = 0.779323387E+01 vz = 0.000000000E+00 speed = 0.779323387E+01 fpa = -0.381666562E-12  
 sma = 0.656300000E+04 eccen = 0.889452357E-15 inc = 0.000000000E+00 argp = 0.000000000E+00 anlong = 0.000000000E+00  
 meaan = 0.000000000E+00 truan = 0.000000000E+00 tfp = 0.000000000E+00 rperi = 0.656300000E+04 vperi = 0.779323387E+01  
 altp = 0.184860000E+03 alta = 0.184860000E+03 rapoap = 0.656300000E+04 rperi = 0.656300000E+04  
 lat = 0.000000000E+00 long = 0.000000000E+00 longp = 0.000000000E+04 altit = 0.184860000E+03 period = 0.529132654E+04

final conditions for phase 5

date = 8 20 1977 0.00 julian =2443375.500000000 tdurp = 20.000000000 critr = timrfl propid = conic  
 primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000  
 timrfl = 0.200000000E+02  
 state relative to idbody: earth  
 x = -0.589969126E+04 y = -0.287517165E+04 z = 0.000000000E+00 radius = 0.656300000E+04 scmass = 0.100000000E+07  
 vx = 0.341412237E+01 vy = -0.700558795E+01 vz = 0.000000000E+00 speed = 0.779323387E+01 fpa = -0.368944343E-12



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```

sma = 0.656300000E+04 eccen = 0.933848152E-15 inc = 0.000000000E+00 arqp = 0.000000000E+00 anlong = 0.000000000E+00
mean = -0.154018047E+03 truan = -0.154018047E+03 tfp = -0.262011247E-01 rperi = 0.656300000E+04 vperi = 0.779323387E+01
altp = 0.184860000E+03 alta = 0.184860000E+03 rapoap = 0.656300000E+04 altit = 0.184860000E+03 period = 0.529132654E+04
lat = 0.000000000E+00 long = -0.114591559E+03 longp = 0.000000000E+00

```

initial conditions for phase 10 before launch maneuver

```

date = 8 20 1977 0.00 julian =2443375.500000000 tdurp = earth 20.000000000 critr = timrfl propid = 1step
primid = sun secid = earth idbody = earth frame = ecliptic epoch = mean2000
state relative to idbody: earth
x = -0.589969126E+04 y = -0.287517165E+04 z = 0.000000000E+00 radius = 0.656300000E+04 scmass = 0.100000000E+07
vx = 0.341412337E+01 vy = -0.700558795E+01 vz = 0.000000000E+00 speed = 0.779323387E+01 fpa = -0.368944343E-12
sma = 0.656300000E+04 eccen = 0.977989025E-12 inc = 0.000000000E+00 arqp = 0.000000000E+00 anlong = 0.000000000E+00
mean = -0.154018047E+03 truan = -0.154018047E+03 tfp = -0.262011247E-01 rperi = 0.656300000E+04 vperi = 0.779323387E+01

```

launch maneuver print block

```

dvx = 0.000000000E+00 dvz = 0.000000000E+00 dvmag = 0.726903802E+01 tburn = 0.363451901E+05
thrust = 0.200000000E+06 dmass = 0.786526125E+06 wprop = 0.213473875E+06

```

initial conditions for phase 10 after launch maneuver

```

date = 8 20 1977 0.00 julian =2443375.500000000 tdurp = earth 0.000000000 critr = timrfl propid = 1step
primid = sun secid = earth idbody = earth frame = ecliptic epoch = mean2000
state relative to idbody: earth
x = 0.539908538E+04 y = -0.363079018E+04 z = -0.860353840E+03 radius = 0.656300000E+04 scmass = 0.213473875E+06
vx = 0.846624114E+01 vy = 0.113982302E+02 vz = 0.502743918E+01 speed = 0.150622719E+02 fpa = 0.678730369E-10
sma = -0.378167899E+04 eccen = 0.273547253E+01 inc = 0.210140784E+02 arqp = 0.338557485E+03 anlong = 0.346214360E+03
mean = 0.110262831E-09 truan = 0.932129933E-10 tfp = 0.820447591E-14 rperi = 0.656300000E+04 vperi = 0.150622719E+02

```

Incoming Asymptote

```

altp = 0.184860000E+03 vinfm = 0.102665986E+02 vinfz = 0.845879397E+01 vinfz = 0.515509334E+01 vinfz = 0.269756621E+01
bnag = 0.962867007E+04 btheta = 0.146505405E+02 bdt = 0.931560777E+04 bdr = 0.243531091E+04 hypta = 0.685574849E+02
c3 = 0.105403046E+03 ra = 0.313596327E+02 dec = 0.152334011E+02 altit = 0.184860000E+03

```

Outgoing Asymptote

```

altp = 0.184860000E+03 vinfm = 0.102665986E+02 vinfz = 0.845879397E+01 vinfz = 0.515509334E+01 vinfz = 0.269756621E+01
bnag = 0.962867007E+04 btheta = 0.335159352E-10 bdt = 0.962867007E+04 bdr = 0.563241978E-08 hypta = 0.000000000E+00
c3 = 0.105403046E+03 ra = 0.477356494E+02 dec = 0.210140784E+02 altit = 0.184860000E+03
state relative primary body: sun
x = 0.127217712E+09 y = -0.820339672E+08 z = -0.436792502E+04
vx = 0.241195310E+02 vy = 0.36332875E+02 vz = 0.502764333E+01
sma = -0.764065373E+09 eccen = 0.119808406E+01 inc = 0.657694804E+01
arqp = 0.358595914E+03 anlong = 0.327199149E+03 mean = 0.826427088E-01

```

final conditions for phase 10

```

date = 9 9 1977 0.00 julian =2443395.500000000 tdurp = earth 20.000000000 critr = tdurp propid = 1step
primid = sun secid = earth idbody = earth frame = ecliptic epoch = mean2000
state relative to idbody: earth
x = 0.376000157E+07 y = 0.158739624E+08 z = 0.624533713E+07 radius = 0.174678263E+08 scmass = 0.213473875E+06
vx = 0.203173312E+01 vy = 0.882694248E+01 vz = 0.346898945E+01 speed = 0.969931652E+01 fpa = 0.896603749E+02
sma = -0.423902809E+04 eccen = 0.244520940E+02 inc = 0.209861894E+02 arqp = 0.354658935E+03 anlong = 0.350247545E+03
mean = 0.235819227E+06 truan = 0.920041723E+02 tfp = 0.208244417E+02 rperi = 0.994140853E+05 vperi = 0.101019848E+02
Incoming Asymptote
altp = 0.930359453E+05 vinfm = 0.969696358E+01 vinfz = 0.862309935E+01 vinfz = 0.344170678E+01
bnag = 0.103566397E+06 btheta = 0.293642861E+01 bdt = 0.103430413E+06 bdr = 0.530549055E+04 hypta = 0.876561614E+02

```

```

c3 = 0.940311026E+02 ra = 0.720238854E+02 dec = 0.207889236E+02 altit = 0.174614482E+08
Outgoing Asymptote
a1tp = 0.930359453E+05 vinfm = 0.969696358E+01 vinfx = 0.203123344E+01 vinfy = 0.882480269E+01 vinfz = 0.346814804E+01
bmag = 0.103566397E+06 btheta = 0.114902014E+01 bdt = 0.103545572E+06 bdr = 0.207680044E+04 hypta = 0.000000000E+00
c3 = 0.940311026E+02 ra = 0.724091512E+02 dec = 0.209561280E+02 altit = 0.174614482E+08

```

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```

state relative primary body: sun
x = 0.150285280E+09 y = -0.192526118E+08 z = 0.624480435E+07
vx = 0.850190251E+01 vy = 0.376899896E+02 vz = 0.347024635E+01
sma = 0.540629909E+09 eccen = 0.722689833E+00 inc = 0.546372471E+01
argp = 0.122731869E+02 anlong = 0.327174715E+03 meanan = 0.149709769E+01

```

initial conditions for phase 15

```

date = 9 9 1977 0.00 julian =2443395.500000000 tdurp = 0.000000000 critr = tdurp propid = lstep
primid = sun secid = jupiter idbody = jupiter epoch = mean2000
timrfl = 0.400000000E+02
state relative to idbody: jupiter
x = 0.489745562E+08 y = -0.775239332E+09 z = 0.116229646E+08 scmass = 0.776871690E+09
vx = 0.216184244E+02 vy = 0.353434449E+02 vz = 0.318606692E+01 speed = 0.415531755E+02 fpa = -0.545703154E+02
sma = -0.733840318E+05 eccen = 0.613754382E+04 inc = 0.886012383E+01 argp = 0.601522267E+02 anlong = 0.268106570E+03
meanan = -0.494219226E+06 truan = -0.545779220E+02 tftp = -0.176328142E+03 rperi = 0.450324327E+09 vperi = 0.415560211E+02
Incoming Asymptote
altp = 0.450252929E+09 vinfm = 0.415492509E+02 vinfz = 0.353394476E+02 vinfz = 0.318593345E+01
bmag = 0.450397705E+09 btheta = -0.769927828E+01 bdr = 0.446337319E+09 bdr = -0.603341448E+08 hypta = 0.899906647E+02
c3 = 0.172634025E+04 ra = 0.585455258E+02 altit = 0.439766997E+01 altit = 0.776800292E+09
Outgoing Asymptote
altp = 0.450252929E+09 vinfm = 0.415492509E+02 vinfz = 0.353465658E+02 vinfz = 0.31842471E+01
bmag = 0.450397705E+09 btheta = -0.770070079E+01 bdr = 0.446335820E+09 bdr = -0.603525296E+08 hypta = 0.000000000E+00
c3 = 0.172634025E+04 ra = 0.585506623E+02 altit = 0.439516837E+01 altit = 0.776800292E+09
state relative primary body: sun
x = 0.150285280E+09 y = -0.192526118E+08 z = 0.624480435E+07
vx = 0.850190251E+01 vy = 0.376899896E+02 vz = 0.347024635E+01
sma = 0.540629909E+09 eccen = 0.722689833E+00 inc = 0.546372471E+01
argp = 0.122731869E+02 anlong = 0.327174715E+03 meanan = 0.149709769E+01

```

final conditions for phase 15

```

date = 7 12 1979 22.47 julian =244067.43630849 tdurp = 671.93630849 critr = timrfl
primid = sun secid = jupiter idbody = jupiter epoch = mean2000
timrfl = 0.711936308E+03
state relative to idbody: jupiter
x = 0.433346698E+06 y = 0.555192933E+06 z = -0.910720487E+05 radius = 0.710156794E+06
vx = -0.160812524E+02 vy = 0.124780486E+02 vz = -0.428381733E+00 speed = 0.203590738E+02 fpa = -0.800349572E-02
sma = -0.219524281E+07 eccen = 0.132349806E+01 inc = 0.746726841E+01 argp = 0.260688481E+03 anlong = 0.151430683E+03
meanan = -0.169603607E-02 truan = -0.140507246E-01 tftp = -0.990053290E-04 rperi = 0.710156782E+06 vperi = 0.203590739E+02
Incoming Asymptote
altp = 0.638758782E+06 vinfm = 0.759666021E+01 vinfz = 0.429597088E+00 vinfz = -0.840759004E+00
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdr = 0.189874637E+07 bdr = 0.130453055E+06 hypta = 0.409244977E+02
c3 = 0.577092463E+02 ra = 0.932619112E+02 altit = 0.635421746E+01 altit = 0.638758794E+06
Outgoing Asymptote
altp = 0.638758782E+06 vinfm = 0.759666021E+01 vinfz = 0.429597088E+00 vinfz = -0.840759004E+00
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdr = 0.189874637E+07 bdr = 0.130453055E+06 hypta = 0.409244977E+02
c3 = 0.577092463E+02 ra = -0.106626238E+03 altit = 0.476825608E+01 altit = 0.638758794E+06
state relative primary body: sun
x = -0.590802760E+09 y = 0.535750241E+09 z = 0.109528856E+08
vx = -0.250125686E+02 vy = 0.338743411E+01 vz = -0.19089988E+00
sma = -0.436025897E+09 eccen = 0.180235266E+01 inc = 0.206538027E+01
argp = 0.749073322E+02 anlong = 0.340181580E+03 meanan = 0.663792506E+02

```

initial conditions for phase 20

initial conditions for phase 20

```
date = 7 12 1979 22.47 julian = 2444067.43630849 tdurp = 0.00000000 critr = timrf1 propid = conic  
primid = jupiter secid = sun idbody = jupiter frame = ecliptic epoch = mean2000  
timrf1 = 0.711936308E+03
```

```

state relative to idbody: jupiter
x = 0.433346698E+06 y = 0.555192933E+06 z = -0.910720487E+05
vx = -0.160812524E+02 vy = 0.124780486E+02 vz = -0.428381733E+00
sma = -0.219524281E+07 eccen = 0.132349806E+01 inc = 0.746726841E+01
meaan = -0.169603607E-02 truan = -0.140507246E-01 tfp = 0.710156782E+06
Incoming Asymptote
altp = 0.638758782E+06 vlnfm = 0.759666021E+01 vlnfx = 0.429597088E+00
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdt = 0.189874637E+07
c3 = 0.577092463E+02 ra = 0.932619112E+02 dec = -0.635542174E+01
Outgoing Asymptote
altp = 0.638758782E+06 vlnfm = 0.759666021E+01 vlnfx = -0.143864811E+01
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdt = 0.189874637E+07
c3 = 0.577092463E+02 ra = -0.106626238E+03 dec = 0.476825608E+01
state relative to secondary body: sun
x = -0.590802760E+09 y = 0.535750241E+09 z = 0.109528856E+08
vx = -0.250125686E+02 vy = 0.338743411E+01 vz = -0.190899988E+00
sma = -0.436025897E+09 eccen = 0.180235266E+01 inc = 0.206538027E+01
argp = 0.749073322E+02 anlong = 0.340181580E+03 meaan = 0.663792505E+02
    
```

final conditions for phase 20

```

date = 7 13 1979 22.47 julian = 2440068.43630849 tdurp = 1.00000000
primid = jupiter secid = sun
timfl = 0.712936308E+03
state relative to idbody: jupiter
x = -0.102687501E+07 y = 0.100077151E+07 z = -0.508351063E+05
vx = -0.152561988E+02 vy = 0.908046614E+00 vz = 0.851749155E+00
sma = -0.219524281E+07 eccen = 0.132349806E+01 inc = 0.746726841E+01
meaan = 0.171290593E+02 truan = 0.834908744E+02 tfp = 0.999900995E+00
Incoming Asymptote
altp = 0.638758782E+06 vlnfm = 0.759666021E+01 vlnfx = -0.429597088E+00
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdt = 0.189874637E+07
c3 = 0.577092463E+02 ra = 0.932619112E+02 dec = -0.635542174E+01
Outgoing Asymptote
altp = 0.638758782E+06 vlnfm = 0.759666021E+01 vlnfx = 0.143864811E+01
bmag = 0.190322247E+07 btheta = 0.393032065E+01 bdt = 0.189874637E+07
c3 = 0.577092463E+02 ra = -0.106626238E+03 dec = 0.476825608E+01
state relative to secondary body: sun
x = -0.593034070E+09 y = 0.535409868E+09 z = 0.110136302E+08
vx = -0.241741362E+02 vy = -0.819466808E+01 vz = 0.108898104E+01
sma = -0.414014692E+09 eccen = 0.26036857E+01 inc = 0.248596821E+01
argp = 0.338523390E+03 anlong = 0.119411006E+03 meaan = 0.485978921E+02
    
```

initial conditions for phase 23 before impuls maneuver

```

date = 7 13 1979 22.47 julian = 2440068.43630849 tdurp = 1.00000000
primid = sun secid = jupiter
state relative to idbody: jupiter
x = -0.102687501E+07 y = 0.100077151E+07 z = -0.508351063E+05
vx = -0.152561988E+02 vy = 0.908046614E+00 vz = 0.851749155E+00
sma = -0.219524281E+07 eccen = 0.132349806E+01 inc = 0.746726841E+01
meaan = 0.171290593E+02 truan = 0.834908744E+02 tfp = 0.999900995E+00
impuls maneuver print block
dvx = 0.455302180E-04 dvz = 0.246251752E-04 dvmag = -0.146724351E-03
thrust = 0.200000000E+06 sp1 = 0.480000000E+03 dmass = 0.705586125E+01 wprop = 0.213466820E+06
    
```

```
Initial conditions for phase 23 after impuls maneuver
date = 7 13 1979 22.47 julian =2444068.43630849 tdurp = 0.000000000 critr = tdurp propid = 1step
primid = sun secid = jupiter idbody = jupiter frame = ecliptic epoch = mean2000
```

```

timrfl = 0.712936308E+03
state relative to idbody: jupiter
x = -0.102687501E+07 y = 0.100077151E+07 z = -0.508551063E+05
vx = -0.152561533E+07 vy = 0.908071239E+00 vz = 0.851602431E+00
sma = -0.219530346E+07 eccen = 0.132348641E+01 inc = 0.74650342E+01
meanan = 0.171284271E+02 truan = 0.834914876E+02 tfp = 0.999905525E+00
Incoming Asymptote
altp = 0.638752836E+06 vinfm = 0.429428880E+00 vinfy = 0.753767121E+01
bmag = 0.190323603E+07 btheta = 0.392959822E+01 bdt = 0.189876158E+07
c3 = 0.577076519E+02 ra = 0.932606748E+02 dec = -0.635376275E+01
Outgoing Asymptote
altp = 0.638752836E+06 vinfm = 0.759655526E+01 vinfy = -0.743231726E+01
bmag = 0.190323603E+07 btheta = 0.575283674E+01 bdt = 0.189365049E+07
c3 = 0.577076519E+02 ra = -0.106620240E+03 dec = 0.476760027E+01
state relative primary body: sun
x = -0.593034070E+09 y = 0.535409868E+09 z = 0.110136302E+08
vx = -0.241740906E+02 vy = -0.819464346E+01 vz = 0.108883431E+01
sma = -0.414018469E+09 eccen = 0.260367099E+01 inc = 0.248561659E+01
argp = 0.338526525E+03 anlong = 0.119408289E+03 meanan = 0.485974250E+02
    
```

final conditions for phase 23

```

date = 5 8 1980 22.47 julian = 2444368.43630849 tdurp = 300.00000000 critr = 1step
primid = sun secid = jupiter idbody = saturn frame = ecliptic epoch = mean2000
timrfl = 0.101293631E+04
state relative to idbody: jupiter
x = -0.208098024E+09 y = -0.301360930E+08 z = 0.167864915E+08
vx = -0.824688791E+01 vy = -0.767464927E+00 vz = 0.624257848E+00
sma = -0.186883390E+07 eccen = 0.589728833E+01 inc = 0.173292466E+03
meanan = 0.630628788E+04 truan = 0.968242418E+02 tfp = 0.289154191E+03
Incoming Asymptote
altp = 0.908081205E+07 vinfm = 0.823338891E+01 vinfy = -0.743318183E+01
bmag = 0.108614396E+08 btheta = -0.176635948E+03 bdt = -0.108427236E+08
c3 = 0.677886930E+02 ra = -0.155148057E+03 dec = 0.576370769E+01
Outgoing Asymptote
altp = 0.908081205E+07 vinfm = 0.823338891E+01 vinfy = -0.817496277E+01
bmag = 0.108614396E+08 btheta = -0.174902994E+03 bdt = -0.108184903E+08
c3 = 0.677886930E+02 ra = -0.174170329E+03 dec = 0.430912103E+01
state relative primary body: sun
x = -0.974184351E+09 y = 0.229413788E+09 z = 0.328818838E+08
vx = -0.126002267E+02 vy = -0.125491850E+02 vz = 0.770292069E+00
sma = -0.256300375E+10 eccen = 0.129348410E+01 inc = 0.2569899943E+01
argp = 0.351055672E+03 anlong = 0.119694447E+03 meanan = 0.719129706E+01
    
```

initial conditions for phase 25

```

date = 5 8 1980 22.47 julian = 2444368.43630849 tdurp = 0.00000000 critr = 1step
primid = sun secid = saturn idbody = saturn frame = ecliptic epoch = mean2000
timrfl = 0.101293631E+04
state relative to idbody: saturn
x = 0.436006288E+09 y = 0.126641919E+09 z = -0.213492406E+08
vx = -0.113743257E+02 vy = -0.288227647E+01 vz = 0.552717232E+00
sma = -0.275171223E+06 eccen = 0.569607410E+02 inc = 0.269841300E+01
meanan = -0.944095269E+05 truan = -0.890306541E+02 tfp = -0.447017053E+03
Incoming Asymptote
altp = 0.153387855E+08 vinfm = 0.117397370E+02 vinfy = -0.113674760E+02
    
```

```

bmag = 0.156715411E+08      btheta = -0.903710839E-01      bdt      = 0.156715216E+08      bdr      = -0.247182878E+05      hypta   = 0.889940664E+02
c3    = 0.137821425E+03      ra      = -0.165781050E+03      dec     = 0.269690121E+01      altit   = 0.454467721E+09
Outgoing Asymptote
altp  = 0.153387855E+08      vinfm  = 0.117397370E+02      vinfx   = -0.112592652E+02      vinfy   = -0.327816061E+01      vinfz   = 0.551393273E+00
bmag  = 0.156715411E+08      btheta = -0.185063650E+00      bdt     = 0.156714593E+08      bdr     = -0.506185198E+05      hypta   = 0.000000000E+00
c3    = 0.137821425E+03      ra      = -0.163913460E+03      dec     = 0.269206494E+01      altit   = 0.454467721E+09

```



state relative primary body: sun  
 x = -0.974184351E+09 y = 0.328818838E+08  
 vx = -0.126002267E+02 vy = -0.125491850E+02  
 sma = -0.256300375E+10 eccen = 0.129348410E+01  
 argp = 0.351055672E+03 anlong = 0.119694447E+03  
 mean = 0.719129706E+01

final conditions for phase 25

date = 8 26 1981 0.00 julian = 2444842.50000000 tdurp = 474.06369151  
 primid = sun secid = saturn idbody = saturn  
 timrf1 = 0.148700000E+04  
 state relative to idbody: saturn  
 x = -0.135228263E+06 y = 0.404454447E+05 z = 0.141744757E+06  
 vx = -0.151987656E+02 vy = -0.117929374E+02 vz = -0.111465811E+02  
 sma = -0.329365722E+06 eccen = 0.160733463E+01 inc = 0.602120192E+02  
 mean = -0.100297619E-01 truan = -0.342173925E-01 tfp = -0.621887707E-04  
 rperi = 0.200035208E+06  
 Incoming Asymptote  
 altp = 0.140035208E+06 vinfm = 0.107305177E+02 vinfz = -0.102574128E+02  
 bmag = 0.414467811E+06 btheta = -0.601741047E+02 bdr = 0.206142240E+06  
 c3 = 0.115144010E+03 ra = -0.163139777E+03 altit = 0.140035230E+06  
 Outgoing Asymptote  
 altp = 0.140035208E+06 vinfm = 0.107305177E+02 vinfz = -0.310866635E+01  
 bmag = 0.414467811E+06 btheta = -0.260199533E+02 bdr = 0.372457905E+06  
 c3 = 0.115144010E+03 ra = -0.150496956E+03 dec = -0.564389236E+02  
 altit = 0.140035230E+06  
 state relative primary body: sun  
 x = -0.140523513E+10 y = -0.291999978E+09 z = 0.610647598E+08  
 vx = -0.137454390E+02 vy = -0.212817024E+02 vz = -0.110387217E+02  
 sma = -0.229235104E+09 eccen = 0.570065114E+01 inc = 0.332341103E+02  
 argp = 0.130483133E+03 anlong = 0.154617110E+02 mean = 0.216645061E+03

initial conditions for phase 30

initial conditions for phase 30

final conditions for phase 30

date = 8 26 1981 0.00 julian = 2444842.50000000 tdurp = 474.06369151  
 primid = sun secid = saturn idbody = saturn  
 timrf1 = 0.148700000E+04  
 state relative to idbody: saturn  
 x = -0.135228263E+06 y = 0.404454447E+05 z = 0.141744757E+06  
 vx = -0.151987656E+02 vy = -0.117929374E+02 vz = -0.111465811E+02  
 sma = -0.329365722E+06 eccen = 0.160733463E+01 inc = 0.602120192E+02  
 mean = -0.100297619E-01 truan = -0.342173925E-01 tfp = -0.621887707E-04  
 rperi = 0.200035208E+06  
 Incoming Asymptote  
 altp = 0.140035208E+06 vinfm = 0.107305177E+02 vinfz = -0.102574128E+02  
 bmag = 0.414467811E+06 btheta = -0.601741047E+02 bdr = 0.206142240E+06  
 c3 = 0.115144010E+03 ra = -0.163139777E+03 altit = 0.140035230E+06  
 Outgoing Asymptote  
 altp = 0.140035208E+06 vinfm = 0.107305177E+02 vinfz = -0.310866635E+01  
 bmag = 0.414467811E+06 btheta = -0.260199533E+02 bdr = 0.372457905E+06  
 c3 = 0.115144010E+03 ra = -0.150496956E+03 dec = -0.564389236E+02  
 altit = 0.140035230E+06  
 state relative primary body: sun  
 x = -0.140523513E+10 y = -0.291999978E+09 z = 0.610647598E+08  
 vx = -0.137454390E+02 vy = -0.212817024E+02 vz = -0.110387217E+02  
 sma = -0.229235104E+09 eccen = 0.570065114E+01 inc = 0.332341103E+02  
 argp = 0.130483133E+03 anlong = 0.154617110E+02 mean = 0.216645061E+03

argp = 0.130483133E+03 anlong = 0.154617110E+02 mean = 0.216645061E+03  
initial conditions for phase 90

execution date and time Fri Oct 23

esn = 90.000 fesn= 90.000  
time= 2.4484250D+06  
normal termination  
cpu = 43.180 seconds

\*\*\* n p s o l s u m m a r y o u t p u t \*\*\*

variables		constraints		objective function	
name	phase	name	phase	name	value
1	critr	20.0	0.71193631E+03	0.00000000E+00	
2	depsv1	20.0	0.18987465E+07	0.12067911-152	
3	depsv1	20.0	0.13045306E+06	0.12067911-152	
				dvsum	90.0 0.726919361E+01

total number of iterations = 14  
total number of reloaded in evals = 12  
total number of function evaluations = 108  
total cpu time = 5434.930 seconds

## **3.2 MANNED MARS**

The manned Mars case is launched from Earth park orbit, performs a Venus gravity assist, orbits into a high elliptic Mars orbit, remains in orbit for two months, then launches back to Earth where the S/C inserts into an elliptical holding orbit. The simulation has 13 events with a total mission time of 610 days. This mission is a pure targeting case with no master controls, constraints, or objective function. All targeting is done on the subproblem level. Each subproblem is full rank (number of controls = number of constraints).

To understand this case we begin with the simulation, or first \$TRAJ input. At event 5, the initial conditions are specified, such as a S/C mass of 1000000 kg and an initial circular park orbit of 6878 radius.

The next event (#10) performs an impulsive launch maneuver, .5 days later, to insert the S/C on an Earth escape hyperbola. The 1STEP propagator is activated to account for 3 body motion (Earth-Sun-S/C). The S/C will leave Earth and begin its journey toward Mars, via Venus.

At event 20, 40 days after park orbit escape, the secondary body for 1STEP is changed to Venus (from Earth). The reference body (IDBODY) for target calculations is also switched to Venus.

Events 25 and 30 are simultaneous, but contiguous events. Event 25 is triggered by a mission flight time of 190 days. This is intended to correspond to Venus closest approach. Event 30 performs an impulsive midcourse correction.

At event 35, 40 days after Venus closest approach, the secondary body and reference body are changed to Mars.

Event 40 and 45 are simultaneous contiguous events. Event 40 corresponds to Mars closest approach, 350 days after Earth escape. Event 45 performs an impulsive orbit insertion into a highly elliptical Mars orbit whose inclination is the same as the approach hyperbola. The propagator is switched to a simple conic. At this point subsequent events could have simulated a Mars surface descent and subsequent ascent. However, for test case simplicity, only the 60 day orbital phase is simulated.

At event 50, after a two month stay in orbit, the S/C is inserted into an escape trajectory towards Earth. The 1STEP propagator is reactivated with Mars as the secondary body (and the Sun as primary). After 40 days, event 60 switches the secondary body and target reference body to Earth.

The final 3 events (#65, #70, #75) are all simultaneous contiguous events. Event 65 corresponds to Earth closest approach after a total mission time of 610 days. Event 70 performs an impulsive orbit insertion into a highly elliptical holding orbit about Earth. The orbit might be typical of a staging orbit which transfers crew and material to and from the low Earth Space Station orbit. Event 75 exists to allow conditions after the orbit insertion (before event 75) to be used as output values.

We now return to the optimization formulation, or \$TOP. No optimization algorithm was selected and only subproblem targeting will be done. Forward differences are specified for the finite differencing construction of the Jacobian. The maximum subproblem targeting iterations is 300.

The 3 subproblems all use the Newton-Raphson targeting algorithm. The subproblems correspond to Earth-Venus, Venus-Mars, Mars-Earth legs. The first subproblem varies escape V-infinity to achieve desired B dot T, B dot R, TFP at Venus closest approach. The second subproblem varies Venus midcourse delta V to achieve desired closest approach distance, time, and B dot T at Mars. The third subproblem varies Mars escape V-infinity to achieve desired closest approach distance, time, and B dot T at Earth return.

The output for this case is straightforward.

The final trajectory is displayed, corresponding to each event in the specified simulation input, along with the subproblem summary output (achieved by setting ISUB (i) = 1 in \$TOP). Of particular note are the conditions before and after each maneuver. The final S/C mass at Earth return is 70404 kg, reduced from an initial mass of 1 million kg in Earth park orbit.

```

p$top
c
c earth-mars roundtrip mission via venus flyby
c on out-bound leg. initial inputs from iprep
c
srchm = 'none',
iephem = 1,
fesn = 75,
istm = 'forward',
npad(1) = 0,
mxitar = 300,
ftol = 1.d-6,
c
c subproblem setup
c
modelt = 'nraph','nraph','nraph',
spfesn = 25,40,65,
tolf = 1.d0,
tolu = 1.d0,
npi = 5,
isub = 1,1,1,
c
c controls
c
indx1 = 1,1,1,2,2,3,3,3,
indxv = 'vinfxo','vinfyo','vinfzo','dvx','dvy','dvz',
'vlnfxo','vlnfyo','vlnfzo',
indxph = 10,10,10,30,30,50,50,50,
usub = 4.88694,-1.87826,1.51525,0.d0,0.d0,0.d0,5.01604,-4.14147,.72013,
pertsb = .001,.001,.001,.0001,.0001,.0001,.0001,.0001,.0001,.0001,
c
c targets
c
indxsd = 1,1,1,2,2,3,3,3,
depsvr = 'bdti','bdri','tfp','rperi','tfp',
'bdti','rperi','tfp','bdti',
depsph = 25,25,25,40,40,40,65,65,65,
depsvl = 9789.20,-810.461,0.3880,.0,.5190.08,6878.0,.16882.4,
wvsnlc = 10000.0,-600.0,-.001,4000.0,-.001,5500.7000.0,-.001,17000.0,
depsub = 9820.0,-820.0,-.001,3850.0,-.001,5150.6850.0,-.001,16400.0,
depsub = 9720.0,-800.0,.001,3900.0,.001,5250.6900.0,.001,17000.0,
depstl = 1.1,.0001,1.1,.0001,1.1,.0001,1.1,
c
$
p$traj
c
c initial park orbit
c
event = 5,
juldat = 2455522.0,
idbody = 3,
ipbody = 3,0,
idfram = 'ecliptic','mean2000',
iePOCH = 'julian',
iprop = 'conic',
scmass = 1.d6,

```

```

thrust = 2.d5,
inputx = 'conic',
x      = 6878.,0.,0.,0.,0.,0.,0.,0.,
$
p$traj
c
c earth escape...use launch maneuver
event = 10,
critr = 'timrfl',
value = .5,
mantyp = 'launch',
flnch = 2,
inc = -1.,
spi = 480.,
rperi = 6878.,
rapoap = 6878.,
lprop = 'lstep',
ipbody = 0,3,
tol = 1.d-7,
$
p$traj
c exited earth soi, change secondary, input body
c
event = 20,
critr = 5htdurp,
value = 40.d0,
ipbody = 0,2,
idbody = 2,
$
p$traj
c venus closest approach
event = 25,
critr = 6htimrfl,
value = 168.,
$
p$traj
c on the way to mars, do impulse correction
event = 30,
critr = 5htdurp,
value = 0.0d0,
mantyp = 'impuls',
dvx = 0., 0.,0.,
$
p$traj
c exited venus soi, change secondary body, input body
c
event = 35,
critr = 5htdurp,
value = 40.d0,
ipbody = 0,4,
idbody = 4,
$
p$traj
c mars closest approach
c

```



```
event = 40,  
critr = 6htimrfl,  
value = 323.,  
$
```

```
p$traj  
c orbit insertion  
c
```

```
event = 45,  
critr = Shtdurp,  
value = 0.,  
mantyp = 'orbins',  
rapoap = 36327.,  
rperi = 3880.,  
inc = -1.,  
iprop = 'conic',  
ipbody = 4,0,  
$
```

```
p$traj  
c depart mars 60 days after arrival  
c
```

```
event = 50,  
critr = Shtdurp,  
value = 60.,  
mantyp = 'launch',  
rapoap = 36327.,  
rperi = 3880.,  
inc = -1.,  
iprop = 'lstep',  
ipbody = 0,4,  
$
```

```
p$traj  
c exited mars soi, change secondary, input body  
c
```

```
event = 60,  
critr = Shtdurp,  
value = 40.d0,  
ipbody = 0,3,  
ibody = 3,  
$
```

```
p$traj  
c earth closest approach  
c
```

```
event = 65,  
critr = 6htimrfl,  
value = 583.,  
$
```

```
p$traj  
c orbit insertion  
c
```

```
event = 70,  
critr = Shtdurp,  
value = 0.d0,  
mantyp = 'orbins',  
rapoap = 78036.,  
rperi = 6878.,  
inc = -1.,  
$
```

```
p$traj
```

```
c final event for print out
c
  event = 75,
  critr = 5htdurp,
  value = 0.d0,
  namlst = 'none',
  $
```

```
*** core requirements for problem 1 are ***
```

parameter	octal	decimal
event criteria data	- 1060b	560
general data	- 332b	218
table data	- 34b	28

execution date and time Fri Oct 23

\*\*\*\* ipost input summary \*\*\*\*

\*\*\* trajectory inputs \*\*\*

initial epoch

julian date ...245522.0000

calendar date ...2010 nov 21, 12 hr 0 min 0.0000 secs

initial body and frame of reference 3 , earth , ecliptic, mean2000

initial state

cartesian 6.878000000000D+03 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00  
 0.000000000000D+00 7.61268440196D+00 0.000000000000D+00  
 conic 6.878000000000D+03 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00  
 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00

initial state, heliocentric, ecliptic

7.63136840775D+07 1.26559269107D+08 -3.84577196748D+03  
 -2.59845881927D+01 2.28755234840D+01 5.76965101277D-04

input units - metric, output units - metric

event number	summary	trigger	value	type	propagator
5.000		time	1.000000000000D+10	none	conic
10.000		timrfl	5.000000000000D-01	launch	lstep
20.000		tdurp	4.000000000000D+01	none	lstep
25.000		timrfl	1.680000000000D+02	none	lstep
30.000		tdurp	0.000000000000D+00	impuls	lstep
35.000		tdurp	4.000000000000D+01	none	lstep
40.000		timrfl	3.230000000000D+02	none	lstep
45.000		tdurp	0.000000000000D+00	orbins	conic
50.000		tdurp	6.000000000000D+01	launch	lstep
60.000		tdurp	4.000000000000D+01	none	lstep
65.000		timrfl	5.830000000000D+02	none	lstep
70.000		tdurp	0.000000000000D+00	orbins	lstep
75.000		tdurp	0.000000000000D+00	none	lstep

\*\*\*targeting/optimization inputs\*\*\*

master problem optimization algorithm - none

master prob. control/indep parameters

evtnum name

master problem target/dep parameters

evtnum name

total number of subproblems is 3

subproblem number 1

subproblem controls vinfxo vinfyo vinfzo

at event 10 10 10

subproblem targets bdti

at events 25 25

subproblem values 0.97892E+04 -0.81046E+03 0.00000E+00

with tolerance 0.10000E+01 0.10000E+01 0.10000E-03

subproblem number 2

subproblem controls dvx dvz

at event 30 30

subproblem targets rperi tfp bdti

at events 40 40

subproblem values 0.38800E+04 0.00000E+00 0.51901E+04

with tolerance 0.10000E+01 0.10000E-03 0.10000E+01

```

subproblem number 3
subproblem controls  vinfxo  vinfyo  vinfzo
subproblem at event  50      50      50
subproblem targets  rperi  tfp  bdti
subproblem at events 65      65
subproblem values  0.68780E+04  0.00000E+00  0.16882E+05
with tolerance  0.10000E+01  0.10000E-03  0.10000E+01
subproblem number 1

date -11 21 2010 12.00  julian -2455522.00000000  tduwp = 0.00000000
primid = earth  secid = sun  idbody = earth
timrfl = 0.00000000E+00
state relative to idbody: earth
x = 0.6878000000E+04  y = 0.0000000000E+00  z = 0.0000000000E+00
vx = 0.0000000000E+00  vy = 0.761268440E+01  vz = 0.0000000000E+00
sma = 0.6878000000E+04  eccen = 0.932142818E-15  inc = 0.0000000000E+00
meaan = 0.0000000000E+00  truan = 0.0000000000E+00  tfp = 0.0000000000E+00
altp = 0.4998600000E+03  alta = 0.4998600000E+03  raposp = 0.6878000000E+04
lat = 0.0000000000E+00  long = 0.0000000000E+00  longp = 0.0000000000E+00
state relative to secondary body: sun
x = 0.763136841E+08  y = 0.12655269E+09  z = -0.384577197E+04
vx = -0.259845882E+02  vy = 0.228755235E+02  vz = 0.576965101E-03
sma = 0.222110443E+09  eccen = 0.374429852E+00  inc = 0.193959703E-02
argp = 0.271059439E+03  anlong = 0.109148029E+03  meaan = 0.170337865E+02

critr = time  radius = 0.6878000000E+04  scmass = 0.1000000000E+07
frame = ecliptic  speed = 0.761268440E+01  fpa = -0.381666562E-12
epoch = mean2000  argp = 0.0000000000E+00  anlong = 0.0000000000E+00
vperi = 0.761268440E+01  rperi = 0.6878000000E+04
period = 0.567680811E+04
altit = 0.4998600000E+03  altit = 0.6878000000E+04

```

final conditions for phase 5

```

date      -11 22 2010 0.00 julian =2455522.50000000 tdurp = 0.50000000
primid   = earth
timrfl   = 0.50000000E+00
state relative to idbody: earth
x        = -0.530206260E+04 y        = -0.438121172E+04 z        = 0.00000000E+00
vx       = 0.484919775E+01 vy       = -0.586841077E+01 vz       = 0.00000000E+00
sma      = 0.687800000E+04 eccen    = 0.347400286E-15 inc      = 0.00000000E+00
meanlon  = -0.140432324E+03 truan   = -0.140432324E+03 tfp      = -0.256303804E-01
altp     = 0.499860000E+03 alta    = 0.499860000E+03 rapoap   = 0.687800000E+04
lat      = 0.000000000E+00 long    = -0.114591559E+03 longp   = 0.00000000E+00
state relative to secondary body: sun
x        = 0.751760719E+08 y        = 0.127209403E+09 z        = -0.381914384E+04
vx       = -0.212692499E+02 vy      = 0.917019882E+01 vz      = 0.653922455E-03
sma      = 0.105342067E+09 eccen    = 0.418966590E+00 inc      = 0.206703171E-02
argp     = 0.123945970E+03 anlong  = 0.105179580E+03 meanlon = -0.157350680E+03
    
```

initial conditions for phase 10 before launch maneuver

```

date      -11 22 2010 0.00 julian =2455522.50000000 tdurp = 0.50000000
primid   = sun
state relative to idbody: earth
x        = -0.530206260E+04 y        = -0.438121172E+04 z        = 0.00000000E+00
vx       = 0.484919775E+01 vy       = -0.586841077E+01 vz       = 0.00000000E+00
sma      = 0.687800000E+04 eccen    = 0.683258405E-12 inc      = 0.00000000E+00
meanlon  = -0.140432324E+03 truan   = -0.140432324E+03 tfp      = -0.256303804E-01

launch maneuver print block
dvx      = 0.00000000E+00 dvy      = 0.00000000E+00 dvz      = 0.00000000E+00
thrust   = 0.20000000E+06 spi      = 0.48000000E+03 dmass   = 0.611692249E+06
    
```

initial conditions for phase 10 after launch maneuver

```

date      -11 22 2010 0.00 julian =2455522.50000000 tdurp = 0.00000000
primid   = sun
timrfl   = 0.50000000E+00
state relative to idbody: earth
x        = -0.592058832E+04 y        = -0.326417341E+04 z        = -0.126439311E+04
vx       = 0.528086388E+01 vy       = -0.105528008E+02 vz       = 0.251531798E+01
sma      = -0.134344506E+05 eccen    = 0.151196734E+01 inc      = 0.161377276E+02
meanlon  = -0.350418797E-11 truan   = -0.151611100E-14 tfp      = -0.174587029E-14

Incoming Asymptote
altp     = 0.499860000E+03 vinfm   = 0.544701982E+01 vinfx   = -0.131297115E+01
bmag     = 0.152335195E+05 btheta  = 0.160174267E+02 bdt     = 0.146437321E+05
c3       = 0.296700250E+02 ra       = -0.103956777E+03 dec     = 0.199306976E+01

Outgoing Asymptote
altp     = 0.499860000E+03 vinfm   = 0.544701982E+01 vinfx   = 0.488927835E+01
bmag     = 0.152335195E+05 btheta  = -0.17909054E-10 bdt     = 0.152335195E+05
c3       = 0.296700250E+02 ra       = -0.125166693E+03 dec     = 0.161377276E+02

state relative primary body: sun
x        = 0.751754533E+08 y        = 0.127210520E+09 z        = -0.508353695E+04
vx       = -0.208375838E+02 vy      = 0.448580879E+01 vz      = 0.251597190E+01
sma      = 0.993630316E+08 eccen    = 0.558992454E+00 inc      = 0.709169299E+01
argp     = 0.164108951E+03 anlong  = 0.594347477E+02 meanlon = -0.134908160E+03
    
```

final conditions for phase 10

execution date and time Fri Oct 23

```

date = 1 1 2011 0.00 julian = 2455562.500000000 tdurp = earth 40.000000000 critr = tdurp propid = 1step
primid = sun secid = earth --0.666837022E+07 z = 0.481674995E+07 radius = 0.175937891E+08 scmass = 0.388307751E+06
timrfl = 0.405000000E+02 --0.244754059E+01 vz = 0.115330601E+01 speed = 0.456947153E+01 fpa = 0.798838431E+02
state relative to idbody: earth --0.161705292E+03 inc = 0.161705292E+03 argp = 0.355741412E+02 anlong = 0.937043641E+02
x = 0.155227233E+08 y = 0.191315145E+05 truean = 0.517888522E+05 tfp = 0.438485287E+02 rperi = 0.307453563E+07 vperi = 0.459282593E+01
vx = 0.369097569E+01 vy = 0.802326591E+02 --0.456451077E+01 vinfm = 0.456451077E+01 vinfz = 0.371500213E+01 vinfz = 0.113399371E+01
sma = -0.191315145E+05 eccen = 0.309360799E+07 btheta = -0.169568589E+03 bdt = -0.304247794E+07 bdr = -0.560123493E+06 hypta = 0.896456755E+02
mean = 0.517888522E+05 truean = 0.328354531E+02 dec = 0.143850457E+02 altit = 0.175874110E+08
Incoming Asymptote --0.456451077E+01 vinfm = 0.456451077E+01 vinfz = 0.368674683E+01 vinfz = 0.112400604E+01
altp = 0.306815749E+07 vinfm = 0.456451077E+01 vinfz = 0.368674683E+01 vinfz = 0.112400604E+01
bmag = 0.309360799E+07 btheta = -0.169568589E+03 bdt = -0.304072451E+07 bdr = -0.569565468E+06 hypta = 0.000000000E+00
c3 = 0.208347586E+02 ra = -0.333533378E+02 dec = 0.142595653E+02 altit = 0.175874110E+08
Outgoing Asymptote --0.138184253E+09 z = 0.481316317E+07 --0.244525393E+01 vinfz = 0.112400604E+01
altp = 0.306815749E+07 vinfm = 0.456451077E+01 vinfz = 0.368674683E+01 vinfz = 0.112400604E+01
bmag = 0.309360799E+07 btheta = -0.169390728E+03 bdt = -0.304072451E+07 bdr = -0.569565468E+06 hypta = 0.000000000E+00
c3 = 0.208347586E+02 ra = -0.333533378E+02 dec = 0.142595653E+02 altit = 0.175874110E+08
state relative primary body: sun --0.138184253E+09 z = 0.481316317E+07 --0.244525393E+01 vinfz = 0.112400604E+01
x = -0.101183285E+08 y = -0.775214417E+01 vz = 0.112458002E+01 --0.142466850E+02 speed = 0.189092604E+02 fpa = 0.350198257E+02
vx = -0.261358954E+02 vy = 0.303458560E+00 inc = 0.303458560E+00 argp = 0.725561590E+02
sma = 0.113422157E+09 eccen = 0.303458560E+00 --0.125271215E+03 mean = -0.125271215E+03 rperi = 0.796870912E+08 vperi = 0.189092994E+02
argp = 0.182890485E+03 anlong = 0.593013863E+02 tfp = 0.350202006E+02 tfp = 0.341783161E+02

```

initial conditions for phase 20

```

date = 1 1 2011 0.00 julian = 2455562.500000000 tdurp = venus 0.000000000 critr = tdurp propid = 1step
primid = sun secid = venus --0.671837720E+08 z = 0.805460103E+06 radius = 0.973037582E+08 scmass = 0.388307751E+06
timrfl = 0.405000000E+02 --0.186940818E+02 vz = 0.142466850E+02 speed = 0.189092604E+02 fpa = 0.350198257E+02
state relative to idbody: venus --0.877080195E+05 inc = 0.981680549E+00 argp = 0.29688017E+03 anlong = 0.725561590E+02
x = 0.703826212E+08 y = 0.877080195E+05 eccen = 0.877080195E+05 truean = 0.352130711E+07 truean = 0.341783161E+02
vx = -0.284097516E+01 vy = 0.877080195E+05 eccen = 0.877080195E+05 truean = 0.352130711E+07 truean = 0.341783161E+02
sma = -0.908560017E+03 ra = 0.350202006E+02 tfp = 0.341783161E+02 tfp = 0.341783161E+02
mean = 0.352130711E+07 truean = 0.350202006E+02 tfp = 0.341783161E+02 tfp = 0.341783161E+02
Incoming Asymptote --0.284061322E+01 vinfm = 0.189092038E+02 vinfz = 0.284061322E+01 vinfz = 0.142460299E+01
altp = 0.796810392E+08 vinfm = 0.189092038E+02 vinfz = 0.284061322E+01 vinfz = 0.142460299E+01
bmag = 0.796879997E+08 btheta = 0.881688115E+00 bdt = 0.796785648E+08 bdr = 0.122621928E+07 hypta = 0.899993467E+02
c3 = 0.357553452E+03 ra = 0.986402010E+02 dec = 0.431668248E+00 altit = 0.972977062E+08
Outgoing Asymptote --0.284061322E+01 vinfm = 0.189092038E+02 vinfz = 0.284061322E+01 vinfz = 0.142460299E+01
altp = 0.796810392E+08 vinfm = 0.189092038E+02 vinfz = 0.284061322E+01 vinfz = 0.142460299E+01
bmag = 0.796879997E+08 btheta = 0.881688115E+00 bdt = 0.796785648E+08 bdr = 0.122621928E+07 hypta = 0.899993467E+02
c3 = 0.357553452E+03 ra = 0.986402010E+02 dec = 0.431668248E+00 altit = 0.972977062E+08
state relative primary body: sun --0.138184253E+09 z = 0.481316317E+07 --0.244525393E+01 vinfz = 0.112400604E+01
x = -0.101183285E+08 y = -0.775214417E+01 vz = 0.112458002E+01 --0.142466850E+02 speed = 0.189092604E+02 fpa = 0.350198257E+02
vx = -0.261358954E+02 vy = 0.303458560E+00 inc = 0.303458560E+00 argp = 0.725561590E+02
sma = 0.113422157E+09 eccen = 0.303458560E+00 --0.125271215E+03 mean = -0.125271215E+03 rperi = 0.796870912E+08 vperi = 0.189092994E+02
argp = 0.182890485E+03 anlong = 0.593013863E+02 tfp = 0.350202006E+02 tfp = 0.341783161E+02

```

final conditions for phase 20

```

date = 5 8 2011 12.00 julian = 2455690.000000000 tdurp = venus 127.500000000 critr = timrfl propid = 1step
primid = sun secid = venus --0.737709939E+04 z = 0.591387009E+03 radius = 0.746012375E+04 scmass = 0.388307751E+06
timrfl = 0.168000000E+03 --0.167884287E+01 vz = -0.342414513E+00 speed = 0.143457578E+02 fpa = -0.639960672E+00
state relative to idbody: venus --0.372583355E+01 inc = 0.372583355E+01 argp = 0.473446410E+01 anlong = 0.156525251E+03
x = -0.939251327E+03 y = -0.167884287E+01 truean = 0.372583355E+01 truean = 0.372583355E+01
vx = 0.142430687E+02 vy = 0.372583355E+01 eccen = 0.372583355E+01 eccen = 0.372583355E+01
sma = -0.273660439E+04 anlong = 0.156525251E+03 tfp = 0.341783161E+02 tfp = 0.341783161E+02

```

```

mean = -0.168050387E+01      truan = -0.811720352E+00      tfp = -0.852656040E-04      rperi = 0.745953352E+04      vperi = 0.143459980E+02
Incoming Asymptote
altp = 0.140753352E+04      vinfm = 0.108953526E+02      vinfx = 0.100969617E+02      vinfy = -0.409384683E+01      vinfz = -0.221602862E-01
bmag = 0.982202753E+04      btheta = -0.473303294E+01      bdt = 0.978853423E+04      bdr = -0.810445840E+03      hpyta = 0.744311480E+02
c3 = 0.118708708E+03      ra = -0.220702583E+02      dec = -0.116535168E+00      altit = 0.140612375E+04
Outgoing Asymptote

```



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altp = 0.140753352E+04 vlnfm = 0.108953526E+02 vlnfx = 0.107510861E+02 vlnfy = 0.169963345E+01 vlnfz = -0.483841312E+00  
 bmag = 0.982202753E+04 bbeta = -0.399342539E+01 bdt = 0.979818012E+04 bdr = -0.684025682E+03 hpyta = 0.000000000E+00  
 c3 = 0.118708708E+03 ra = 0.955508988E+01 dec = -0.254523061E+01 altit = 0.140812375E+04  
 state relative primary body: sun  
 x = 0.103560979E+09 y = -0.328492345E+08 z = -0.642620342E+07  
 vx = 0.246445190E+02 vy = 0.315505174E+02 vz = -0.487464857E+00  
 sma = 0.158796701E+09 eccen = 0.456578464E+00 inc = 0.342386879E+01  
 argp = 0.208467739E+03 anlong = 0.637486442E+02 meanan = 0.2748464183E+02

initial conditions for phase 25

subproblem iteration 20 final icnvgd = 1  
 subp. ind. vars. 1 4.88927835E+00-1.86355420E+00 1.51398411E+00 3  
 subp. dep. vars. 1 9.78853423E+03-8.10445840E+02-8.52656040E-05 3  
 subproblem number 2 6.65774332E-01-1.51598210E-02 8.52656040E-05

initial conditions for phase 25

final conditions for phase 25  
 date = 5 8 2011 12.00 julian =2455690.00000000 tdurp = venus 0.00000000  
 primid = sun secid = venus  
 timfl = 0.168000000E+03  
 state relative to idbody: venus  
 x = -0.939251327E+03 y = -0.737709393E+04 z = 0.591387009E+03  
 vx = 0.142430687E+02 vy = -0.167884287E+01 vz = -0.342414513E+00  
 sma = -0.273660439E+04 eccen = 0.372583555E+01 inc = 0.473446410E+01  
 meanan = -0.168050387E+01 truan = -0.811720352E+00 tfp = -0.852656040E-04

initial conditions for phase 25

Incoming Asymptote  
 altp = 0.140753352E+04 vlnfm = 0.108953526E+02 vlnfx = 0.100969617E+02 vlnfy = -0.409384683E+01 vlnfz = -0.221602862E-01  
 bmag = 0.982202753E+04 bbeta = -0.473303294E+01 bdt = 0.978853423E+04 bdr = -0.810445840E+03 hpyta = 0.744311480E+02  
 c3 = 0.118708708E+03 ra = -0.220702583E+02 dec = -0.116535168E+00 altit = 0.140812375E+04  
 Outgoing Asymptote  
 altp = 0.140753352E+04 vlnfm = 0.108953526E+02 vlnfx = 0.107510861E+02 vlnfy = 0.169963345E+01 vlnfz = -0.483841312E+00  
 bmag = 0.982202753E+04 bbeta = -0.399342539E+01 bdt = 0.979818012E+04 bdr = -0.684025682E+03 hpyta = 0.000000000E+00  
 c3 = 0.118708708E+03 ra = 0.955508988E+01 dec = -0.254523061E+01 altit = 0.140812375E+04  
 state relative primary body: sun  
 x = 0.103560979E+09 y = -0.328492345E+08 z = -0.642620342E+07  
 vx = 0.246445190E+02 vy = 0.315505174E+02 vz = -0.487464857E+00  
 sma = 0.158796701E+09 eccen = 0.456578464E+00 inc = 0.342386879E+01  
 argp = 0.208467739E+03 anlong = 0.637486442E+02 meanan = 0.2748464183E+02

initial conditions for phase 30 before impuls maneuver

date = 5 8 2011 12.00 julian =2455690.00000000 tdurp = venus 0.00000000  
 primid = sun secid = venus  
 state relative to idbody: venus  
 x = -0.939251327E+03 y = -0.737709393E+04 z = 0.591387009E+03  
 vx = 0.142430687E+02 vy = -0.167884287E+01 vz = -0.342414513E+00  
 sma = -0.273660439E+04 eccen = 0.372583555E+01 inc = 0.473446410E+01  
 meanan = -0.168050387E+01 truan = -0.811720352E+00 tfp = -0.852656040E-04

```

impuls  maneuver print block
dvx  =-0.145887869E-01  dvy  = 0.302675298E-02  dvz  =-0.518018869E-02  dtburn  = 0.306263995E+02
thrust = 0.20000000E+06  spi  = 0.48000000E+03  dmass = 0.129908194E+04  dvmag  = 0.157742921E-01  wprop  = 0.387008669E+06

initial conditions for phase 30 after impuls  maneuver
date  = 5 8 2011 12.00  julian =2455690.00000000  tdurp  = 0.00000000  critr  =  tdurp  propid  = 1step
primid = sun  secid  = venus  idbody  = venus  frame  =  ecliptic  epoch  =  mean2000
timrf1 = 0.16800000E+03  state relative to idbody: venus  radius  = 0.746012375E+04  scmass  = 0.387008669E+06
x  =-0.939251327E+03  y  =-0.737709393E+04  z  = 0.591387009E+03  speed  = 0.143317531E+02  fpa  =-0.622917861E+00
vx  = 0.142284799E+02  vy  =-0.168186962E+01  vz  =-0.347594702E+00

```

```

sma --0.274589438E+04 eccen = 0.371662461E+01 inc = 0.474105451E+01 argp = 0.107231532E+03 anlong = 0.156249743E+03
mean --0.162990473E+01 truan --0.790517914E+00 tfp = -0.831197619E-04 rperi = 0.745956425E+04 vperi = 0.143319810E+02
Incoming Asymptote
altp = 0.140756425E+04 vlnfm = 0.108769062E+02 vlnfx = 0.100754007E+02 vlnfy --0.409789471E+01 vlnfz --0.254642063E-01
bmag = 0.982911237E+04 btheta --0.473916092E+01 bdt = 0.979550811E+04 bdr --0.812078101E+03 hypta = 0.743915812E+02
c3 = 0.118307089E+03 ra = -0.221326942E+02 dec = -0.134136753E+00 altit = -0.140812375E+04
Outgoing Asymptote
altp = 0.140756425E+04 vlnfm = 0.108769062E+02 vlnfx = 0.107321883E+02 vlnfy = 0.169986571E+01 vlnfz = -0.487525043E+00
bmag = 0.982911237E+04 btheta = -0.398605354E+01 bdt = 0.980533575E+04 bdr = 0.683257506E+03 hypta = 0.000000000E+00
c3 = 0.118307089E+03 ra = 0.957644254E+01 dec = -0.256897396E+01 altit = 0.140812375E+04
state relative primary body: sun
x = 0.103560979E+09 y = -0.328492345E+08 z = -0.642620342E+07
vx = 0.246299302E+02 vy = 0.315474907E+02 vz = -0.492645046E+00
sma = 0.158624976E+09 eccen = 0.455979490E+00 inc = 0.342253349E+01 v2 = -0.492645046E+00
argp = 0.208286225E+03 anlong = 0.638971570E+02 mean = 0.275486293E+02 tinc = 0.342253349E+01

```

final conditions for phase 30

```

date = 6 17 2011 12.00 julian =2455730.00000000 tdurp = venus tbody = venus critr = 40.00000000 frame = ecliptic propid = lstep
primid = sun secid = venus idbody = mars mars = 0.00000000 tdurp = mars mars = 0.00000000 frame = ecliptic propid = lstep
timrfl = 0.208000000E+03
state relative to idbody: venus
x = 0.489655767E+08 y = 0.903579853E+07 z = 0.237216236E+07 radius = 0.498487764E+08 scmass = 0.387008669E+06
vx = 0.196193832E+02 vy = 0.667951334E+01 vz = -0.965469220E+00 speed = 0.207477282E+02 fpa = 0.816630390E+02
sma --0.754686610E+03 eccen = 0.957736372E+04 inc = 0.273265023E+01 argp = 0.192893179E+03 anlong = 0.958880603E+02
mean = 0.374443086E+07 truan = 0.816689582E+02 tfp = 0.275138972E+02 rperi = 0.722715348E+07 vperi = 0.207495805E+02
Incoming Asymptote
altp = 0.722110148E+07 vlnfm = 0.207474141E+02 vlnfx = 0.196204726E+02 vlnfy = 0.667533188E+01 vlnfz = -0.965500511E+00
bmag = 0.722790812E+07 btheta = 0.610713378E+00 bdt = 0.722749753E+01 bdr = 0.770405191E+05 hypta = 0.899940176E+02
c3 = 0.430455193E+03 ra = 0.187894745E+02 dec = -0.266714892E+01 altit = 0.498427244E+08
Outgoing Asymptote
altp = 0.722110148E+07 vlnfm = 0.207474141E+02 vlnfx = 0.196190788E+02 vlnfy = 0.667943389E+01 vlnfz = -0.965454360E+00
bmag = 0.722790812E+07 btheta = 0.611270731E+00 bdt = 0.722749678E+07 bdr = 0.771108257E+05 hypta = 0.000000000E+00
c3 = 0.430455193E+03 ra = 0.188002098E+02 dec = -0.266714892E+01 altit = 0.498427244E+08
state relative primary body: sun
x = 0.123825196E+09 y = 0.870181568E+08 z = 0.562413535E+07
vx = -0.575163219E+01 vy = 0.307835144E+02 vz = -0.829003904E+00
sma = 0.172088150E+09 eccen = 0.427685649E+00 inc = 0.338609689E+01 v2 = -0.829003904E+00
argp = 0.221411371E+03 anlong = 0.740056455E+02 mean = 0.501923109E+02 tinc = 0.338609689E+01

```

initial conditions for phase 35

```

date = 6 17 2011 12.00 julian =2455730.00000000 tdurp = mars tbody = mars critr = 0.00000000 frame = ecliptic propid = lstep
primid = sun secid = mars idbody = mars mars = 0.00000000 tdurp = mars mars = 0.00000000 frame = ecliptic propid = lstep
timrfl = 0.208000000E+03
state relative to idbody: mars
x = -0.475054667E+08 y = -0.450091738E+08 z = -0.418356853E+07 radius = 0.655751275E+08 scmass = 0.387008669E+06
vx = 0.811370981E+01 vy = 0.952183309E+01 vz = 0.430262841E-01 speed = 0.125099738E+02 fpa = -0.829811566E+02
sma --0.273566643E+03 eccen = 0.292804740E+05 inc = 0.150384887E+03 argp = 0.270400715E+03 anlong = 0.499118207E+02
mean = -0.136260529E+08 truan = -0.829830577E+02 tfp = -0.602144383E+02 rperi = 0.801280918E+07 vperi = 0.125103488E+02
Incoming Asymptote
altp = 0.800941198E+07 vlnfm = 0.125099216E+02 vlnfx = 0.811367384E+01 vlnfy = 0.952183309E+01 vlnfz = 0.430245223E-01
bmag = 0.801308284E+07 btheta = 0.150385483E+03 bdt = -0.696633183E+01 bdr = 0.395976229E+07 hypta = 0.899980432E+02
c3 = 0.156498137E+03 ra = 0.495651526E+02 dec = -0.197053866E+00 altit = 0.655717303E+08
Outgoing Asymptote
altp = 0.800941198E+07 vlnfm = 0.125099216E+02 vlnfx = 0.811423931E+01 vlnfy = 0.952131222E+01 vlnfz = 0.434467758E-01

```

```

bmag = 0.801308284E+07 btheta = 0.150385495E+03 bdt      = -0.696633264E+07 bdr      = 0.395976087E+07 hpyta = 0.000000000E+00
c3   = 0.156498137E+03 ra      = 0.495637180E+02 dec      = 0.198987810E+00 altit   = 0.655717303E+08
state relative primary body: sun
x    = 0.123825196E+09 y      = 0.870181568E+08 z      = -0.562413535E+07
vx   = -0.575163219E+01 vy    = 0.307835144E+02 vz    = 0.829003904E+00
sma  = 0.172088150E+09 eccen  = 0.427685649E+00 inc    = 0.338609689E+01
argp = 0.221411371E+03 anlong = 0.740056455E+02 meaan  = 0.501923109E+02

```

execution date and time Fri Oct 23

final conditions for phase 35

```

date =10 10 2011 12.00 julian =2455845.000000000 tdurp = 115.000000000
primid = sun secid = mars
timrfl = 0.323000000E+03
state relative to ldbody: mars
x = 0.279646024E+04 y = -0.268195846E+04 z = 0.219065841E+03
vx = 0.484947579E+01 vy = 0.510840155E+01 vz = 0.629314835E+00
sma = -0.153299371E+04 eccen = 0.353155693E+01 inc = 0.604937751E+01
mean = -0.655473392E-02 ttrun = -0.346415439E-02 tfp = -0.384028891E-06
Incoming Asymptote
altp = 0.483660842E+03 vinfm = 0.528561061E+01 vinfy = 0.455477922E+01
bmag = 0.519227805E+04 btheta = -0.16671974E+01 bdt = 0.519008006E+04
c3 = 0.279376795E+02 ra = 0.299810722E+02 dec = 0.581592413E+01
Outgoing Asymptote
altp = 0.483660842E+03 vinfm = 0.528561061E+01 vinfx = 0.239770784E+01
bmag = 0.519227805E+04 btheta = -0.456169921E+01 bdt = 0.517583030E+04
c3 = 0.279376795E+02 ra = 0.458758002E+02 dec = 0.397735071E+01
state relative primary body: sun
x = -0.338137002E+08 y = 0.235261746E+09 z = 0.576011729E+07
vx = -0.182143713E+02 vy = 0.371924357E+01 vz = 0.116651544E+01
sma = 0.172476869E+09 eccen = 0.491122390E+00 inc = 0.359534798E+01
argp = 0.226479289E+03 anlong = 0.794917109E+02 mean = 0.122469476E+03

```

initial conditions for phase 40

```

subproblem iteration 32 final icnvgd = 1
subp. ind. vars. 4 -1.45887869E-02 -3.02675298E-03 -5.18018869E-03
subp. dep. vars. 4 3.88086084E+03 -3.84028891E-07 5.19008006E+03
subproblem number 3 -8.60841762E-01 3.84028891E-07 -5.87811764E-05

```

initial conditions for phase 40

```

final conditions for phase 40
date =10 10 2011 12.00 julian =2455845.000000000 tdurp = 0.000000000
primid = sun secid = mars
timrfl = 0.323000000E+03
state relative to ldbody: mars
x = 0.279646024E+04 y = -0.268195846E+04 z = 0.219065841E+03
vx = 0.484947579E+01 vy = 0.510840155E+01 vz = 0.629314835E+00
sma = -0.153299371E+04 eccen = 0.353155693E+01 inc = 0.604937751E+01
mean = -0.655473392E-02 ttrun = -0.346415439E-02 tfp = -0.384028891E-06
Incoming Asymptote
altp = 0.483660842E+03 vinfm = 0.528561061E+01 vinfy = 0.455477922E+01
bmag = 0.519227805E+04 btheta = -0.16671974E+01 bdt = 0.519008006E+04
c3 = 0.279376795E+02 ra = 0.299810722E+02 dec = 0.581592413E+01
Outgoing Asymptote
altp = 0.483660842E+03 vinfm = 0.528561061E+01 vinfx = 0.239770784E+01
bmag = 0.519227805E+04 btheta = -0.456169921E+01 bdt = 0.517583030E+04

```

```

c3      = 0.279376795E+02  ra      = 0.458758002E+02  dec      = 0.397735071E+01  altit   = 0.483660847E+03
state relative primary body: sun
x      = -0.338137002E+08  y      = 0.235261746E+09  z      = 0.576011729E+07
vx     = -0.182143713E+02  vy     = 0.371924357E+01  vz     = 0.116651544E+01
sma    = 0.172476869E+09  eccen  = 0.491122390E+00  inc    = 0.359534798E+01
argp   = 0.226479289E+03  anlong = 0.754917109E+02  meana  = 0.122469476E+03

initial conditions for phase 45 before orbits maneuver
date   = 10 10 2011 12.00  julian = 2455845.00000000  tdurp   = 0.00000000  critr  = tdurp      propid = conic
primid = mars             secid  = sun              idbody  = mars      frame  = ecliptic  epoch  = mean2000
state relative to idbody: mars
x      = 0.279646024E+04  y      = -0.268195846E+04  z      = 0.219065841E+03  radius = 0.388086085E+04  scmass = 0.387008669E+06
vx     = 0.484947579E+01  vy     = 0.510840155E+01  vz     = 0.629314835E+00  speed  = 0.707171967E+01  fpa    = -0.269970313E-02

```

```

sma --0.153299371E+04 eccen = 0.353155693E+01 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
measn --0.655473392E-02 truan --0.346415439E-02 tfp --0.384028891E-06 rperi = 0.388000000E+04 vperi = 0.707171967E+01

```

```

orbins maneuver print block
dvx --0.145887869E-01 dvz --0.302675298E-02 dvmag = 0.260621089E+01 tburn = 0.504309171E+04
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.164541093E+06 wprop = 0.222467576E+06

```

```

initial conditions for phase 45 after orbins maneuver
date =10 10 2011 12.00 julian =2455845.00000000 tdurp = 0.00000000 propid = conic
primid = mars secid = sun idbody = mars epoch = mean2000
timfr1 = 0.323000000E+03
state relative to idbody: mars radius = 0.388000000E+04 scmass = 0.222467576E+06
x = 0.279600081E+04 y --0.268119410E+04 z = 0.219038125E+03 fpa = 0.381666562E-12
vx = 0.30626127E+01 vy = 0.322621981E+01 vz = 0.397436432E+00 speed = 0.446609975E+01
sma = 0.201035000E+05 eccen = 0.80699781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
measn = 0.262945617E-15 truan = 0.804571863E-15 tfp = 0.731596672E-18 rperi = 0.388000000E+04 vperi = 0.446609975E+01
altp = 0.482800000E+03 alta = 0.329298000E+05 rapoap = 0.363270000E+05 altit = 0.482800000E+03 period = 0.865410237E+05
lat = 0.000000000E+00 long = 0.171887339E+03 longp = 0.286478898E+03
state relative to secondary body: sun
x --0.338137007E+08 y = 0.235261747E+09 z = 0.576011726E+07
vx --0.200012343E+02 vy = 0.183706182E+01 vz = 0.934637042E+00
sma = 0.186365139E+09 eccen = 0.355225961E+00 inc = 0.277885896E+01
argp = 0.237499518E+03 anlong = 0.682257680E+02 measn = 0.128078496E+03

```

```

final conditions for phase 45
date =12 9 2011 12.00 julian =2455905.00000000 tdurp = 60.00000000 propid = conic
primid = mars secid = sun idbody = mars epoch = mean2000
timfr1 = 0.383000000E+03
state relative to idbody: mars radius = 0.17529224E+05 scmass = 0.222467576E+06
x = 0.174242594E+05 y = 0.534144104E+03 z --0.177839432E+04 fpa = 0.534531795E+02
vx --0.129920633E+01 vy --0.102879184E-01 vz = 0.107327232E+00 speed = 0.166068325E+01
sma = 0.201035000E+05 eccen = 0.80699781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
measn = 0.351984804E+02 truan = 0.138018007E+03 tfp --0.979331444E-01 rperi = 0.388000000E+04 vperi = 0.446609975E+01
altp = 0.482800000E+03 alta = 0.329298000E+05 rapoap = 0.363270000E+05 altit = 0.141257224E+05
lat = 0.000000000E+00 long = 0.401070457E+03 longp = 0.286478898E+03
state relative to secondary body: sun
x --0.144221665E+09 y = 0.198916666E+09 z = 0.770694762E+07
vx --0.174003685E+02 vy --0.131800675E+02 vz = 0.311697669E+00
sma = 0.220101204E+09 eccen = 0.118651171E+00 inc = 0.19899094E+01
argp = 0.235652198E+03 anlong = 0.614189311E+02 measn = 0.168813507E+03

```

```

initial conditions for phase 50 before launch maneuver
date =12 9 2011 12.00 julian =2455905.00000000 tdurp = 60.00000000 propid = lstep
primid = sun secid = mars idbody = mars epoch = mean2000
state relative to idbody: mars radius = 0.17529224E+05 scmass = 0.222467576E+06
x = 0.174242594E+05 y = 0.534144104E+03 z --0.177839432E+04 fpa = 0.534531795E+02
vx = 0.129920633E+01 vy --0.102879184E-01 vz = 0.107327232E+00 speed = 0.166068325E+01
sma = 0.201035000E+05 eccen = 0.80699781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
measn = 0.351984804E+02 truan = 0.138018007E+03 tfp --0.979331444E-01 rperi = 0.388000000E+04 vperi = 0.446609975E+01
lat = 0.000000000E+00 long = 0.401070457E+03 longp = 0.286478898E+03
state relative to secondary body: sun
x --0.144221665E+09 y = 0.198916666E+09 z = 0.770694762E+07
vx --0.174003685E+02 vy --0.131800675E+02 vz = 0.311697669E+00
sma = 0.220101204E+09 eccen = 0.118651171E+00 inc = 0.19899094E+01
argp = 0.235652198E+03 anlong = 0.614189311E+02 measn = 0.168813507E+03

```

```

launch maneuver print block
dvx --0.145887869E-01 dvz --0.302675298E-02 dvmag = 0.260621089E+01 tburn = 0.504309171E+04
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.164541093E+06 wprop = 0.222467576E+06

```

initial conditions for phase 50 after launch maneuver

```

date =12 9 2011 12.00 julian =2455905.00000000 tdurp = 0.00000000
primid = sun secid = mars
timrfl = 0.383000000E+03
state relative to idbody: mars
x =-0.302691118E+04 y =-0.2425777039E+04 z =-0.885817392E+02
vx = 0.499077110E+01 vy =-0.625959852E+01 vz = 0.877470951E+00
vya = 0.100103773E+04 eccen = 0.487597776E+01 inc = 0.639142809E+01
meaan =-0.651497419E+09 truan =-0.206957351E+09 tfp =-0.201412605E-13
Incoming Asymptote
altp = 0.482800000E+03 vinfm = 0.654093942E+01 vinfx = 0.292071129E+01
blmp = 0.47728509E+04 btheta = 0.257483466E+01 bdt = 0.477246193E+04
c3 = 0.427838885E+02 ra =-0.633289928E+02 dec = 0.585180749E+01
Outgoing Asymptote
altp = 0.482800000E+03 vinfm = 0.654093942E+01 vinfx = 0.501374565E+01
blmp = 0.47728509E+04 btheta =-0.215388652E-10 bdt = 0.47728509E+04
c3 = 0.427838885E+02 ra =-0.547790228E+02 dec = 0.639142809E+01
state relative primary body: sun
x =-0.144207268E+09 y = 0.198913706E+09 z = 0.770863743E+07
vx =-0.137088037E+02 vy =-0.184188742E+02 vz = 0.108184139E+01
vya = 0.240662237E+09 eccen = 0.297775446E+00 inc = 0.383356774E+01
meaan = 0.139186832E+03 anlong = 0.980212618E+02 mean =-0.771008284E+02

```

final conditions for phase 50

```

date = 1 18 2012 12.00 julian =2455945.00000000 tdurp = 40.00000000
primid = sun secid = mars
timrfl = 0.423000000E+03
state relative to idbody: mars
x = 0.178913628E+08 y =-0.149251718E+08 z = 0.242582832E+07
vx = 0.555762988E+01 vy =-0.464809298E+01 vz = 0.645548932E+00
vya =-0.809530476E+03 eccen = 0.431968600E+03 inc = 0.947842140E+02
meaan = 0.165755640E+07 truan = 0.892773168E+02 tfp = 0.372663101E+02
Incoming Asymptote
altp = 0.345485016E+06 vinfm = 0.727358887E+01 vinfx = 0.555690279E+01
blmp = 0.349690810E+06 btheta =-0.948052429E+02 bdt =-0.292932592E+05
c3 = 0.529050951E+02 ra =-0.398849297E+02 dec = 0.535599592E+01
Outgoing Asymptote
altp = 0.345485016E+06 vinfm = 0.727358887E+01 vinfx = 0.555743786E+01
blmp = 0.349690810E+06 btheta =-0.948032116E+02 bdt =-0.292809055E+05
c3 = 0.529050951E+02 ra =-0.399099546E+02 dec = 0.509165016E+01
state relative primary body: sun
x =-0.182292745E+09 y = 0.132317242E+09 z = 0.104263493E+08
vx =-0.788523682E+01 vy =-0.221008314E+02 vz = 0.609935752E+00
vya = 0.211970237E+09 eccen = 0.286340551E+00 inc = 0.352537246E+01
meaan = 0.167354273E+03 anlong = 0.953193762E+02 mean =-0.868798376E+02

```

initial conditions for phase 60

```

date = 1 18 2012 12.00 julian =2455945.00000000 tdurp = earth
primid = sun secid = earth
timrfl = 0.423000000E+03
state relative to idbody: earth
x =-0.114061345E+09 y = 0.190575515E+07 z = 0.104298645E+08
radius = 0.114553064E+09
scmass = 0.103819271E+06
propid = 1step epoch = mean2000
critr = tdurp frame = ecliptic

```



vx = 0.190043391E+02 vY = -0.818599076E+01 vz = 0.610586295E+00 fpa = -0.666317000E+02  
sma = -0.930133391E+03 eccen = 0.488496640E+05 inc = 0.174136625E+02 atgp = 0.843450076E+02 anlong = 0.162094779E+03  
meaan = -0.647756922E+07 truan = -0.666327767E+02 tfp = -0.587928657E+02 rperi = 0.454357735E+08 vperi = 0.207016606E+02  
Incoming Asymptote

```

altp = 0.454293953E+08   vinfm = 0.207012368E+02   vinfx = 0.190041714E+02   vinfz = -0.818595464E+01
bmag = 0.454367036E+08   btheta = -0.173339706E+02   bdt = 0.433731647E+08   bdr = -0.135374523E+08
c3 = 0.428541206E+03     ra = -0.233037267E+02   dec = 0.169020826E+01   altit = 0.114546686E+09
Outgoing Asymptote
altp = 0.454293953E+08   vinfm = 0.207012368E+02   vinfx = 0.190044988E+02   vinfz = -0.818521453E+01
bmag = 0.454367036E+08   btheta = -0.17340367E+02   bdt = 0.433731491E+08   bdr = -0.135375023E+08
c3 = 0.428541206E+03     ra = -0.233018445E+02   dec = 0.168950934E+01   altit = 0.114546686E+09
state relative primary body: sun
x = -0.182292745E+09   y = 0.132317242E+09   z = 0.104263493E+08
vx = -0.78852368E+01   vy = -0.221008314E+02   vz = 0.609935752E+00
vyma = 0.211970237E+09   eccen = 0.286340551E+00   inc = 0.352537246E+01
argp = 0.167354273E+03   anlong = 0.953199762E+02   meanan = -0.868798376E+02

```

final conditions for phase 60

```

date = 6 26 2012 12.00   julian =2456105.00000000   tdurp = 160.00000000   critr = timrf1
primid = sun             secid = earth
timrf1 = 0.583000000E+03
state relative to idbody: earth
x = 0.302481089E+04   y = -0.586397149E+04   z = -0.194506645E+04
vx = 0.935566338E+01   vy = 0.608449291E+01   vz = -0.379163000E+01
sma = -0.173042955E+05   eccen = 0.139752415E+01   inc = 0.253602065E+02
mean = -0.102203474E-02   truan = -0.631396077E-02   tfp = -0.744374105E-06
Incoming Asymptote
altp = 0.500735324E+03   vinfm = 0.479945529E+01   vinfx = 0.417156720E+01   vinfz = -0.119651454E+01
bmag = 0.168934043E+05   btheta = -0.206774582E+01   bdt = 0.168924044E+05   bdr = -0.609533276E+03
c3 = 0.230347710E+02   ra = -0.160042755E+02   dec = -0.252813304E+02   altit = 0.500735349E+03
Outgoing Asymptote
altp = 0.500735324E+03   vinfm = 0.479945529E+01   vinfx = 0.115071279E+01   vinfz = 0.465823139E+01
bmag = 0.168934043E+05   btheta = 0.253299735E+02   bdt = 0.152692531E+05   bdr = 0.722751805E+04
c3 = 0.230347710E+02   ra = 0.481547288E+02   dec = -0.1128095029E+01   altit = 0.500735349E+03
state relative primary body: sun
x = 0.135426994E+08   y = -0.151476745E+09   z = 0.294353651E+04
vx = 0.385420732E+02   vy = 0.863663485E+01   vz = -0.379222870E+01
sma = 0.776899225E+09   eccen = 0.807965674E+00   inc = 0.553136848E+01
argp = 0.196756036E+03   anlong = 0.951203674E+02   meanan = -0.106296698E+01

```

Initial conditions for phase 65

```

subproblem iteration 31 final   icnvgd = 1
subp. ind. vars. 5.01374565E+00-4.13715562E+00 7.28139046E-01 9
subp. dep. vars. 6.87887532E+03-7.44374105E-07 1.68824044E+04 9
                  -8.75324266E-01 7.44374105E-07-4.38249842E-03

```

initial conditions for phase 65

```

final conditions for phase 65
date = 6 26 2012 12.00   julian =2456105.00000000   tdurp = 0.00000000   critr = tdurp
primid = sun             secid = earth
timrf1 = 0.583000000E+03
state relative to idbody: earth
propid = 1step
epoch = mean2000

```

```

x = 0.302481089E+04
vx = 0.935566338E+01
sma = -0.173042955E+05
meaan = -0.102203474E-02
Incoming Asymptote
  altp = 0.500735324E+03
  bmag = 0.168934043E+05
  c3 = 0.230347710E+02
Outgoing Asymptote
  altp = 0.500735324E+03
  bmag = 0.168934043E+05
  c3 = 0.230347710E+02
y = -0.586397149E+04
vy = 0.608449291E+01
eccen = 0.139752415E+01
truan = -0.631396077E-02
vinfm = 0.479945529E+01
btheta = -0.206774582E+01
ra = -0.160042755E+02
vinfm = 0.479945529E+01
btheta = 0.253299735E+02
ra = 0.481547288E+02
z = -0.586397149E+04
vz = 0.608449291E+01
inc = 0.139752415E+01
tfp = -0.631396077E-02
vinfx = 0.479945529E+01
bdx = -0.206774582E+01
dec = -0.160042755E+02
vinfx = 0.479945529E+01
bdx = 0.253299735E+02
dec = 0.481547288E+02
radius = 0.687887535E+04
speed = 0.117866853E+02
argp = 0.221319779E+03
rperi = 0.687887532E+04
vinfy = -0.119651454E+01
bdr = -0.609533276E+03
altit = 0.500735349E+03
vinfy = 0.465823139E+01
bdr = 0.722751805E+04
altit = 0.500735349E+03
scmass = 0.103819271E+06
fpa = -0.368042702E-02
anlong = 0.788281155E+02
vperi = 0.117866853E+02
vinfz = -0.204967097E+01
hypta = 0.443116145E+02
vinfz = -0.107291524E+00
hypta = 0.000000000E+00

```

state relative primary body: sun  
 x = 0.135426994E+08 y = -0.151476745E+09 z = 0.294353651E+04  
 vx = 0.385420732E+02 vy = 0.863663485E+01 vz = -0.379222870E+01  
 sma = 0.776899252E+09 eccen = 0.807965674E+00 inc = 0.553136848E+01  
 argp = 0.196756036E+03 anlong = 0.951203674E+02 meanan = -0.106296698E+01

initial conditions for phase 70 before orbits maneuver

date = 6 26 2012 12.00 julian = 2456105.00000000 tdurp = 0.00000000  
 primid = sun secid = earth idbody = earth  
 state relative to idbody: earth  
 x = 0.302481089E+04 y = -0.586397149E+04 z = -0.194506645E+04  
 vx = 0.935566338E+01 vy = 0.608449291E+01 vz = -0.379163000E+01  
 sma = -0.173042955E+05 eccen = 0.139752415E+01 inc = 0.253602065E+02  
 meanan = -0.102203474E-02 truan = -0.631396077E-02 tfp = -0.744374105E-06

orbins maneuver print block

dvx = -0.145887869E-01 dvz = -0.302675298E-02 dtburn = 0.761357577E+03  
 thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.277942906E+05

initial conditions for phase 70 after orbits maneuver

final conditions for phase 70  
 date = 6 26 2012 12.00 julian = 2456105.00000000 tdurp = 0.00000000  
 primid = sun secid = earth idbody = earth  
 timrfl = 0.583000000E+03  
 state relative to idbody: earth  
 x = 0.302502760E+04 y = -0.586283403E+04 z = -0.194506277E+04  
 vx = 0.919185986E+01 vy = 0.532814871E+01 vz = -0.331991825E+01  
 sma = 0.424570000E+05 eccen = 0.83800801E+00 inc = 0.253602065E+02  
 meanan = 0.613834713E-11 truan = 0.206760636E-10 tfp = 0.171818575E-13  
 altp = 0.499860000E+03 alta = 0.716578600E+05 rapoap = 0.780360000E+05  
 lat = 0.000000000E+00 long = 0.000000000E+00 longp = 0.286478898E+03

state relative primary body: sun  
 x = 0.135426997E+08 y = -0.151476744E+09 z = 0.294354020E+04  
 vx = 0.373782697E+02 vy = 0.788029065E+01 vz = -0.332051695E+01  
 sma = 0.482542864E+09 eccen = 0.690201821E+00 inc = 0.50027705E+01  
 argp = 0.196592887E+03 anlong = 0.951215847E+02 meanan = -0.222790525E+01

initial conditions for phase 75

esn = 75.000 fesn = 75.000  
 time = 2.45610500D+06  
 normal termination  
 cpu = 55.380 seconds

total cpu time = 55.390 seconds

critr = tdurp propid = lstep  
 frame = ecliptic epoch = mean2000  
 radius = 0.687887535E+04 scmass = 0.103819271E+06  
 speed = 0.117866853E+02 fpa = -0.368042702E-02  
 argp = 0.221319779E+03 anlong = 0.788281155E+02  
 rperi = 0.687800000E+04 vperi = 0.117866853E+02  
 dtmag = 0.146671222E+01 tburn = 0.761357577E+03  
 wprop = 0.760249809E+05

### **3.3 LUNAR ORBITER**

This case examines flight from a low Earth orbit (LEO) into a low lunar orbit. It has a master-subproblem formulation, and minimizes total  $\Delta V$ .

The simulation starts with a specified Cartesian state vector at Earth (which corresponds to circular orbit of 6878 km radius). An impulsive maneuver is identified. The conic propagator is activated with Earth as the primary body. At a mission time specified as an optimization control, an impulsive midcourse correction is applied, at which time the primary and reference bodies are switched to the Moon. 3 days after Earth orbit escape, the S/C arrives at lunar closest approach and inserts into lunar orbit.

The optimization defines NPSOL as the optimization algorithm using finite difference perturbations computed internally by NPSOL. 50 iterations are allowed for the master problem and 200 iterations each for the 2 subproblems. The master control parameters are the Earth escape delta V components and the mission times of the midcourse maneuver and lunar closest approach.

The first subproblem varies midcourse  $\Delta V$  to achieve desired hyperbolic conditions (closest approach distance, inclination, time from periapsis) at lunar arrival. The second subproblem varies lunar insertion  $\Delta V$ , applied at hyperbolic periapsis, to achieve desired lunar orbit conditions (periapsis and apoapsis radii, and inclination).

The output echoes the namelist \$TOP and all \$TRAJ namelists. A summary of the problem is given, and execution output begins with a summary of each iteration of each subproblem for master iteration 0. Following the first converged iteration (13) of subproblem 2 is the summary of master iteration 0. The sequence repeats for all master iterations. Only master iterations 0, 1, 2, and the final iteration (13) are shown. After the iteration summary is displayed, the final trajectory simulation is output.

The total  $\Delta V$  was 3.968 km/s, reduced from 4.058 km/s for the initial guess. Note that the iteration summaries display the weighted objective function value. The midcourse maneuver time has been moved from 2.39 days to 1.50 days, the lower control bound. Lunar closest approach time has been moved from 3.00 days to 3.5 days, the upper control bound.

```

c
c civil space test case for lunar missions
c during the period of march 1995
c using patched conic initial conditions
c from lprep
c
  srchm = 'npsol',
  iprint = 0,
  fesn = 75,
  mxitar = 50,
  mxitar = 200,
  iephem = 1,
  istm = 'autopert',
  npad(1) = 0,
c
c master problem controls
c vary initial velocity at loi from leo
c
  indvr = 'dvx','dvy','dvz','critr','critr',
  indph = 1,1,1,15,30,
  indxi = 1,2,3,4,5,
  u = 2.475224, 1.293166, 1.320728, 2.39376, 3.0,
  wvu = 30., 20., 20., 24.9, 35.,
  indplb = 1., .5, .5, 1.50, 2.5,
  indpub = 3., 2., 2., 2.49, 3.5,
  pert = 5*.0001,
c
c minimize the delta-v at the soi
c
  optvar = 'dvsum',
  opt = -1,
  optph = 75,
  wopt = 10.,
  etanl = .5,
c
c subproblem setup
c
  modelt = 'nraph','nraph',
  spfesn = 30, 35,
  tolf = 1.0d0,
  tolu = 1.0d0,
  npi = 5,
c
c controls
c
  indxsl = 1,1,1, 2,2,2,
  indsvr = 'dvx','dvy','dvz','dvx','dvy','dvz',
  indspk = 3*15, 3*32,
  c usub = .029158, -.007079, -.007728, .442687, -.790124, -.090804,
  usub = 6*-2.,
  indslb = 6*2.,
  indsub = 6*1.d-5,
  pertsb = 6*2.,
  wvus = 6*2.,
c
c targets

```

```

c
indxsd = 1,1,1, 2,2,2,
depsvr = 'rperi', 'inc', 'tftp', 'rperi', 'rapoap', 'inc'
depsph = 3*30, 3*35,
depsv1 = 1838., 16., -0.00001, 1838., 1838., 16.,
deps1b = 1838., 16., -0.00001, 1838., 1838., 16.,
depsub = 1838., 16., -0.00001, 1838., 1838., 16.,
depsti = .01, .01, .00001, .01, .01, .01,
wvsnic = 1838., 16., -0.00001, 1838., 1838., 16.,

$
p$traj
c earth escape...use launch maneuver

event = 1,
juldat = 2450004.3,
idbody = 3,
idfram = 'eartheq', 'mean2000',
lepoch = 'julian',
inputx = 'cartes',
x = 3709.62, -5603.24, -1466.03, 6.099613, 3.186706, 3.254626,
mantyp = 'impuls',
icoord = 2,
iprop = 'conic',
dt = .1,
ipbody = 3, 10,
tol = 1.d-7,

$
p$traj
event = 15,
critr = 'timrfl',
mantyp = 'impuls',
icoord = 2,

$
p$traj
event = 20,
critr = 'tdurp',
value = 0.d0,
idbody = 10,
ipbody = 10, 3,
idfram = 'bodyeq', 'mean2000',

$
p$traj
event = 30,
critr = 'timrfl',
value = 3.0,

$
p$traj
c final impulse to circularize
event = 32,
critr = 'tdurp',
icoord = 3,
value = 0.d0,

```

```
mantyp = 'impuls',
```

```
$
```

```
p$traj
```

```
event = 35,
```

```
critr = 'tdurp',
```

```
value = 0.,
```

```
$
```

```
p$traj
```

```
c i hope we are done
```

```
event = 75,
```

```
critr = 'tdurp',
```

```
value = 0.d0,
```

```
namlst = 'none',
```

```
$
```

```
*** core requirements for problem 1 are ***
```

parameter	octal	decimal
event criteria data	- 456b	302
general data	- 152b	106
table data	- 20b	16



execution date and time Thu Oct 29

\*\*\* ipost input summary \*\*\*\*

\*\*\* trajectory inputs \*\*\*

initial epoch  
 julian date ...2450004.3000  
 calendar date ...1995 oct 13, 19 hr 11 min 60.0000 secs  
 initial body and frame of reference 3 , earth , eartheq , mean2000  
 initial state  
 cartesian 3.70962000000D+03 -5.60324000000D+03 -1.46603000000D+03  
 6.09961300000D+00 3.18670600000D+00 3.25462600000D+00  
 conic 6.87799118809D+03 6.73340314442D-07 4.98051222686D-01  
 5.71001203235D+00 0.00000000000D+00 -4.62494638841D-01  
 initial state, heliocentric, elliptic  
 1.40218765146D+08 5.11245319086D+07 2.02671364462D+03  
 -4.58141704386D+00 3.20902105104D+01 1.71936831591D+00

input units - metric, output units - metric

event summary number	trigger	value	type	propagator
1.000	time	1.00000000000D+10	impuls	conic
15.000	timrf1	1.00000000000D+10	impuls	conic
20.000	tdurp	0.00000000000D+00	none	conic
30.000	timrf1	3.00000000000D+00	none	conic
32.000	tdurp	0.00000000000D+00	impuls	conic
35.000	tdurp	0.00000000000D+00	none	conic
75.000	tdurp	0.00000000000D+00	none	conic

\*\*\*targeting/optimization inputs\*\*\*

75

master problem optimization parameter dvsum at event  
 master problem optimization algorithm - npsol

master prob. control/indep parameters

evtnum	name	value
1.000	dvx	
1.000	dvy	
1.000	dvz	
15.000	critr	
30.000	critr	

master problem target/dep parameters

evtnum	name	value
1	total number of subproblems is	2
1	subproblem number	
15	subproblem controls at event	dvx 15 dvz 15
30	subproblem targets at events	rperi inc 30 tfp 30
0.18380E+04	subproblem values with tolerance	0.16000E+02 -0.10000E-04
0.10000E-01	subproblem controls with tolerance	0.10000E-01 0.10000E-04
2	subproblem number	
32	subproblem controls at event	dvx 32 dvz 32
35	subproblem targets at events	rperi rapoap inc 35
0.18380E+04	subproblem values with tolerance	0.18380E+04 0.16000E+02
0.10000E-01	subproblem controls with tolerance	0.10000E-01 0.10000E-01

OPTIONS file  
-----

BEGIN OPTIONS FOR NPSOL 4.0

VERIFY LEVEL 0  
DERIV LEVEL 0  
DIFFERENCE INTERVAL 1.E-4  
MAJOR ITERATIONS LIMIT 30  
MAJOR PRINT LEVEL 10  
NONLINEAR FEASIBILITY TOLERANCE 3.E-7  
OPTIMALITY TOLERANCE 1.E-6  
HESSIAN NO  
COLD START  
END

Calls to NPOPTN  
-----

major iteration limit = 50

NPSOL --- Version 4.05 Nov 1989  
=====

Parameters  
-----

Linear constraints.....	0	Linear feasibility.....	5.96E-08
Variables.....	5	Infinite bound size....	1.00E+20
Step limit.....	2.00E+00	Infinite step size.....	1.00E+20
Nonlinear constraints..	0	Optimality tolerance...	1.00E-06
Nonlinear Jacobian vars	5	Nonlinear feasibility..	3.00E-07
Nonlinear objectiv vars	5	Linesearch tolerance...	9.00E-01
EPS (machine precision)	3.55E-15	Derivative level.....	0
Major iterations limit.	50	Major print level.....	10
Minor iterations limit.	50	Minor print level.....	0
RUN loaded from file...	0	RUN to be saved on file	0
Difference interval....	1.00E-04	Central diffece interval	5.11E-05
Workspace provided is	IW( 2500), W( 770500).		
To solve problem we need	IW( 15), W( 100).		

The user sets 0 out of 5 objective gradient elements.  
Each iteration, 5 gradient elements will be estimated numerically.

ItN ItOP Step Nfun Objective Bnd Lin Nz Norm Gf Norm Gz Cond H Cond Hz Cond T Conv  
 0 5 0.0E+00 1 4.057780E-01 5 0 0 0.0E+00 0.0E+00 1.E+00 1.E+00 0.E+00 F TF

tts - divergence in function calculations iteration = 6  
 fcn errors 1.22121864D+01 1.21802457D+01 1.03229038D+01 9.72506383D+00  
 fcn errors 9.26737379D+00 7.62112485D+00

\*\*error\*\* tts control diverg in newton raphson\*

Iteration	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.8E-03	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01	4.051820E-01
0.0E+00	1.1E+01	6.3E+01	1.8E+01	5.4E+00	1.1E+01	3.6E+00	2.2E+01	8.2E+00	3.8E+00	3.8E+00	3.8E+00	3.8E+00	3.8E+00	3.8E+00	3.8E+00
2.1E-03	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01	4.043624E-01
1.4E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01	4.000760E-01
4.3E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01	3.998416E-01
1.6E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01	3.996555E-01
1.0E+00	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01	3.975420E-01
1.0E+00	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01	3.970350E-01
1.0E+00	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01	3.968211E-01
1.0E+00	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01	3.968006E-01
1.0E+00	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01
7.2E-03	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01	3.967914E-01
1.2E+02	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01	3.967908E-01

Exit NP phase. INFORM = 6 MAJITS = 16 NFUN = 50 NGRAD = 15

Variable	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
VARBL 1	FR	0.8216976E-01	0.333333E-01	0.1000000	0.000000E+00	0.1783E-01
VARBL 2	FR	0.6660273E-01	0.250000E-01	0.1000000	0.000000E+00	0.3340E-01
VARBL 3	FR	0.6100295E-01	0.250000E-01	0.1000000	0.000000E+00	0.3600E-01
VARBL 4	LL	0.6024096E-01	0.6024096E-01	0.1000000E+00	0.1593707	0.0000E+00
VARBL 5	UL	0.1000000	0.7142857E-01	0.1000000	-0.1686883	0.0000E+00

Exit NPSOL - Current point cannot be improved upon.

Final nonlinear objective value = 0.3967908

Initial conditions for phase 1 before impuls maneuver

date	-10 13 1995 19.20	julian	=2450004.30000000	tdurp	= 0.00000000	critr	= time
primid	= earth	secid	= moon	tbody	= earth	frame	= eartheq
state	relative to	tbody	earth	radius	= 0.00000000E+00	scmass	= 0.1000000000E+07
x	= 0.37096200E+04	y	= -0.56032400E+04	z	= -0.14660300E+04	speed	= 0.00000000E+00
vx	= 0.60996130E+01	vy	= 0.31867060E+01	vz	= 0.32546260E+01	argp	= 0.00000000E+00
sma	= 0.68779911E+04	eccen	= 0.67334031E-06	inc	= 0.28536230E+02	rperi	= 0.00000000E+00
measn	= -0.26498990E+02	truan	= 0.00000000E+00	tfp	= 0.00000000E+00	anlong	= 0.327159590E+03
impuls	maneuver print block	dvx	= 0.13320545E+01	dvz	= 0.12200589E+01	dvmag	= 0.305607534E+04
thrust	= 0.10000000E+07	spi	= 0.10000000E+07	chmass	= 0.31158440E+03	wprop	= 0.999688416E+06
date	-10 13 1995 19.20	julian	=2450004.30000000	tdurp	= 0.00000000	critr	= time
propid	= conic	epoch	= mean2000	tburn	= 0.305607534E+04	propid	= conic

```

primid = earth
timrfl = 0.00000000E+00
state relative to idbody: earth
  x = 0.370962000E+04 y = -0.560324000E+04 z = -0.146603000E+04
  vx = 0.856470593E+01 vy = 0.451876056E+01 vz = 0.447468499E+01
  sma = 0.188927030E+06 eccen = 0.963594514E+00 inc = 0.280496717E+02
  meanan = -0.851281492E-03 truan = -0.171730805E+00 tfp = -0.223670677E-04
  altp = 0.49840405E+03 alta = 0.364597940E+06 rapoap = 0.370976080E+06
  lat = 0.00000000E+00 long = 0.229183118E+03 longp = 0.630253575E+03
state relative to secondary body: moon
  x = -0.759006979E+05 y = -0.379305777E+06 z = -0.131479114E+06
  vx = 0.951205607E+01 vy = 0.430833861E+01 vz = 0.444468661E+01
  sma = -0.380733699E+02 eccen = 0.829760956E+04 inc = 0.237655305E+02
  argp = 0.346372413E+03 anlong = 0.309208910E+03 meanan = -0.389913692E+06

```

final conditions for phase 1

```

date =10 15 1995 7.20 julian =2450005.80000000 tdurp = 1.50000000
primid = earth
timrfl = 0.150000000E+01
state relative to idbody: earth
  x = -0.940651529E+05 y = 0.218931354E+06 z = 0.717762941E+05
  vx = -0.641943429E+00 vy = 0.805702796E+00 vz = 0.179884081E+00
  sma = 0.188927030E+06 eccen = 0.963594514E+00 inc = 0.280496717E+02
  meanan = 0.570885381E+02 truan = 0.168950122E+03 tfp = 0.149997763E+01
  altp = 0.49840405E+03 alta = 0.364597940E+06 rapoap = 0.370976080E+06
  lat = 0.00000000E+00 long = 0.401070457E+03 longp = 0.630253575E+03
state relative to secondary body: moon
  x = -0.490857658E+05 y = -0.162488384E+06 z = -0.554224461E+05
  vx = 0.317050107E+00 vy = 0.89772776E+00 vz = 0.252849089E+00
  sma = -0.535511541E+04 eccen = 0.26422074E+01 inc = 0.535655879E+02
  argp = 0.310765779E+03 anlong = 0.592438130E+02 meanan = -0.177537257E+04

```

initial conditions for phase 15 before impuls maneuver

```

date =10 15 1995 7.20 julian =2450005.80000000 tdurp = 1.50000000
primid = earth
timrfl = 0.150000000E+01
state relative to idbody: earth
  x = -0.940651529E+05 y = 0.218931354E+06 z = 0.717762941E+05
  vx = -0.641943429E+00 vy = 0.805702796E+00 vz = 0.179884081E+00
  sma = 0.188927030E+06 eccen = 0.963594514E+00 inc = 0.280496717E+02
  meanan = 0.570885381E+02 truan = 0.168950122E+03 tfp = 0.149997763E+01
impuls maneuver print block
dvx = -0.274819515E-01 dvz = -0.214944086E-01 dvz = 0.382630952E-01
thrust = 0.100000000E+07 spi = 0.100000000E+07 dmass = 0.527859218E+01

```

initial conditions for phase 15 after impuls maneuver

```

final conditions for phase 15
date =10 15 1995 7.20 julian =2450005.80000000 tdurp = 1.50000000
primid = earth
timrfl = 0.150000000E+01
state relative to idbody: earth
  x = -0.940651529E+05 y = 0.218931354E+06 z = 0.717762941E+05
  vx = -0.641943429E+00 vy = 0.805702796E+00 vz = 0.179884081E+00
  sma = 0.188927030E+06 eccen = 0.963594514E+00 inc = 0.280496717E+02
  meanan = 0.570885381E+02 truan = 0.168950122E+03 tfp = 0.149997763E+01

```

vx --0.669425381E+00 vy = 0.784208387E+00 vz = 0.218147177E+00 speed = 0.105389816E+01 fpa = 0.726323088E+02

```

sma = 0.190470310E+06 eccn = 0.958785506E+00 inc = 0.215995786E+02 argp = 0.320308678E+03 anlong = 0.342787237E+01
meaan = 0.565958086E+02 truan = 0.168108968E+03 tfp = 0.150528909E+01 rperi = 0.785013748E+04 vperi = 0.997295182E+01
altp = 0.147199748E+04 alta = 0.366712342E+06 rapoap = 0.373090482E+06 altit = 0.242481313E+06 period = 0.827278788E+06
lat = 0.00000000E+00 long = 0.401070457E+03 longp = 0.630253575E+03
state relative to secondary body: moon
x = -0.490857638E+05 y = -0.162488384E+06 z = 0.554224461E+05
vx = 0.289568155E+00 vy = 0.876278367E+00 vz = 0.291112184E+00
vma = -0.556159178E+04 eccn = 0.133048215E+01 inc = 0.282013955E+02
sma = 0.358243518E+03 anlong = 0.356805098E+02 meaan = -0.167144329E+04
argp = 0.358243518E+03 anlong = 0.356805098E+02

```

initial conditions for phase 20

```

date =10 15 1995 7.20 julian =2450005.80000000 tdurp = 0.00000000 critr = tdurp propid = conic
primid = moon secid = earth idbody = moon frame = bodyeq epoch = mean2000
timrf1 = 0.150000000E+01
state relative to idbody: moon
x = 0.120175771E+06 y = 0.131335948E+06 z = 0.138631727E+05
vx = -0.668965723E+00 vy = -0.694433710E+00 vz = -0.818931114E-01
vma = -0.556159178E+04 eccn = 0.133048215E+01 inc = 0.160000013E+02 argp = 0.300827185E+03 anlong = 0.243298919E+03
meaan = -0.167144329E+04 truan = -0.137187113E+03 tfp = -0.200000999E+01 rperi = 0.183800683E+04 vperi = 0.249328026E+01
Incoming Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx = -0.649310548E+00 vinfy = -0.673507087E+00 vinfz = -0.799543808E-01
bmag = 0.488085612E+04 btheta = 0.152622669E+02 bdt = 0.470871314E+04 bdr = 0.128482567E+04 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra = -0.133952082E+03 dec = -0.486055149E+01 altit = 0.176821521E+06
Outgoing Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx = 0.716465488E+00 vinfy = -0.550859624E+00 vinfz = 0.254510832E+00
bmag = 0.488085612E+04 btheta = 0.297539208E+01 bdt = 0.487427692E+04 bdr = 0.253339542E+03 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra = -0.139689519E+03 dec = 0.157280446E+02 altit = 0.176821521E+06
state relative to secondary body: earth
x = -0.179790760E+05 y = -0.247230328E+06 z = -0.213371395E+05
vx = 0.240181669E+00 vy = -0.102001655E+01 vz = -0.112162056E+00
vma = 0.190470310E+06 eccn = 0.958785506E+00 inc = 0.682936048E+01
argp = 0.580306402E+02 anlong = 0.399099132E+02 meaan = 0.565958086E+02

```

final conditions for phase 20

```

date =10 17 1995 7.20 julian =2450007.80000000 tdurp = 2.00000000 critr = timrf1 propid = conic
primid = moon secid = earth idbody = moon frame = bodyeq epoch = mean2000
timrf1 = 0.350000000E+01
state relative to idbody: moon
x = -0.177874576E+04 y = -0.157497959E+03 z = 0.435350032E+03
vx = 0.133834579E+00 vy = -0.246469328E+01 vz = 0.351880260E+00
vma = -0.556159178E+04 eccn = 0.133048215E+01 inc = 0.160000013E+02 argp = 0.300827185E+03 anlong = 0.243298919E+01
meaan = -0.835248487E-02 truan = -0.671145151E-01 tfp = -0.999438825E-05 rperi = 0.183800683E+04 vperi = 0.249328026E+01
Incoming Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx = -0.649310548E+00 vinfy = -0.673472415E+00 vinfz = -0.799543808E-01
bmag = 0.488085612E+04 btheta = 0.152622667E+02 bdt = 0.470871315E+04 bdr = 0.128482565E+04 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra = -0.133955141E+03 dec = -0.486055217E+01 altit = 0.999175488E+02
Outgoing Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx = 0.716436071E+00 vinfy = -0.550897883E+00 vinfz = 0.254510830E+00
bmag = 0.488085612E+04 btheta = 0.29752992E+01 bdt = 0.487427692E+04 bdr = 0.253339604E+03 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra = -0.139689121E+03 dec = 0.157280445E+02 altit = 0.999175488E+02
state relative to secondary body: earth
x = 0.247748464E+05 y = -0.399028725E+06 z = -0.375184198E+05
vx = 0.110257493E+01 vy = -0.236826329E+01 vz = 0.360845359E+00
vma = -0.802132375E+05 eccn = 0.270586764E+01 inc = 0.3199556731E+02

```

argp = 0.265417195E+03 anlong = 0.282191705E+03 meaan = 0.224979356E+03  
initial conditions for phase 30  
initial conditions for phase 30

final conditions for phase 30

```

date =10 17 1995 7.20 julian =2450007.80000000 tdurp = 0.00000000 critr = tdurp propid = conic
primid = moon secid = earth idbody = moon frame = bodyeq epoch = mean2000
state relative to idbody: moon
x =-0.177874576E+04 y =-0.157497959E+03 z =-0.435350032E+03 radius = 0.183800755E+04 scmass = 0.999683137E+06
vx = 0.133834579E+00 vy =-0.246469328E+01 vz = 0.351880260E+00 speed = 0.249327985E+01 fpa =-0.383159621E-01
sma =-0.556159178E+04 eccen = 0.13304815E+01 inc = 0.160000013E+02 argp = 0.300827182E+03 anlong = 0.243295862E+03
meaan =-0.835248487E-02 truan =-0.671145151E+01 tfp =-0.999438825E-05 rperi = 0.183800683E+04 vperi = 0.249328026E+01
Incoming Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx =-0.649346509E+00 vinfz =-0.673472415E+00 vinfz =-0.795543919E-01
bmag = 0.488085612E+04 btheta = 0.152622667E+02 bdt =-0.470871315E+04 bdr = 0.128482565E+04 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra =-0.133955141E+03 dec =-0.486055217E+01 altit = 0.999175488E+02
Outgoing Asymptote
altp = 0.999168289E+02 vinfm = 0.938906217E+00 vinfx = 0.716436071E+00 vinfz =-0.550897883E+00 vinfz = 0.254510830E+00
bmag = 0.488085612E+04 btheta = 0.297525992E+01 bdt = 0.487427692E+04 bdr = 0.253339604E+03 hypta = 0.412702068E+02
c3 = 0.881544884E+00 ra =-0.139689121E+03 dec = 0.157280445E+02 altit = 0.999175488E+02
state relative to secondary body: earth
x = 0.247748464E+05 y =-0.399028725E+06 z =-0.375184198E+05
vx = 0.110257493E+01 vy =-0.236826329E+01 vz = 0.360845359E+00
sma =-0.802132375E+05 eccen = 0.270586764E+01 inc = 0.319956731E+02
argp = 0.265417195E+03 anlong = 0.282191705E+03 meaan = 0.224979356E+03

```

initial conditions for phase 32 before impuls maneuver

```

date =10 17 1995 7.20 julian =2450007.80000000 tdurp = 0.00000000 critr = tdurp propid = conic
primid = moon secid = earth idbody = moon frame = bodyeq epoch = mean2000
state relative to idbody: moon
x =-0.177874576E+04 y =-0.157497959E+03 z =-0.435350032E+03 radius = 0.183800755E+04 scmass = 0.999683137E+06
vx = 0.133834579E+00 vy =-0.246469328E+01 vz = 0.351880260E+00 speed = 0.249327985E+01 fpa =-0.383159621E-01
sma =-0.556159178E+04 eccen = 0.13304815E+01 inc = 0.160000013E+02 argp = 0.300827182E+03 anlong = 0.243295862E+03
meaan =-0.835248487E-02 truan =-0.671145151E-01 tfp =-0.999438825E-05 rperi = 0.183800683E+04 vperi = 0.249328026E+01
impuls maneuver print block
dvx =-0.472193816E-01 dvz = 0.850095765E+00 dtburn = 0.859778813E+03
thrust = 0.100000000E+07 spi = 0.100000000E+07 dmass = 0.876691951E+02 wprop = 0.999595468E+06

```

initial conditions for phase 32 after impuls maneuver

```

final conditions for phase 32
date =10 17 1995 7.20 julian =2450007.80000000 tdurp = 0.00000000 critr = tdurp propid = conic
primid = moon secid = earth idbody = moon frame = bodyeq epoch = mean2000
state relative to idbody: moon
x =-0.177874576E+04 y =-0.157497959E+03 z =-0.435350032E+03 radius = 0.183800755E+04 scmass = 0.999595468E+06
vx = 0.866151970E-01 vy =-0.161459752E+01 vz = 0.230242221E+00 speed = 0.163322957E+01 fpa =-0.125208332E-03
sma = 0.183800001E+04 eccen = 0.464584100E-05 inc = 0.160000000E+02 argp = 0.927014015E+02 anlong = 0.243295870E+03
meaan =-0.151941091E+03 truan =-0.151941342E+03 tfp =-0.345410362E-01 rperi = 0.183799147E+04 vperi = 0.163324385E+01
altp = 0.999014743E+02 alta = 0.999185524E+02 rapoap = 0.183800855E+04 altit = 0.999175488E+02 period = 0.707092718E+04
lat = 0.000000000E+00 long = 0.343774677E+03 longp = 0.286478898E+03
state relative to secondary body: earth
x = 0.247748464E+05 y =-0.399028725E+06 z =-0.375184198E+05
vx = 0.105535555E+01 dvz =-0.151816753E+01 vz = 0.239207320E+00

```



sma --0.267420743E+06 eccen = 0.161775606E+01 inc = 0.225267625E+02  
argp = 0.258611030E+03 anlong = 0.286629773E+03 meaan = 0.518711433E+02

execution date and time Thu Oct 29

initial conditions for phase 35

initial conditions for phase 35

final conditions for phase 35

```

date -10 17 1995 7.20 julian =2450007.80000000 tdurp = 0.00000000 critr = tdurp      propid = conic
primid = moon          timrfl = 0.350000000E+01          idbody = moon          epoch = mean2000
state relative to idbody: moon
x      = -0.177874576E+04 y      = -0.157497959E+03 z      = 0.435350032E+03 radius = 0.183800755E+04 scmass = 0.999595468E+06
vx     = 0.866151970E-01 vy     = -0.161459752E+01 vz     = 0.230242221E+00 speed  = 0.163322957E+01 fpa    = -0.125208332E-03
vma   = 0.18380001E+04 eccen  = 0.464584100E-05 inc    = 0.160000000E+02 argp   = 0.927014015E+02 anlong = 0.243295870E+03
meaan = -0.151941091E+03 truan = -0.151941342E+03 tfp    = -0.345410362E-01 rperi  = 0.183799147E+04 vperi  = 0.163324385E+01
altp  = 0.999014743E+02 alta  = 0.999185524E+02 rapoap = 0.183800855E+04 altit  = 0.999175488E+02 period = 0.707092718E+04
lat   = 0.00000000E+00 long   = 0.343774677E+03 longp  = 0.286478898E+03
state relative to secondary body: earth
x      = 0.247748464E+05 y      = -0.399028725E+06 z      = -0.375184198E+05 radius = 0.183800755E+04
vx     = 0.105535555E+01 vy     = -0.151816753E+01 vz     = 0.239207320E+00 speed  = 0.163322957E+01 fpa    = -0.125208332E-03
vma   = -0.267420743E+06 eccen  = 0.161775606E+01 inc    = 0.225267625E+02 argp   = 0.927014015E+02 anlong = 0.243295870E+03

```

initial conditions for phase 75

```

esn = 75.000 fesn= 75.000
time= 2.45000780D+06
normal termination
cpu = 75.370 seconds

```

\*\*\* n p s o l s u m m a r y o u t p u t \*\*\*

		variables		constraints		objective function	
name	phase	value	residual	name	phase	name	value
1 dvx	1.0	0.24650929E+01	0.00000000E+00	dvsum	75.0	dvsum	0.396790824E+01
2 dvz	1.0	0.13320546E+01	0.00000000E+00				
3 dvz	1.0	0.12200590E+01	0.00000000E+00				
4 critr	15.0	0.15000000E+01	0.00000000E+00				
5 critr	30.0	0.35000000E+01	0.00000000E+00				

total number of iterations = 16  
 total number of reloaded fn evals = 17  
 total number of function evaluations = 198  
 total cpu time = 16164.980 seconds

### **3.4 EARTH TO JUPITER (COLLOCATION)**

The following sample case is a portion of the Voyager mission, Earth to Jupiter phase, to illustrate collocation. Of particular interest is the difference between explicit optimization such as the test case described in Section 3.1, and implicit optimization, or collocation.

The mission starts (event 10) with a S/C mass of 2213689 kg and an input state corresponding to a post park orbit escape burn. Ideally, the initial state should produce a trajectory which leaves Earth and flies by Jupiter with the desired encounter conditions. This would be true for an accurate explicit propagator. With collocation, trajectories are defined as segments between events, and by Hermite cubic polynomials between segment end points, or nodes. In this case, the number of segments per phase is set to 1 for all phases. This represents a rather poor trajectory approximation, unless the events are placed very close together. More will be said about this later. An impulsive  $\Delta V$  maneuver is placed at this first event (ideally the  $\Delta V$  should be zero), and at every event except the final event.

The next event (#11) occurs 14 minutes later (.01 days), where another impulsive  $\Delta V$  is performed (again, ideally equal to zero).

There are 6 more events in the case (#12, 13, 17, 18, 19, 20) which are planned at mission times of 0.21 days, 2.21, 666.1, 684.1, 685.6, and 686.1 days. The last event (#20) ideally corresponds to Jupiter closest approach.

The placing of event times is an attempt to normalize accelerations within each phase. If there is a large difference in accelerations, or trajectory curvature, within a segment (= phase for this case), then the Hermite polynomials are very poor representations of a real trajectory. Inaccurate Hermites will cause divergence in the optimization process.

In this case, the optimization specifies "colloc" with "autoperts". The MXITOP array indicates that Jacobian rescaling occurs immediately after it is initially calculated by finite differencing. A maximum of 150 iterations is allowed after rescaling.

The mission control variables are the  $\Delta V$  components of the impulsive maneuver at each of the first seven events. Other input control variables for the collocation formulation are specified by the U(22) array elements. These correspond to the Cartesian state vectors at each event from #11 through #20, a total of 7 (components per state) x 7 (events) = 49 elements. These state vectors were obtained from a previous explicit optimization run. In practice, the state vectors could have been obtained by a "WAG" simulation run since collocation can be robust.

The constraints are TFP, B dot T and B dot R at Jupiter closest approach (event 20). Note that lower and upper bounds for the constraints may contain more than 3 elements each. This is not a problem because the collocation process overrides all non-mission constraints, that is, specifies upper and lower bounds for constraints introduced by the collocation process. The collocation process also computes weightings for the non-mission constraints.

The test case output first echoes namelist inputs. Then a summary of NPSOL parameters is displayed. The problem begins with computation of the Jacobian. IPOST will only allow non-zero elements of the Jacobian to be numerically computed. The explicit zeroing out of null elements saves a considerable amount of CP time because a collocation Jacobian will be a sparse matrix. In this case, there are a total of 126 controls and 108 constraints. Of the 13608 Jacobian elements, about 9600 are theoretically non-zero.

The first (before rescaling) iteration (0) summary follows. Of critical interest is the Jacobian condition value (COND T). A value of 3.E7 before rescaling and 3000 after rescaling indicates a poorly conditioned Jacobian. The independent (control) and dependent (constraint) parameter values are displayed after each iteration summary.

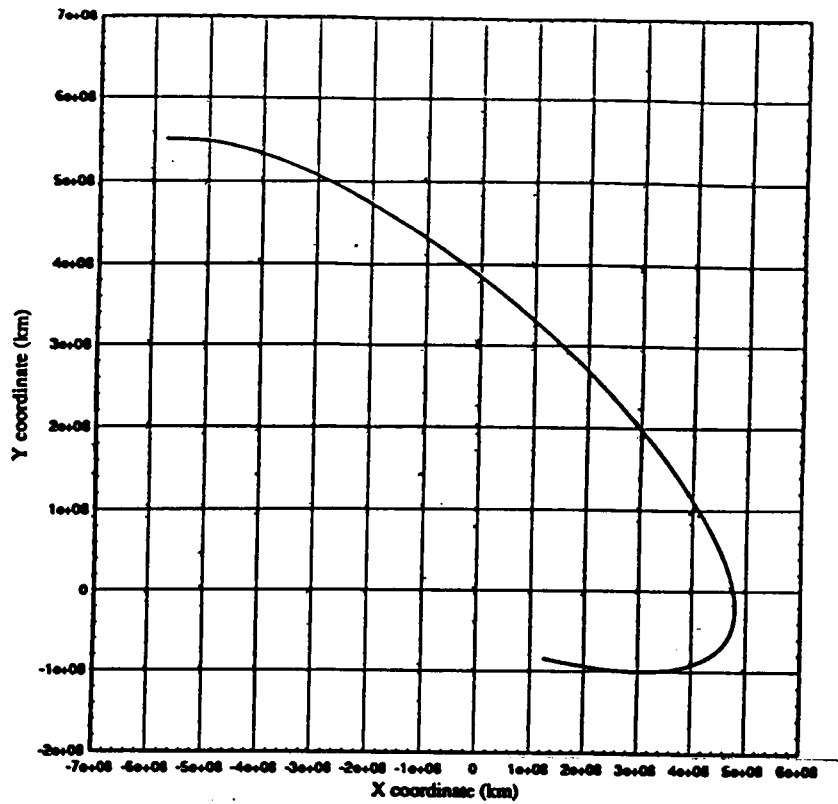
The next iteration takes place and the resultant independent and dependent parameter values are displayed after the iteration 1 summary. Noteworthy items include the Jacobian condition of 40000 (a significant worsening), norm of the nonlinear constraints of 8.84 (also degraded), and an objective (total  $\Delta V$ ) of 4.40 (internal units).

Intermediate iterations are omitted to save space. The final converged iteration (#140) is displayed. The Jacobian condition number has improved slightly, but is still bad. The norm of constraint violation is very small, indicating constraints have been met. However, this has occurred at the expense of an objective value increase to 5.19.

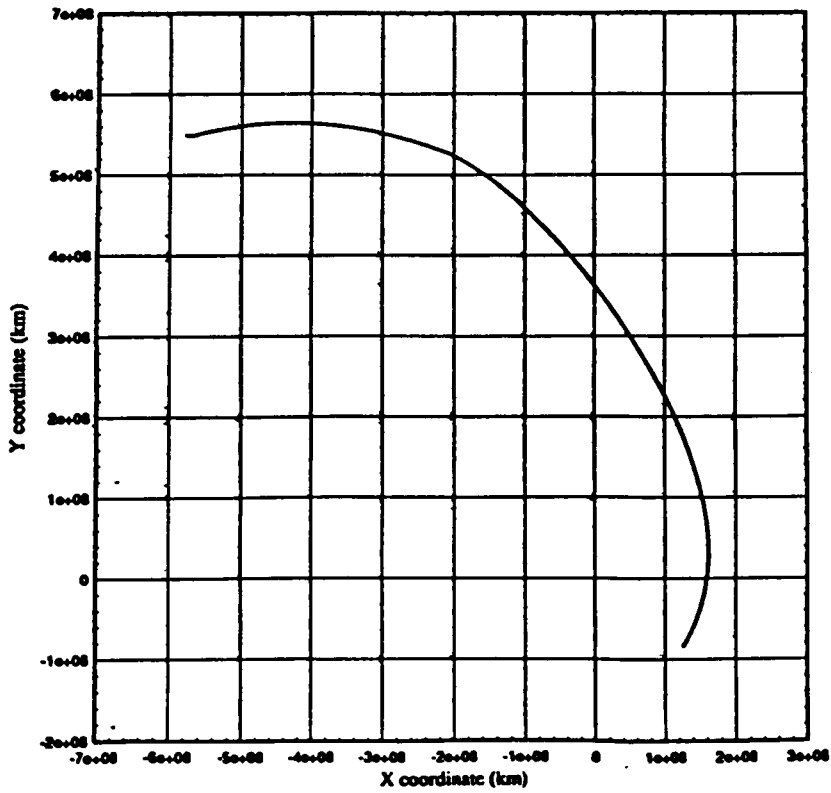
The final solution is displayed after convergence. In this case, a whopping 51.9 km/s total  $\Delta V$  is required. This large  $\Delta V$  indicates an aberrant solution. Figure 3 - 1a is an x-y plot of the final trajectory. This points out an interesting phenomenon. Even though NPSOL has found an optimal, and a "feasible", solution, as indicated by the TTT convergence flags, the solution is not realistic from an engineering perspective. A local optimum has been found. Sometimes the mathematical robustness of collocation is deceiving.

The problem in this case is the number of segments per phase. When they are increased to two segments per phase, then a solution illustrated in Figure 3 - 1b occurs. The total  $\Delta V$  in that case is 14 km/s. The input file shown can be used for two (or more) segments per phase by changing NSEGPH to more than 1. With COINTP = 'LINEAR', IPOST will interpolate linearly between the event states to supply the internal node states.

Unfortunately, collocation is not as simple as always increasing the number of segments per phase. As with any optimization problem, particularly one with high dimensionality such as collocation, the local performance manifold is strongly determined by weightings (independent and dependent parameters), bounds, and initial conditions. These can be very tricky with the large dimensions associated with collocation, and may produce misleading solutions. Caveat emptor!



a) 1 Segment/Phase,  $\Delta V = 52\text{km/s}$



b) 2 Segments/Phase,  $\Delta V = 14\text{ km/s}$

Figure 3 - 1. Ecliptic View of Earth to Jupiter Mission

i p o s t - interplanetary post simulation. version 2.18 , dated 03-05-90.

```

pstop
c... galileo 1989 veega trajectory
c earth to jupiter trajectory. more events added in between.
c input modified for local body relative simulation
c more events added at end for jupiter effect.
c control=critr removed.
  ideb = 0,
  iephem = 1,
  srchm = 'colloc',
  irscl = 2, = 0,
  iprint = -1,
  ipro = -1,
  fesn = 20,
  istm = 'autopert',
  npad(1) = 0, 150, -1,
  mxitop = 50, -1,
  c mxitop = 0, 0, -1,
  c mxitop = 0, -1,
  c mxitop = -1,
c
c minimize delta-v for total mission
c
c
c earth escape
c event = 10,
c
c initial conditions for phase 10 after launch maneuver
c state relative primary body: sun (from v2collold.out)
c x = 0.125746521e+09 y = -0.842704960e+08 z = 0.164441001e+04
c vx = 0.245437654e+02 vy = 0.367619898e+02 vz = 0.291782080e+01
c x = 0.514649030e+04 y = -0.289808128e+04 z = -0.286142123e+04
c optvar = 5hdvsum, radius = 0.6563000000e+04 scm
c dvsum 30.0 0.726729002e+01
c opt = -1,
c optph = 20,
c wopt = 10.,
c etanl = .5,
c
c controls
c
c
c indxi(1) = 1,2,3,
c indvr(1) = 'dvx','dvy','dvz',
c indph(1) = 3*10,
c u(1) = 3*0.,
c wvu(1) = 3*0.01,
c
c indxi(4) = 4,5,6,
c indvr(4) = 'dvx','dvy','dvz',
c indph(4) = 3*11,
c u(4) = 3*0.,
c wvu(4) = 3*0.01,
c
c indxi(7) = 7,8,9,

```



indvr(7) = 'dvx', 'dvy', 'dvz',  
indph(7) = 3\*12,  
u(7) = 3\*0.,  
wvu(7) = 3\*0.01,

C  
indxi(10) = 10,11,12,  
indvr(10) = 'dvx', 'dvy', 'dvz',  
indph(10) = 3\*13,  
u(10) = 3\*0.,  
wvu(10) = 3\*0.01,

C  
indxi(13) = 13,14,15,  
indvr(13) = 'dvx', 'dvy', 'dvz',  
indph(13) = 3\*17,  
u(13) = 3\*0.,  
wvu(13) = 3\*0.01,

C  
indxi(16) = 16,17,18,  
indvr(16) = 'dvx', 'dvy', 'dvz',  
indph(16) = 3\*18,  
u(16) = 3\*0.,  
wvu(16) = 3\*0.01,

C  
indxi(19) = 19,20,21,  
indvr(19) = 'dvx', 'dvy', 'dvz',  
indph(19) = 3\*19,  
u(19) = 3\*0.,  
wvu(19) = 3\*0.01,

C event = 11 timrfl = 0.01,

C  
u(22) = 0.125765354e+09,-0.842386258e+08,0.491805827e+04,  
0.200757546e+02,0.363034584e+02,0.404838808e+01,  
0.213689293e+06,

C event = 12 timrfl = 0.21,

C  
0.126112260e+09,-0.836113020e+08,7.487420400e+04,  
0.200757546e+02,0.363034584e+02,0.404838808e+01,  
0.213689293e+06,

C event = 13 timrfl = 2.21,

C  
0.129581350e+09,-0.773380640e+08,7.744356600e+05,  
0.200757546e+02,0.363034584e+02,0.404838808e+01,  
0.213689293e+06,

C event = 17 timrfl = 0.66613102e+03,

C  
-0.522570460e+09,0.561850030e+09,0.118911340e+08,  
-0.324878541e+02,-0.719277290e+01,-0.642151228e+00,  
0.213689293e+06,

C event = 18 timrfl = 0.68413102e+03,

C  
-0.560000000e+09,0.555000000e+09,0.112000000e+08,  
-0.324878541e+02,-0.719277290e+01,-0.642151228e+00,  
0.213689293e+06,



```

c pinc = 2.,
c princ = 2.,
  conode = 'float',
  nsegph = 1,
  nspph0 = 0,
  nsppwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
  thrust = 2.d5,
  spi = 480,
  scmass = 0.213689293e+06,
  inputx = 'cartes',
  ibody = 3,
  x = 0.514649030e+04,-0.289808128e+04,-0.286142123e+04,
    0.844735665e+01,0.121185055e+02,0.291946710e+01,
cc inputx = 'conic',
cc x = 6563.,0.,0.,0.,0.,0.,
$
p$traj
c
c
  event = 11,
  critr = Shtdurp,
  value = 0.01,
  mantyp = 'impuls',
  nsegph = 1,
  nspph0 = 0,
  nsppwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
$
p$traj
c
c
  event = 12,
  critr = 6htimrfl,
  value = 0.21,
  mantyp = 'impuls',
  nsegph = 1,
  nspph0 = 0,
  nsppwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
$
p$traj
c
c
  event = 13,
  critr = 6htimrfl,
  value = 2.21,
  ipbody(1) = 0,
  mantyp = 'impuls',
  nsegph = 1,
  nspph0 = 0,
  nsppwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
$

```

```

p$traj
c
c
    event = 17,
    critr = 6htimrfl,
    value = 0.66613102e+03,
    ipbody(1) = 5,
    idbody = 5,
    mantyp = 'impuls',
    nsegph = 1,
    nsqph0 = 0,
    nsgpwd = 0,
    nsgpwi = 0,
    cointp = 'linear',
    $
p$traj
c
c
    event = 18,
    critr = 6htimrfl,
    value = 0.68413102e+03,
    ipbody(1) = 5,
    idbody = 5,
    mantyp = 'impuls',
    nsegph = 1,
    nsqph0 = 0,
    nsgpwd = 0,
    nsgpwi = 0,
    cointp = 'linear',
    $
p$traj
c
c
    event = 19,
    critr = 6htimrfl,
    value = 0.68563102e+03,
    ipbody(1) = 5,
    idbody = 5,
    mantyp = 'impuls',
    nsegph = 1,
    nsqph0 = 0,
    nsgpwd = 0,
    nsgpwi = 0,
    cointp = 'linear',
    $
p$traj
c
c
    event = 20,
    ipbody = 5,
    idbody = 5,
    critr = 6htimrfl,
    value = 686.13102,
    nsegph = 1,
    nsqph0 = 0,
    namlst = 'none',

```

5

\*\*\* core requirements for problem 1 are \*\*\*

parameter	octal	decimal
event criteria data	- 531b	345
general data	- 372b	250
table data	- 22b	18

execution date and time Thu Oct 29

\*\*\*\* ipost input summary \*\*\*\*

\*\*\* trajectory inputs \*\*\*

initial epoch

julian date ...2443375.5000

calendar date ...1977 aug 20, 0 hr 0 min 0.0000 secs

initial body and frame of reference 3, earth, ecliptic, mean2000

initial state

cartesian 5.14649030000D+03 -2.89808128000D+03 -2.86142123000D+03

8.44735665000D+00 1.21185055000D+01 2.91946710000D+00

conic -3.786644734676D+03 2.73328700933D+00 4.97418836903D-01

5.89490535761D-01 5.1308212711D+00 -1.87520109686D-10

initial state, heliocentric, ecliptic

1.27217459621D+08 -8.20332344476D+07 -6.36899241172D+03

2.41006464945D+01 3.70535628673D+01 2.91967125215D+00

input units - metric, output units - metric

event summary

number	trigger	value	type	propagator
10.000	time	1.00000000000D+10	impuls	none
11.000	tdurp	1.00000000000D-02	impuls	none
12.000	timrfl	2.10000000000D-01	impuls	none
13.000	timrfl	2.21000000000D+00	impuls	none
17.000	timrfl	6.66131020000D+02	impuls	none
18.000	timrfl	6.84131020000D+02	impuls	none
19.000	timrfl	6.85631020000D+02	impuls	none
20.000	timrfl	6.86131020000D+02	none	none

\*\*\*targeting/optimization inputs\*\*\*

master problem optimization parameter dvsum at event 20

master problem optimization algorithm - colloc

master prob. control/indep parameters

evtnum name

10.000	dvx
10.000	dvz
10.000	dvz
11.000	dvx
11.000	dvz
11.000	dvz
12.000	dvx
12.000	dvz
12.000	dvz
13.000	dvx
13.000	dvz
13.000	dvz
17.000	dvx
17.000	dvz
17.000	dvz
18.000	dvx
18.000	dvz
18.000	dvz
19.000	dvx
19.000	dvz
19.000	dvz

```

master problem target/dep parameters
evtnum      name
20.000     tfp
20.000     bdti
20.000     bdri
total number of subproblems is 0
phzcmi - change of reference      3
2.1022709E-19 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.0000000E+00
phzcmi - change of reference      3
2.1022709E-19 -5.2990956E+05 -1.2464656E+05 7.7787823E+05 5.3680124E+00 1.0790953E+01
4.0478631E+00
phzcmi - change of reference      5
2.1022709E-19 -5.2257046E+08 5.6185003E+08 1.1891134E+07 -3.2487854E+01 -7.1927729E+00
-6.4215123E-01

```

```

OPTIONS file
-----

```

```

BEGIN OPTIONS FOR NPSOL 4.0
VERIFY LEVEL          0
DERIV LEVEL          0
MAJOR ITERATIONS LIMIT 200
MAJOR PRINT LEVEL    10
MINOR PRINT LEVEL    0
MAJOR DEBUG         1
DIFFERENCE INTERVAL  1.E-6
LINEAR FEASIBILITY TOLERANCE 1.E-6
NONLINEAR FEASIBILITY TOLERANCE 1.E-7
OPTIMALITY TOLERANCE 1.E-7
HESSIAN             YES
COLD START

```

```

END

```

```

Calls to NPOPTN
-----

```

```

major iteration limit = 0

```

```

NPSOL --- Version 4.05 Nov 1989
=====

```

```

Parameters
-----

```

Linear constraints.....	0	Linear feasibility.....	1.00E-06	COLD start.....	
Variables.....	126	Infinite bound size....	1.00E+20	Crash tolerance.....	1.00E-02
Step limit.....	2.00E+00	Infinite step size.....	1.00E+20		
Nonlinear constraints..	108	Optimality tolerance...	1.00E-07	Function precision.....	9.90E-14
Nonlinear Jacobian vars	126	Nonlinear feasibility..	1.00E-07		

```

Nonlinear objectiv vars      126      Linesearch tolerance...  9.00E-01      Verify level.....  0
EPS (machine precision) 3.55E-15      Derivative level.....
Major iterations limit.      0      Major print level.....  10
Minor iterations limit.      702      Minor print level.....  0
RUN loaded from file...      0      RUN to be saved on file
Difference interval..... 1.00E-06      Central diffce interval  5.11E-05

Workspace provided is      IW( 2500), W( 770500).
To solve problem we need IW( 594), W( 63756).
phzcmi - change of reference      -1
2.1022709E-19  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
0.0000000E+00
phzcmi - change of reference      3
2.1022709E-19 -5.2990956E+05 -1.2464656E+05  7.7787823E+05  5.3680124E+00  1.0790953E+01
4.0478631E+00
phzcmi - change of reference      0
2.1022709E-19 -5.2257046E+08  5.6185003E+08  1.1891134E+07 -3.2487854E+01 -7.1927729E+00
-6.4215123E-01

```

The user sets 9604 out of 13608 Jacobian elements.  
Each iteration, 4004 Jacobian elements will be estimated numerically.

The user sets 0 out of 126 objective gradient elements.  
Each iteration, 126 gradient elements will be estimated numerically.

Verification of the constraint gradients.  
-----

Every column contains a constant or missing element.

```

//NFCRSH// Working set selected....
//NFCRSH// FIXED LINACT NLNACT
//NFCRSH// 0 0 108

```

```

//NPIQP // NOPERR
//NPIQP // 0

```

```

//NPFEEAS// The maximum violation is 2.58E+02 in constraint 187

```

```

//NPMRT // QPCURV GRDALE
//NPMRT // 4.72E+06 5.30E+06

```

```

//NPMRT // SCALE RHONRM GRDALE
//NPMRT // 1.00E+00 1.06E+02 -2.36E+06

```

```

Itn ItOP      Step Nfun      Merit Bnd Lin Nln Nz      Norm Gf      Norm Gz      Cond H      Cond Hz      Cond T      Norm C      Penalty Conv
0 3 0.0E+00 1 3.537582E+06 0 0 108 18 4.6E-03 3.0E-03 1.E+00 1.E+00 3.E+07 3.1E+02 1.1E+02 F FF
Exit NP phase. INFORM = 4 MAJITS = 0 NFUN = 1 NGRAD = 1

```



Variable	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
VARBL 1	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 2	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 3	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 4	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 5	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 6	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 7	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 8	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 9	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 10	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 11	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 12	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 13	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 14	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 15	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 16	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 17	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 18	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 19	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 20	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 21	FR	0.000000E+00	-0.100000E+14	0.100000E+14	0.000000E+00	0.1000E+14
VARBL 22	FR	-0.5479069	-37515.49	37515.49	0.000000E+00	0.3751E+05
VARBL 23	FR	-0.8365333	-37515.49	37515.49	0.000000E+00	0.3751E+05
VARBL 24	FR	0.3160850E-02	-37515.49	37515.49	0.000000E+00	0.3751E+05
VARBL 25	FR	0.344482	-0.7781155E+10	0.7781155E+10	0.000000E+00	0.7781E+10
VARBL 26	FR	0.8843830	-0.7781155E+10	0.7781155E+10	0.000000E+00	0.7781E+10
VARBL 27	FR	0.3149954	-0.7781155E+10	0.7781155E+10	0.000000E+00	0.7781E+10
VARBL 28	FR	1.000000	-467969.2	467969.2	0.000000E+00	0.4680E+06
VARBL 29	FR	-0.5620824	-40634.63	40634.63	0.000000E+00	0.4063E+05
VARBL 30	FR	-0.8264678	-40634.63	40634.63	0.000000E+00	0.4063E+05
VARBL 31	FR	0.3184858E-01	-40634.63	40634.63	0.000000E+00	0.4063E+05
VARBL 32	FR	0.3515340	-0.7792062E+10	0.7792062E+10	0.000000E+00	0.7792E+10
VARBL 33	FR	0.8814330	-0.7792062E+10	0.7792062E+10	0.000000E+00	0.7792E+10
VARBL 34	FR	0.3154356	-0.7792062E+10	0.7792062E+10	0.000000E+00	0.7792E+10
VARBL 35	FR	1.000000	-467969.2	467969.2	0.000000E+00	0.4680E+06
VARBL 36	FR	-0.5581288	-105325.3	105325.3	0.000000E+00	0.1053E+06
VARBL 37	FR	-0.1312844	-105325.3	105325.3	0.000000E+00	0.1053E+06
VARBL 38	FR	0.8193025	-105325.3	105325.3	0.000000E+00	0.1053E+06
VARBL 39	FR	0.4222132	-0.7865354E+10	0.7865354E+10	0.000000E+00	0.7865E+10
VARBL 40	FR	0.8487467	-0.7865354E+10	0.7865354E+10	0.000000E+00	0.7865E+10
VARBL 41	FR	0.3183788	-0.7865354E+10	0.7865354E+10	0.000000E+00	0.7865E+10
VARBL 42	FR	1.000000	-467969.2	467969.2	0.000000E+00	0.4680E+06
VARBL 43	FR	-0.6809658	-130.3108	130.3108	0.000000E+00	129.6
VARBL 44	FR	0.7321513	-130.3108	130.3108	0.000000E+00	129.6
VARBL 45	FR	0.1549543E-01	-130.3108	130.3108	0.000000E+00	130.3
VARBL 46	FR	-0.9761752	-0.3004739E+10	0.3004739E+10	0.000000E+00	0.3005E+10
VARBL 47	FR	-0.2161241	-0.3004739E+10	0.3004739E+10	0.000000E+00	0.3005E+10
VARBL 48	FR	-0.1929497E-01	-0.3004739E+10	0.3004739E+10	0.000000E+00	0.3005E+10
VARBL 49	FR	1.000000	-467969.2	467969.2	0.000000E+00	0.4680E+06
VARBL 50	FR	0.8782371	-3488.120	3488.120	0.000000E+00	3487.
VARBL 51	FR	0.4780978	-3488.120	3488.120	0.000000E+00	3488.
VARBL 52	FR	0.1105206E-01	-3488.120	3488.120	0.000000E+00	3488.
VARBL 53	FR	-0.9963593	-0.4248389E+10	0.4248389E+10	0.000000E+00	0.4248E+10
VARBL 54	FR	0.7658641E-01	-0.4248389E+10	0.4248389E+10	0.000000E+00	0.4248E+10
VARBL 55	FR	-0.3745247E-01	-0.4248389E+10	0.4248389E+10	0.000000E+00	0.4248E+10
VARBL 56	FR	1.000000	-467969.2	467969.2	0.000000E+00	0.4680E+06

VARBL 57	FR	0.8091057	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 58	FR	0.5876627	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 59	FR	-0.7006262E-03	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 60	FR	-0.9963062	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL 61	FR	0.7729733E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL 62	FR	-0.3740303E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL 63	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 64	FR	0.6381483	-7949.562	7949.562	0.0000000E+00	7949.
VARBL 65	FR	0.7698296	-7949.562	7949.562	0.0000000E+00	7949.
VARBL 66	FR	-0.1136648E-01	-7949.562	7949.562	0.0000000E+00	7950.
VARBL 67	FR	-0.9962885	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 68	FR	0.7753357E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 69	FR	-0.3738654E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 70	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 71	FR	0.7841673	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 72	FR	-0.4415787	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 73	FR	-0.4359929	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 74	FR	0.5609930	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 75	FR	0.8047957	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 76	FR	0.1938832	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 77	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 78	FR	-0.5479069	-37515.49	37515.49	0.0000000E+00	0.3751E+05
VARBL 79	FR	-0.8365333	-37515.49	37515.49	0.0000000E+00	0.3751E+05
VARBL 80	FR	0.3160850E-02	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 81	FR	0.3444482	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 82	FR	0.8843830	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 83	FR	0.3149954	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 84	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 85	FR	-0.5620824	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 86	FR	-0.8264678	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 87	FR	0.3184858E-01	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 88	FR	0.3515340	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 89	FR	0.8814330	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 90	FR	0.3154356	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 91	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 92	FR	0.8586801	-662.6572	662.6572	0.0000000E+00	662.1
VARBL 93	FR	-0.5124862	-662.6572	662.6572	0.0000000E+00	662.1
VARBL 94	FR	0.5131853E-02	-662.6572	662.6572	0.0000000E+00	662.7
VARBL 95	FR	0.9934508E-02	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 96	FR	0.1796480E-01	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 97	FR	0.2003349E-02	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 98	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 99	FR	0.9900343	-2046.721	2046.721	0.0000000E+00	2046.
VARBL100	FR	0.1379492	-2046.721	2046.721	0.0000000E+00	2047.
VARBL101	FR	0.2832122E-01	-2046.721	2046.721	0.0000000E+00	2047.
VARBL102	FR	-10.95681	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL103	FR	0.7450888	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL104	FR	-0.4181054	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL105	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL106	FR	0.8782371	-3488.120	3488.120	0.0000000E+00	3487.
VARBL107	FR	0.4780978	-3488.120	3488.120	0.0000000E+00	3488.
VARBL108	FR	0.1105206E-01	-3488.120	3488.120	0.0000000E+00	3488.
VARBL109	FR	-0.9963593	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL110	FR	0.7658641E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL111	FR	-0.3745247E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL112	FR	1.0000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL113	FR	0.8091057	-4949.378	4949.378	0.0000000E+00	4949.
VARBL114	FR	0.5876627	-4949.378	4949.378	0.0000000E+00	4949.

VARBL115	FR	-0.7006262E-03	-4949.378	4949.378	0.0000000E+00	4949.
VARBL116	FR	-0.9963062	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL117	FR	0.7729733E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL118	FR	-0.3740303E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL119	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL120	FR	0.6381483	-7949.562	7949.562	0.0000000E+00	7949.
VARBL121	FR	0.7698296	-7949.562	7949.562	0.0000000E+00	7949.
VARBL122	FR	-0.1136648E-01	-7949.562	7949.562	0.0000000E+00	7950.
VARBL123	FR	-0.9962885	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL124	FR	0.7753357E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL125	FR	-0.3738654E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL126	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06

Nonlfr constr	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
NLCON 1	EQ	-0.3612631E-02	-0.5062759E-05	-0.5062759E-05	-2618724.	-0.3608E-02
NLCON 2	EQ	0.1046931E-01	0.1792972E-02	0.1792972E-02	-924272.6	0.8676E-02
NLCON 3	EQ	0.4179538E-03	0.1160682E-03	0.1160682E-03	78728.15	0.3019E-03
NLCON 4	EQ	0.000000E+00	0.000000E+00	0.000000E+00	195947.5	0.0000E+00
NLCON 5	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-6881.528	0.0000E+00
NLCON 6	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-133743.5	0.0000E+00
NLCON 7	EQ	0.000000E+00	0.000000E+00	0.000000E+00	643451.4	0.0000E+00
NLCON 8	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-1529933.	0.0000E+00
NLCON 9	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-74890.30	0.0000E+00
NLCON 10	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-67.19727	0.0000E+00
NLCON 11	EQ	0.000000E+00	0.000000E+00	0.000000E+00	160313.7	0.0000E+00
NLCON 12	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-37385.66	0.0000E+00
NLCON 13	EQ	0.000000E+00	0.000000E+00	0.000000E+00	6321.098	0.0000E+00
NLCON 14	EQ	0.000000E+00	0.000000E+00	0.000000E+00	548505.0	0.0000E+00
NLCON 15	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-1305610.	0.0000E+00
NLCON 16	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-63943.70	0.0000E+00
NLCON 17	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-64.48641	0.0000E+00
NLCON 18	EQ	0.000000E+00	0.000000E+00	0.000000E+00	148154.1	0.0000E+00
NLCON 19	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-34463.45	0.0000E+00
NLCON 20	EQ	0.000000E+00	0.000000E+00	0.000000E+00	5827.568	0.0000E+00
NLCON 21	EQ	0.000000E+00	0.000000E+00	0.000000E+00	534395.2	0.0000E+00
NLCON 22	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-1300678.	0.0000E+00
NLCON 23	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-64380.00	0.0000E+00
NLCON 24	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-59.06284	0.0000E+00
NLCON 25	EQ	0.1569469E-13	0.000000E+00	0.000000E+00	59070.21	0.1569E-13
NLCON 26	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-14601.25	0.0000E+00
NLCON 27	EQ	0.000000E+00	0.000000E+00	0.000000E+00	1883.499	0.0000E+00
NLCON 28	EQ	0.000000E+00	0.000000E+00	0.000000E+00	395068.8	0.0000E+00
NLCON 29	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-1257839.	0.0000E+00
NLCON 30	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-68313.29	0.0000E+00
NLCON 31	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-50.89077	0.0000E+00
NLCON 32	EQ	0.000000E+00	0.000000E+00	0.000000E+00	942729.4	0.0000E+00
NLCON 33	EQ	0.1213614E-17	0.000000E+00	0.000000E+00	-785671.5	0.1214E-17
NLCON 34	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-23909.25	0.0000E+00
NLCON 35	EQ	0.000000E+00	0.000000E+00	0.000000E+00	81383.59	0.0000E+00
NLCON 36	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-88633.62	0.0000E+00
NLCON 37	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-1344.681	0.0000E+00
NLCON 38	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-39.60854	0.0000E+00
NLCON 39	EQ	0.000000E+00	0.000000E+00	0.000000E+00	35129.92	0.0000E+00
NLCON 40	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-29597.88	0.0000E+00
NLCON 41	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-899.9141	0.0000E+00
NLCON 42	EQ	0.000000E+00	0.000000E+00	0.000000E+00	12767.25	0.0000E+00

NLCON 43	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-25045.32	0.0000E+00
NLCON 44	EQ	0.4716660E-17	0.000000E+00	0.000000E+00	193.8782	0.4717E-17
NLCON 45	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-28.31639	0.0000E+00
NLCON 46	EQ	0.000000E+00	0.000000E+00	0.000000E+00	24776.43	0.0000E+00
NLCON 47	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-20878.24	0.0000E+00
NLCON 48	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-633.9319	0.0000E+00
NLCON 49	EQ	0.000000E+00	0.000000E+00	0.000000E+00	9037.652	0.0000E+00
NLCON 50	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-21914.11	0.0000E+00
NLCON 51	EQ	0.000000E+00	0.000000E+00	0.000000E+00	289.8587	0.0000E+00
NLCON 52	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-17.00319	0.0000E+00
NLCON 53	EQ	0.000000E+00	0.000000E+00	0.000000E+00	15444.44	0.0000E+00
NLCON 54	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-13001.97	0.0000E+00
NLCON 55	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-394.5868	0.0000E+00
NLCON 56	EQ	0.000000E+00	0.000000E+00	0.000000E+00	7792.764	0.0000E+00
NLCON 57	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-20868.30	0.0000E+00
NLCON 58	EQ	0.000000E+00	0.000000E+00	0.000000E+00	321.8631	0.0000E+00
NLCON 59	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-5.66729	0.0000E+00
NLCON 60	EQ	-169.5702	0.000000E+00	0.000000E+00	-521.5694	-169.6
NLCON 61	EQ	-257.9558	0.000000E+00	0.000000E+00	121.6738	-258.0
NLCON 62	EQ	0.9253491	0.000000E+00	0.000000E+00	-20.57026	0.9253
NLCON 63	EQ	-0.1495380	0.000000E+00	0.000000E+00	-849836.4	-0.1495
NLCON 64	EQ	-0.6740589E-01	0.000000E+00	0.000000E+00	2021763.	-0.6741E-01
NLCON 65	EQ	0.2752391E-01	0.000000E+00	0.000000E+00	98991.67	0.2752E-01
NLCON 66	EQ	0.000000E+00	0.000000E+00	0.000000E+00	37.92490	0.0000E+00
NLCON 67	EQ	-0.2117614E-04	0.000000E+00	0.000000E+00	-8908.316	-0.2118E-04
NLCON 68	EQ	-0.1445640E-05	0.000000E+00	0.000000E+00	2074.920	-0.1446E-05
NLCON 69	EQ	-0.2999026E-06	0.000000E+00	0.000000E+00	-350.8710	-0.2999E-06
NLCON 70	EQ	0.1179009	0.000000E+00	0.000000E+00	-30093.92	0.1179
NLCON 71	EQ	-0.7655084E-01	0.000000E+00	0.000000E+00	72429.43	-0.7655E-01
NLCON 72	EQ	0.2116185E-05	0.000000E+00	0.000000E+00	3566.167	0.2116E-05
NLCON 73	EQ	0.000000E+00	0.000000E+00	0.000000E+00	711.6437	0.0000E+00
NLCON 74	EQ	0.1945117E-03	0.000000E+00	0.000000E+00	-90408.51	0.1945E-03
NLCON 75	EQ	-0.2888520E-03	0.000000E+00	0.000000E+00	20675.00	-0.2888E-03
NLCON 76	EQ	-0.6039392E-03	0.000000E+00	0.000000E+00	-3050.345	-0.6039E-03
NLCON 77	EQ	0.1083490	0.000000E+00	0.000000E+00	-280585.2	0.1083
NLCON 78	EQ	-0.6984803E-01	0.000000E+00	0.000000E+00	772078.7	-0.6985E-01
NLCON 79	EQ	0.2065037E-02	0.000000E+00	0.000000E+00	40149.74	0.2065E-02
NLCON 80	EQ	0.000000E+00	0.000000E+00	0.000000E+00	6333.328	0.0000E+00
NLCON 81	EQ	0.7014296	0.000000E+00	0.000000E+00	-795515.6	0.7014
NLCON 82	EQ	-0.6649538	0.000000E+00	0.000000E+00	2675134.	-0.6650
NLCON 83	EQ	-0.4977200E-01	0.000000E+00	0.000000E+00	148189.3	-0.4977E-01
NLCON 84	EQ	-0.3625388E-02	0.000000E+00	0.000000E+00	-0.1190997E+08	-0.3625E-02
NLCON 85	EQ	-0.1280159	0.000000E+00	0.000000E+00	819215.9	-0.1280
NLCON 86	EQ	-0.7617111E-02	0.000000E+00	0.000000E+00	0.1850429E+08	-0.7617E-02
NLCON 87	EQ	0.000000E+00	0.000000E+00	0.000000E+00	1730431.	0.0000E+00
NLCON 88	EQ	0.5417286	0.000000E+00	0.000000E+00	-29600.17	0.5417
NLCON 89	EQ	0.1790756	0.000000E+00	0.000000E+00	24817.51	0.1791
NLCON 90	EQ	0.1273526E-01	0.000000E+00	0.000000E+00	755.9454	0.1274E-01
NLCON 91	EQ	-0.8743459E-02	0.000000E+00	0.000000E+00	-17205.37	-0.8743E-02
NLCON 92	EQ	0.2336671E-01	0.000000E+00	0.000000E+00	21456.08	0.2337E-01
NLCON 93	EQ	0.6252573E-03	0.000000E+00	0.000000E+00	185.7961	0.6253E-03
NLCON 94	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-3212.28	0.0000E+00
NLCON 95	EQ	-2.846881	0.000000E+00	0.000000E+00	-2492.744	-2.847
NLCON 96	EQ	-1.016844	0.000000E+00	0.000000E+00	2100.508	-1.017
NLCON 97	EQ	-0.1065906	0.000000E+00	0.000000E+00	63.82689	-0.1066
NLCON 98	EQ	0.2469226E-02	0.000000E+00	0.000000E+00	-773.1290	0.2469E-02
NLCON 99	EQ	0.2009735E-01	0.000000E+00	0.000000E+00	1664.927	0.2010E-01
NLCON100	EQ	0.3092034E-03	0.000000E+00	0.000000E+00	-17.14874	0.3092E-03

```

NLCON101 EQ 0.0000000E+00 0.0000000E+00 0.0000000E+00 1957.806 0.0000E+00
NLCON102 EQ -10.76769 0.0000000E+00 0.0000000E+00 -832.4065 -10.77
NLCON103 EQ -3.343200 0.0000000E+00 0.0000000E+00 701.2666 -3.343
NLCON104 EQ -0.1337628 0.0000000E+00 0.0000000E+00 21.28563 -0.1338
NLCON105 EQ 0.1159156E-01 0.0000000E+00 0.0000000E+00 -282.5666 0.1159E-01
NLCON106 EQ 0.2653756E-01 0.0000000E+00 0.0000000E+00 718.2611 0.2654E-01
NLCON107 EQ -0.1276858E-04 0.0000000E+00 0.0000000E+00 -10.26991 -0.1277E-04
NLCON108 EQ 0.0000000E+00 0.0000000E+00 0.0000000E+00 326.4612 0.0000E+00

```

Exit NPSOL - Too many major iterations.

Final nonlinear objective value = 0.0000000E+00

Calls to NPOPTN  
-----

major iteration limit = 150

NPSOL --- Version 4.05 Nov 1989  
=====

Parameters  
-----

```

Linear constraints..... 0 Linear feasibility..... 1.00E-06 COLD start..... 1.00E-02
Variables..... 126 Infinite bound size.... 1.00E+20 Crash tolerance..... 1.00E-02
Step limit..... 2.00E+00 Infinite step size..... 1.00E+20
Nonlinear constraints.. 108 Optimality tolerance... 1.00E-07 Function precision..... 9.90E-14
Nonlinear Jacobian vars 126 Nonlinear feasibility.. 1.00E-07
Nonlinear objective vars 126 Line search tolerance... 9.00E-01
EPS (machine precision) 3.55E-15 Derivative level..... 0 Verify level..... 0
Major iterations limit. 150 Major print level..... 10
Minor iterations limit. 702 Minor print level..... 0
RUN loaded from file... 0 RUN to be saved on file Save frequency..... 151
Difference interval.... 1.00E-06 Central diffe interval 5.11E-05

```

```

Workspace provided is IW( 2500), W( 770500).
To solve problem we need IW( 594), W( 63756).
phzcm1 - change of reference -1 3
2.1022709E-19 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.0000000E+00
phzcm1 - change of reference 3 0
2.1022709E-19 -5.2990956E+05 -1.2464656E+05 7.7787823E+05 5.3680124E+00 1.0790953E+01
4.0478631E+00
phzcm1 - change of reference 0 5
2.1022709E-19 -5.2257046E+08 5.6185003E+08 1.1891134E+07 -3.2487854E+01 -7.1927729E+00
-6.4215123E-01

```

The user sets 9604 out of 13608 Jacobian elements.  
 Each iteration, 4004 Jacobian elements will be estimated numerically.

The user sets 0 out of 126 objective gradient elements.  
 Each iteration, 126 gradient elements will be estimated numerically.

Verification of the constraint gradients.  
 -----

Every column contains a constant or missing element.

//NPCRSH// Working set selected....  
 //NPCRSH// FIXED LINACT NLNACT  
 //NPCRSH// 0 0 108

//NPIQP // NQPERR  
 //NPIQP // 0

//NPFAS// The maximum violation is 8.39E-01 in constraint 187

//NPMRT // QPCURV GRDALF  
 //NPMRT // 4.72E+06 5.30E+06

//NPMRT // SCALE RHONRM GRDALF  
 //NPMRT // 1.00E+00 7.84E+06 -2.36E+06

Itn	ItQP	Step	Nfun	Merit	Bnd	Lin	Nln	Nz	Norm	Gf	Norm	Gz	Cond	H	Cond	Hz	Cond	T	Norm	C	Penalty	Conv
0	1	0.0E+00	1	3.537582E+06	0	0	108	18	4.6E-03	3.0E-03	1.E+00	1.E+00	3.E+03	1.5E+00	7.8E+06	F	FF					

//NPSRCH// INFORM = 2

//NPUPDT// SSBFGS min. CURVL CURVL  
 //NPUPDT// T 4.72E+05 -1.56E+08

//NPUPDT// OMEGA(IMAX)  
 //NPUPDT// 2.64E+06

//NPUPDT// ALFA CURVL  
 //NPUPDT// 1.00E+00 4.72E+05

//NPCORE// RPROBN DRMAX DRMIN  
 //NPCORE// 2.82E+05 9.25E+01 9.18E-04  
 //NPCORE// COND RCNDBD  
 //NPCORE// 1.01E+05 1.49E+05

//NPIQP // NQPERR  
 //NPIQP // 0

//NPFAS// The maximum violation is 6.08E+00 in constraint 157

//NPMRT // QPCURV GRDALF  
 //NPMRT // 3.45E+05 7.17E+05

//NPMRT // SCALE RHONRM GRDALF

```

//NPMRT // 1.00E+00 4.50E+04 -2.04E+05 0 0 108 18 2.6E-03 1.8E-03 8.E+02 8.E+02 4.E+04 8.8E+00 4.5E+04 F FF LR
1 1 1.0E+00 4 2.745792E+05 0 0 108 18 2.6E-03 1.8E-03 8.E+02 8.E+02 4.E+04 8.8E+00 4.5E+04 F FF LR
:
:
:
145 1 1.0E+00 279 5.191160E+00 0 0 108 18 2.6E-03 1.7E-03 2.E+04 2.E+04 2.E+04 1.0E-07 7.8E+02 F TT
//NPSRCH// INFORM = 1
//NPUPDT// SSBFGS min. CURVL CURVL
//NPUPDT// F 3.99E-05 4.82E-04
//NPUPDT// ALFA CURVL
//NPUPDT// 3.77E-01 4.82E-04
//NPIQP // NQPERR
//NPIQP // 0
//NPF EAS// The maximum violation is 6.67E-08 in constraint 196
//NPMRT // OPCURV GRDALF
//NPMRT // 2.16E-04 -2.16E-04
//NPMRT // SCALE RHONRM GRDALF
//NPMRT // 1.00E+00 7.78E+02 -2.16E-04
146 1 3.8E-01 281 5.191079E+00 0 0 108 18 2.6E-03 1.8E-03 9.E+03 9.E+03 2.E+04 7.3E-08 7.8E+02 F TT
//NPSRCH// INFORM = 2
//NPUPDT// SSBFGS min. CURVL CURVL
//NPUPDT// F 2.16E-05 2.13E-04
//NPUPDT// ALFA CURVL
//NPUPDT// 1.00E+00 2.13E-04
//NPIQP // NQPERR
//NPIQP // 0
//NPF EAS// The maximum violation is 1.95E-08 in constraint 196
//NPMRT // OPCURV GRDALF
//NPMRT // 2.34E-04 -2.34E-04
//NPMRT // SCALE RHONRM GRDALF
//NPMRT // 1.00E+00 7.78E+02 -2.34E-04
147 1 1.0E+00 282 5.190949E+00 0 0 108 18 2.6E-03 1.8E-03 2.E+04 2.E+04 2.E+04 2.1E-08 7.8E+02 F TT
//NPSRCH// INFORM = 1
//NPUPDT// SSBFGS min. CURVL CURVL
//NPUPDT// F 2.34E-05 2.78E-04
//NPUPDT// ALFA CURVL
//NPUPDT// 3.62E-01 2.78E-04
//NPIQP // NQPERR

```

```

//NPIQP // 0
//NPFAS// The maximum violation is 3.54E-08 in constraint 196
//NPMRT // OPCURV GRDALF
//NPMRT // 1.13E-04 -1.13E-04
//NPMRT // SCALE RHONRM GRDALF
//NPMRT // 1.00E+00 7.78E+02 -1.13E-04
148 1 3.6E-01 284 5.190925E+00 0 0 108 18 2.6E-03 1.8E-03 2.E+04 2.E+04 2.E+04 3.9E-08 7.8E+02 F TT
//NPSRCH// INFORM = 2
//NPUPDT// SSBFGS min. CURVL CURVL
//NPUPDT// F 1.13E-05 1.40E-04
//NPUPDT// ALFA CURVL
//NPUPDT// 1.00E+00 1.40E-04
//NPIQP // NQPERR
//NPIQP // 0
//NPFAS// The maximum violation is 9.18E-09 in constraint 196
//NPMRT // OPCURV GRDALF
//NPMRT // 1.22E-04 -1.22E-04
//NPMRT // SCALE RHONRM GRDALF
//NPMRT // 1.00E+00 7.78E+02 -1.22E-04
149 1 1.0E+00 285 5.190874E+00 0 0 108 18 2.6E-03 1.8E-03 1.E+04 2.E+04 1.1E-08 7.8E+02 F TT
//NPSRCH// INFORM = 2
//NPUPDT// SSBFGS min. CURVL CURVL
//NPUPDT// F 1.22E-05 1.66E-04
//NPUPDT// ALFA CURVL
//NPUPDT// 1.00E+00 1.66E-04
//NPIQP // NQPERR
//NPIQP // 0
//NPFAS// The maximum violation is 2.28E-09 in constraint 164
//NPMRT // OPCURV GRDALF
//NPMRT // 1.26E-04 -1.26E-04
//NPMRT // SCALE RHONRM GRDALF
//NPMRT // 1.00E+00 7.78E+02 -1.26E-04
150 1 1.0E+00 286 5.190844E+00 0 0 108 18 2.6E-03 1.7E-03 1.E+04 2.E+04 2.7E-09 7.8E+02 T TT
Exit NP phase. INFORM = 0 MAJITS = 150 NFUN = 286 NGRAD = 151

```

Variable	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
VARBL 1	FR	2401.793	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 2	FR	-4292.645	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14

C.2



VARBL 3	-275.2018	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 4	2.840364	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 5	-4.892074	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 6	-0.1778320	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 7	3.274723	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 8	-5.168941	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 9	0.1183573	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 10	147.7399	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 11	-194.5295	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 12	63.57746	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 13	0.3215334E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 14	-0.2508060E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 15	0.1208432E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 16	0.5683545E-02	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 17	-0.2628689E-02	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 18	0.1198254E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 19	0.1808043E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 20	-0.7817598E-02	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 21	0.1089764E-01	FR	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 22	0.1206937E-01	FR	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 23	-0.1084348E-01	FR	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 24	-0.8245610E-03	FR	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 25	2.421128	FR	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 26	-2.331155	FR	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 27	0.6139215E-01	FR	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 28	0.2848704E-04	FR	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 29	0.2284917	FR	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 30	-0.2195162	FR	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 31	0.8951446E-02	FR	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 32	2.389676	FR	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 33	-2.304844	FR	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 34	0.6373395E-01	FR	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 35	0.2814659E-04	FR	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 36	6.177240	FR	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 37	-5.959381	FR	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 38	0.1615997	FR	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 39	2.413518	FR	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 40	-2.329426	FR	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 41	0.6440019E-01	FR	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 42	0.278301E-04	FR	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 43	-0.7041034	FR	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 44	0.7048972	FR	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 45	0.1641169E-01	FR	-130.3108	130.3108	0.0000000E+00	130.3
VARBL 46	-0.7869499	FR	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 47	0.6714813E-02	FR	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 48	-0.3034222E-01	FR	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 49	0.1625179E-04	FR	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 50	0.1397607	FR	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 51	-0.2230370E-02	FR	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 52	0.4135316E-02	FR	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 53	0.8206544	FR	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 54	0.3896736	FR	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 55	-0.5677726E-01	FR	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 56	0.1625260E-04	FR	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 57	0.688782E-01	FR	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 58	0.5481994E-01	FR	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 59	-0.2788092E-02	FR	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 60	-0.9145105	FR	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10

VARBL 61	FR	0.3551310	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL 62	FR	-0.5644899E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL 63	FR	0.1625220E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 64	FR	0.3440113E-01	-7949.562	7949.562	0.0000000E+00	7950.
VARBL 65	FR	0.1141276	-7949.562	7949.562	0.0000000E+00	7950.
VARBL 66	FR	-0.8878891E-02	-7949.562	7949.562	0.0000000E+00	7950.
VARBL 67	FR	-0.9648763	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 68	FR	0.2806577	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 69	FR	-0.5143806E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL 70	FR	0.1625223E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 71	FR	0.7841673	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 72	FR	-0.4415787	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 73	FR	-0.4359929	-0.1523693E+08	0.1523693E+08	0.0000000E+00	0.1524E+08
VARBL 74	FR	2.156035	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 75	FR	-2.045970	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 76	FR	0.1112039E-01	-0.6641048E+10	0.6641048E+10	0.0000000E+00	0.6641E+10
VARBL 77	FR	0.2848704E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 78	FR	0.1206937E-01	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 79	FR	-0.1084348E-01	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 80	FR	-0.8245610E-03	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 81	FR	2.423338	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 82	FR	-2.334962	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 83	FR	0.6125377E-01	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 84	FR	0.2814659E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 85	FR	0.2284917	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 86	FR	-0.2195162	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 87	FR	0.4851446E-02	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 88	FR	2.392227	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 89	FR	-2.308872	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 90	FR	0.6382617E-01	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 91	FR	0.2778301E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 92	FR	0.9010559	-662.6572	662.6572	0.0000000E+00	661.8
VARBL 93	FR	-0.5491539	-662.6572	662.6572	0.0000000E+00	662.1
VARBL 94	FR	0.9938968E-03	-662.6572	662.6572	0.0000000E+00	662.7
VARBL 95	FR	0.2319395E-01	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 96	FR	-0.2993392E-02	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 97	FR	0.7200492E-03	-0.4948511E+08	0.4948511E+08	0.0000000E+00	0.4949E+08
VARBL 98	FR	0.1625179E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 99	FR	0.6266237	-2046.721	2046.721	0.0000000E+00	2046.
VARBL100	FR	-0.2901159	-2046.721	2046.721	0.0000000E+00	2046.
VARBL101	FR	0.4271242E-01	-2046.721	2046.721	0.0000000E+00	2047.
VARBL102	FR	-7.984598	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL103	FR	4.244979	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL104	FR	-0.5915615	-0.4719379E+11	0.4719379E+11	0.0000000E+00	0.4719E+11
VARBL105	FR	0.1625260E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL106	FR	0.1397607	-3488.120	3488.120	0.0000000E+00	3488.
VARBL107	FR	-0.2230370E-02	-3488.120	3488.120	0.0000000E+00	3488.
VARBL108	FR	0.4135316E-02	-3488.120	3488.120	0.0000000E+00	3488.
VARBL109	FR	-0.8206568	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL110	FR	0.3896725	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL111	FR	-0.5678235E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL112	FR	0.1625220E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL113	FR	0.6887782E-01	-4949.378	4949.378	0.0000000E+00	4949.
VARBL114	FR	0.5481994E-01	-4949.378	4949.378	0.0000000E+00	4949.
VARBL115	FR	-0.2788092E-02	-4949.378	4949.378	0.0000000E+00	4949.
VARBL116	FR	-0.9145182	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL117	FR	0.3551277	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10
VARBL118	FR	-0.5644437E-01	-0.4244562E+10	0.4244562E+10	0.0000000E+00	0.4245E+10

VARBL119	FR	0.1625223E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL120	FR	0.3440113E-01	-7949.562	7949.562	0.0000000E+00	7950.
VARBL121	FR	0.1141276	-7949.562	7949.562	0.0000000E+00	7949.
VARBL122	FR	-0.8878891E-02	-7949.562	7949.562	0.0000000E+00	7950.
VARBL123	FR	-0.9648763	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL124	FR	0.2806577	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL125	FR	-0.5143806E-01	-0.4243287E+10	0.4243287E+10	0.0000000E+00	0.4243E+10
VARBL126	FR	0.1625223E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06

Nonlnr constr	State	Value	Lower bound	Upper bound	Lagr multiplier	Residual
NLCON 1	EQ	-0.8179635E-03	-0.8179635E-03	-0.8179635E-03	-0.8430971E-01	-0.1268E-10
NLCON 2	EQ	0.1420342	0.1420342	0.1420342	-0.8995378E-01	0.3884E-10
NLCON 3	EQ	0.9064885E-02	0.9064885E-02	0.9064885E-02	-0.7799870E-02	0.1881E-10
NLCON 4	EQ	0.000000E+00	0.000000E+00	0.000000E+00	0.2098225	0.0000E+00
NLCON 5	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-0.5181035E-01	0.0000E+00
NLCON 6	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-0.1551691	0.0000E+00
NLCON 7	EQ	-0.3303124E-14	0.000000E+00	0.000000E+00	0.8943637	-0.3303E-14
NLCON 8	EQ	0.4931092E-13	0.000000E+00	0.000000E+00	-1.286776	0.4931E-13
NLCON 9	EQ	0.3500353E-14	0.000000E+00	0.000000E+00	0.8019190E-01	0.3500E-14
NLCON 10	EQ	0.1044032E-10	0.000000E+00	0.000000E+00	0.4029980E-09	0.1044E-10
NLCON 11	EQ	0.000000E+00	0.000000E+00	0.000000E+00	6.373173	0.0000E+00
NLCON 12	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-4.276942	0.0000E+00
NLCON 13	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-0.7959879	0.0000E+00
NLCON 14	EQ	-0.3798315E-12	0.000000E+00	0.000000E+00	0.7218794	-0.3798E-12
NLCON 15	EQ	-0.2902643E-13	0.000000E+00	0.000000E+00	-1.070901	-0.2903E-13
NLCON 16	EQ	-0.2820574E-13	0.000000E+00	0.000000E+00	0.7493854E-01	-0.2821E-13
NLCON 17	EQ	-0.6767918E-11	0.000000E+00	0.000000E+00	0.6919382E-10	-0.6768E-11
NLCON 18	EQ	0.000000E+00	0.000000E+00	0.000000E+00	0.2819703	0.0000E+00
NLCON 19	EQ	0.1088014E-14	0.000000E+00	0.000000E+00	-0.6630108E-01	0.1088E-14
NLCON 20	EQ	0.000000E+00	0.000000E+00	0.000000E+00	-0.1597573E-01	0.0000E+00
NLCON 21	EQ	-0.2859650E-12	0.000000E+00	0.000000E+00	0.6942502	-0.2860E-12
NLCON 22	EQ	-0.3875615E-14	0.000000E+00	0.000000E+00	-1.062504	-0.3876E-14
NLCON 23	EQ	0.2601334E-13	0.000000E+00	0.000000E+00	0.7629208E-01	0.2601E-13
NLCON 24	EQ	-0.7302938E-11	0.000000E+00	0.000000E+00	0.8599938E-11	-0.7230E-11
NLCON 25	EQ	-0.7307027E-14	0.000000E+00	0.000000E+00	16.71425	-0.7307E-14
NLCON 26	EQ	0.3554770E-14	0.000000E+00	0.000000E+00	-3.627170	0.3555E-14
NLCON 27	EQ	0.1909300E-16	0.000000E+00	0.000000E+00	-0.9740813	0.1909E-16
NLCON 28	EQ	0.1494355E-14	0.000000E+00	0.000000E+00	70.62834	0.1494E-14
NLCON 29	EQ	0.2061330E-15	0.000000E+00	0.000000E+00	-158.9018	0.2061E-15
NLCON 30	EQ	0.6416934E-16	0.000000E+00	0.000000E+00	14.26755	0.6417E-16
NLCON 31	EQ	-0.7820812E-11	0.000000E+00	0.000000E+00	0.9418140E-11	-0.7821E-11
NLCON 32	EQ	-0.1213614E-15	0.000000E+00	0.000000E+00	3.313150	-0.1214E-15
NLCON 33	EQ	0.1383520E-15	0.000000E+00	0.000000E+00	-6.233249	0.1384E-15
NLCON 34	EQ	-0.6068070E-18	0.000000E+00	0.000000E+00	0.7410129	-0.6068E-18
NLCON 35	EQ	0.1406962E-11	0.000000E+00	0.000000E+00	0.2271528	0.1407E-11
NLCON 36	EQ	-0.3558504E-12	0.000000E+00	0.000000E+00	-0.4895646	-0.3559E-12
NLCON 37	EQ	0.3562774E-14	0.000000E+00	0.000000E+00	0.5703453E-01	0.3563E-14
NLCON 38	EQ	-0.2280512E-08	0.000000E+00	0.000000E+00	0.1622285E-10	-0.2281E-08
NLCON 39	EQ	0.000000E+00	0.000000E+00	0.000000E+00	0.1049116	0.0000E+00
NLCON 40	EQ	0.1268971E-17	0.000000E+00	0.000000E+00	-0.2634199	0.1269E-17
NLCON 41	EQ	0.1522765E-17	0.000000E+00	0.000000E+00	0.3027199E-01	0.1523E-17
NLCON 42	EQ	-0.8580547E-12	0.000000E+00	0.000000E+00	0.8340031E-02	-0.8581E-12
NLCON 43	EQ	-0.4467620E-13	0.000000E+00	0.000000E+00	-0.4853620E-01	-0.4468E-13
NLCON 44	EQ	0.1198032E-14	0.000000E+00	0.000000E+00	0.5060694E-02	0.1198E-14
NLCON 45	EQ	-0.6884216E-10	0.000000E+00	0.000000E+00	0.1922204E-10	-0.6884E-10
NLCON 46	EQ	0.000000E+00	0.000000E+00	0.000000E+00	0.9229450E-01	0.0000E+00

NLCON 47	EQ	0.1152367E-16	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1980286	0.1152E-16
NLCON 48	EQ	0.7922523E-17	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.2316926E-01	0.7923E-17
NLCON 49	EQ	-0.8637661E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.3179505E-02	-0.8638E-12
NLCON 50	EQ	-0.8825403E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1921239E-01	-0.8825E-12
NLCON 51	EQ	0.1221174E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1701638E-02	0.1221E-12
NLCON 52	EQ	-0.8074238E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1451955E-10	-0.8074E-09
NLCON 53	EQ	0.4627254E-17	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.7051934E-01	0.4627E-17
NLCON 54	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1082103	0.0000E+00
NLCON 55	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1351957E-01	0.0000E+00
NLCON 56	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.8456894E-02	0.0000E+00
NLCON 57	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.9739340E-02	0.0000E+00
NLCON 58	EQ	-0.1884398E-16	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.582426E-03	-0.1884E-16
NLCON 59	EQ	-0.2558265E-17	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.4839108E-11	-0.2558E-17
NLCON 60	EQ	-0.9796890E-13	0.0000000E+00	0.0000000E+00	0.0000000E+00	-9.948297	-0.9797E-13
NLCON 61	EQ	0.5839055E-14	0.0000000E+00	0.0000000E+00	0.0000000E+00	6.561916	0.5839E-14
NLCON 62	EQ	-0.1560821E-13	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.559511	-0.1561E-13
NLCON 63	EQ	0.4086797E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.8660916	0.4087E-09
NLCON 64	EQ	-0.3380289E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.268229	-0.3380E-11
NLCON 65	EQ	0.3048619E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.8488208E-01	0.3049E-10
NLCON 66	EQ	0.5271162E-20	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2355974E-09	0.5271E-20
NLCON 67	EQ	0.3903064E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.3199563	0.3903E-10
NLCON 68	EQ	-0.2386095E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.8290975E-01	-0.2386E-11
NLCON 69	EQ	0.6207880E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1752628E-01	0.6208E-11
NLCON 70	EQ	0.9823930E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.7082692	0.9824E-09
NLCON 71	EQ	-0.6478620E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.067233	-0.6479E-10
NLCON 72	EQ	0.1632446E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.7567317E-01	0.1632E-09
NLCON 73	EQ	0.1947854E-18	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.3884263E-10	0.1948E-18
NLCON 74	EQ	0.1281493E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2726684	0.1281E-10
NLCON 75	EQ	-0.2224481E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.5922492E-01	-0.2224E-11
NLCON 76	EQ	0.4039331E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1588634E-01	0.4039E-11
NLCON 77	EQ	0.3179708E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.5714162	0.3180E-10
NLCON 78	EQ	-0.5677519E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.035958	-0.5678E-11
NLCON 79	EQ	0.1029282E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.8343251E-01	0.1029E-10
NLCON 80	EQ	0.7197246E-20	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.6118851E-11	0.7197E-20
NLCON 81	EQ	0.1067503E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	-28.42415	0.1068E-11
NLCON 82	EQ	0.2991362E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	64.58139	0.2991E-12
NLCON 83	EQ	0.3263528E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	-5.402213	0.3264E-12
NLCON 84	EQ	-0.1739308E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-148.7270	-0.1739E-10
NLCON 85	EQ	-0.5111264E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	407.6527	-0.5111E-11
NLCON 86	EQ	-0.2850572E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	-26.64372	-0.2851E-11
NLCON 87	EQ	0.6014369E-20	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1290097E-10	0.6014E-20
NLCON 88	EQ	-0.1581111E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2033717	-0.1581E-10
NLCON 89	EQ	-0.6985054E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.3972709	-0.6985E-10
NLCON 90	EQ	0.1366210E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.4706942E-01	0.1366E-10
NLCON 91	EQ	0.1021474E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.8333832E-01	0.1021E-09
NLCON 92	EQ	0.2047434E-09	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1974207	0.2047E-09
NLCON 93	EQ	-0.3887419E-18	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2267330E-01	-0.3887E-18
NLCON 94	EQ	-0.2784792E-18	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1775063E-10	-0.2785E-18
NLCON 95	EQ	0.1810348E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1082311	0.1810E-11
NLCON 96	EQ	0.1852775E-11	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.2757409	0.1853E-11
NLCON 97	EQ	0.1402341E-12	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.3158128E-01	0.1402E-12
NLCON 98	EQ	-0.6846581E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2699478E-02	-0.6847E-10
NLCON 99	EQ	0.9091204E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.3415759E-01	0.9091E-10
NLCON100	EQ	-0.3173042E-10	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.3412408E-02	-0.3173E-10
NLCON101	EQ	0.4210166E-20	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1683780E-10	0.4210E-20
NLCON102	EQ	-0.8790632E-13	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1047093	-0.8791E-13
NLCON103	EQ	-0.9031034E-13	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1881095	-0.9031E-13
NLCON104	EQ	-0.7479671E-13	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.2269984E-01	-0.7480E-13

```

NLCON105 EQ -0.5210694E-10 0.0000000E+00 0.5715803E-02 -0.5211E-10
NLCON106 EQ -0.2467057E-10 0.0000000E+00 0.1436729E-01 -0.2467E-10
NLCON107 EQ -0.3177492E-11 0.0000000E+00 0.0000000E-02 -0.3177E-11
NLCON108 EQ -0.6525769E-18 0.0000000E+00 -0.9678218E-11 -0.6526E-18

```

Exit NPSOL - Optimal solution found.

Final nonlinear objective value = 5.190844

Initial conditions for phase 10 before impuls maneuver

```

date = 8 20 1977 0.00 julian =2443375.50000000 tdurp = 0.00000000 critr = timrfl propid = lstep
primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000
state relative to idbody: earth
x = 0.514649030E+04 y = -0.289808128E+04 z = -0.286142123E+04 radius = 0.000000000E+00 scmass = 0.213689293E+06
vx = 0.844735665E+01 vy = 0.121185055E+02 vz = 0.291946710E+01 speed = 0.000000000E+00 fpa = 0.000000000E+00
sma = -0.378644735E+04 eccen = 0.273328701E+01 inc = 0.285000000E+02 argp = 0.293974405E+03 anlong = 0.337753198E+02
mean = -0.107441109E-07 truan = 0.000000000E+00 tfp = 0.000000000E+00 rperi = 0.656300000E+04 vperi = 0.000000000E+00

impuls maneuver print block
dvx = 0.240179315E+02 dvz = -0.4292664518E+02 dvz = 0.492657578E+02 tburn = 0.526378248E+05
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.213683206E+06 wprop = 0.786316794E+06

```

the file id and parameter list for this data file are

```

ipost file i.d. 0 10
-9 33std profil made by kent pid 3583executed 10/30/92 00:32:55using ipost loaded on 10-1
as config vs-3.0
time x y z vx vy vz sma rapoap period inc
anlong argp mean truan rperi vperi vperi eccen
speed btheti vinfxi vinfyi vinfzi vinfzi bdti bdti radius
deci btheto vinfxi vinfyi vinfzi bdti bdti hypa hypa c3i rai

```

```

date = 8 20 1977 0.24 julian =2443375.51000000 tdurp = earth 0.01000000 critr = timrf1 propid = lstep
primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000
timrf1 = 0.999999978E-02
state relative to idbody: earth
x = 0.321716882E+05 y = -0.289040146E+05 z = 0.433046238E+05 scmass = 0.608737610E+01
vx = 0.311152739E+02 vy = -0.29959875E+02 vz = 0.788985046E+00 speed = 0.432009687E+02 fpa = 0.855776192E+02
sma = -0.215702877E+03 eccen = 0.155893648E+02 inc = 0.116548273E+03 arqp = 0.267502949E+03 anlong = 0.316607533E+03
meanan = 0.113391336E+05 truan = 0.892444914E+02 tfp = 0.114936638E-01 rperi = 0.314696796E+04 vperi = 0.458392633E+02
Incoming Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.324759606E+02 vinfy = -0.278588825E+02 vinfz = -0.413632752E+01
bmag = 0.335574544E+04 btheta = 0.116681802E+03 bdt = -0.150684790E+04 bdr = 0.299840572E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.406240125E+02 dec = -0.552165236E+01 altit = 0.369264838E+05
Outgoing Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.309587872E+02 vinfy = -0.298134212E+02 vinfz = 0.792441916E+00
bmag = 0.335574544E+04 btheta = 0.116553138E+03 bdt = -0.150011089E+04 bdr = 0.300178193E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.425524005E+02 dec = 0.105626704E+01 altit = 0.369264838E+05
final conditions for phase 10
date = 8 20 1977 0.24 julian =2443375.51000000 tdurp = earth 0.01000000 critr = tdurp propid = lstep
primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000
timrf1 = 0.999999978E-02
state relative to idbody: earth
x = 0.321716882E+05 y = -0.289040146E+05 z = 0.433046238E+05 scmass = 0.608737610E+01
vx = 0.311152739E+02 vy = -0.29959875E+02 vz = 0.788985046E+00 speed = 0.432009687E+02 fpa = 0.855776192E+02
sma = -0.215702877E+03 eccen = 0.155893648E+02 inc = 0.116548273E+03 arqp = 0.267502949E+03 anlong = 0.316607533E+03
meanan = 0.113391336E+05 truan = 0.892444914E+02 tfp = 0.114936638E-01 rperi = 0.314696796E+04 vperi = 0.458392633E+02
Incoming Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.324759606E+02 vinfy = -0.278588825E+02 vinfz = -0.413632752E+01
bmag = 0.335574544E+04 btheta = 0.116681802E+03 bdt = -0.150684790E+04 bdr = 0.299840572E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.406240125E+02 dec = -0.552165236E+01 altit = 0.369264838E+05
Outgoing Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.309587872E+02 vinfy = -0.298134212E+02 vinfz = 0.792441916E+00
bmag = 0.335574544E+04 btheta = 0.116553138E+03 bdt = -0.150011089E+04 bdr = 0.300178193E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.425524005E+02 dec = 0.105626704E+01 altit = 0.369264838E+05

```

initial conditions for phase 11 before impuls maneuver

```

date = 8 20 1977 0.24 julian =2443375.51000000 tdurp = earth 0.01000000 critr = tdurp propid = lstep
primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000
timrf1 = 0.999999978E-02
state relative to idbody: earth
x = 0.321716882E+05 y = -0.289040146E+05 z = 0.433046238E+05 scmass = 0.608737610E+01
vx = 0.311152739E+02 vy = -0.29959875E+02 vz = 0.788985046E+00 speed = 0.432009687E+02 fpa = 0.855776192E+02
sma = -0.215702877E+03 eccen = 0.155893648E+02 inc = 0.116548273E+03 arqp = 0.267502949E+03 anlong = 0.316607533E+03
meanan = 0.113391336E+05 truan = 0.892444914E+02 tfp = 0.114936638E-01 rperi = 0.314696796E+04 vperi = 0.458392633E+02
Incoming Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.324759606E+02 vinfy = -0.278588825E+02 vinfz = -0.413632752E+01
bmag = 0.335574544E+04 btheta = 0.116681802E+03 bdt = -0.150684790E+04 bdr = 0.299840572E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.406240125E+02 dec = -0.552165236E+01 altit = 0.369264838E+05
Outgoing Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.309587872E+02 vinfy = -0.298134212E+02 vinfz = 0.792441916E+00
bmag = 0.335574544E+04 btheta = 0.116553138E+03 bdt = -0.150011089E+04 bdr = 0.300178193E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.425524005E+02 dec = 0.105626704E+01 altit = 0.369264838E+05

```

initial conditions for phase 11 after impuls maneuver

```

date = 8 20 1977 0.24 julian =2443375.51000000 tdurp = earth 0.01000000 critr = tdurp propid = lstep
primid = earth secid = earth idbody = earth frame = ecliptic epoch = mean2000
timrf1 = 0.999999978E-02
state relative to idbody: earth
x = 0.321716882E+05 y = -0.289040146E+05 z = 0.433046238E+05 scmass = 0.608737610E+01
vx = 0.311152739E+02 vy = -0.29959875E+02 vz = 0.788985046E+00 speed = 0.432009687E+02 fpa = 0.855776192E+02
sma = -0.215702877E+03 eccen = 0.155893648E+02 inc = 0.116548273E+03 arqp = 0.267502949E+03 anlong = 0.316607533E+03
meanan = 0.113391336E+05 truan = 0.892444914E+02 tfp = 0.114936638E-01 rperi = 0.314696796E+04 vperi = 0.458392633E+02
Incoming Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.324759606E+02 vinfy = -0.278588825E+02 vinfz = -0.413632752E+01
bmag = 0.335574544E+04 btheta = 0.116681802E+03 bdt = -0.150684790E+04 bdr = 0.299840572E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.406240125E+02 dec = -0.552165236E+01 altit = 0.369264838E+05
Outgoing Asymptote
altp = -0.323117204E+04 vinfm = 0.429873767E+02 vinfz = 0.309587872E+02 vinfy = -0.298134212E+02 vinfz = 0.792441916E+00
bmag = 0.335574544E+04 btheta = 0.116553138E+03 bdt = -0.150011089E+04 bdr = 0.300178193E+04 hypta = 0.863221628E+02
c3 = 0.184791455E+04 ra = -0.425524005E+02 dec = 0.105626704E+01 altit = 0.369264838E+05

```

```

state relative to idbody: earth
x      = 0.562307739E+06  y
vx     = 0.306680807E+02  vy
sma    = -0.219600282E+03  eccen
mean   = 0.203175025E+06  truan
Incoming Asymptote
      = -0.540219371E+06  z
      = -0.295793904E+02  vz
      = 0.154913381E+02  inc
      = 0.934517600E+02  tfp
      = 0.119391909E+05  radius = 0.779852234E+06  scmass = 0.601462472E+01
      = 0.817934336E+00  speed  = 0.426162002E+02  fpa    = 0.897506528E+02
      = 0.116807583E+03  argr  = 0.267531086E+03  anLong = 0.316591022E+03
      = 0.211550656E+00  rperi = 0.318230194E+04  vperi  = 0.454491921E+02

```

```

altp  = -0.319583806E+04  vinfm = 0.426042049E+02  vinfz = -0.276078065E+02  vinfz = -0.408695791E+01
bmag  = 0.339480698E+04  btheta = 0.116941799E+03  bdr  = 0.302635915E+04  hypata = 0.862988577E+02
c3    = 0.181511828E+04  ra      = -0.406177133E+02  altit = 0.773474094E+06
Outgoing Asymptote
altp  = -0.319583806E+04  vinfm = 0.426042049E+02  vinfz = -0.295710727E+02  vinfz = 0.817727397E+00
bmag  = 0.339480698E+04  btheta = 0.116812917E+03  bdr  = 0.302981142E+04  hypata = 0.862988577E+02
c3    = 0.181511828E+04  ra      = -0.425714892E+02  altit = 0.773474094E+06
    
```

final conditions for phase 11

```

date   = 8 20 1977  5.04  julian =2443375.71000000  tdurp = 0.20000000  critr = timrfl
primid = earth          secid  = earth          idbody = ecliptic
timrfl = 0.21000000E+00
state relative to idbody: earth
x      = 0.562307739E+06  y      = 0.119391909E+05  radius = 0.779852234E+06
vx     = 0.306680807E+02  vz     = 0.817934336E+00  speed  = 0.426162002E+02
sma    = -0.219600282E+03  eccen  = 0.154913381E+02  argp   = 0.267531086E+03
meanan = 0.203175025E+06  truan  = 0.221155065E+00  rperi  = 0.318230194E+04
Incoming Asymptote
altp  = -0.319583806E+04  vinfm = 0.426042049E+02  vinfz = -0.276078065E+02  vinfz = -0.408695791E+01
bmag  = 0.339480698E+04  btheta = 0.116941799E+03  bdr  = 0.302635915E+04  hypata = 0.862988577E+02
c3    = 0.181511828E+04  ra      = -0.406177133E+02  altit = 0.773474094E+06
Outgoing Asymptote
altp  = -0.319583806E+04  vinfm = 0.426042049E+02  vinfz = -0.295710727E+02  vinfz = 0.817727397E+00
bmag  = 0.339480698E+04  btheta = 0.116812917E+03  bdr  = 0.302981142E+04  hypata = 0.862988577E+02
c3    = 0.181511828E+04  ra      = -0.425714892E+02  altit = 0.773474094E+06
    
```

initial conditions for phase 12 before impuls maneuver

```

date   = 8 20 1977  5.04  julian =2443375.71000000  tdurp = 0.20000000  critr = timrfl
primid = earth          secid  = earth          idbody = ecliptic
timrfl = 0.21000000E+00
state relative to idbody: earth
x      = 0.562307739E+06  y      = 0.119391909E+05  radius = 0.779852234E+06
vx     = 0.306680807E+02  vz     = 0.817934336E+00  speed  = 0.426162002E+02
sma    = -0.219600282E+03  eccen  = 0.154913381E+02  argp   = 0.267531086E+03
meanan = 0.203175025E+06  truan  = 0.221155065E+00  rperi  = 0.318230194E+04
    
```

impuls maneuver print block

```

dvx   = 0.327472271E-01  dvz   = 0.516894090E-01  dvmag  = 0.612011171E-01
thrust = 0.20000000E+06  spi   = 0.48000000E+03  dmass  = 0.776936929E-01  wprop  = 0.786316644E+06
    
```

initial conditions for phase 12 after impuls maneuver

```

date   = 8 22 1977  5.04  julian =2443377.71000000  tdurp = 2.00000000  critr = timrfl
primid = earth          secid  = earth          idbody = ecliptic
timrfl = 0.22100000E+01
state relative to idbody: earth
x      = 0.586491577E+07  y      = 0.1533429146E+06  radius = 0.815073990E+07
vx     = 0.306854362E+02  vz     = 0.818783041E+00  speed  = 0.426543175E+02
sma    = -0.219096367E+03  eccen  = 0.161133523E+02  argp   = 0.267720382E+03
meanan = 0.213106950E+07  truan  = 0.221128689E+01  rperi  = 0.331128057E+04
Incoming Asymptote
altp  = -0.306685943E+04  vinfm = 0.426531710E+02  vinfz = -0.275097491E+02  vinfz = -0.373245976E+01
bmag  = 0.352357178E+04  btheta = 0.120774636E+03  bdr  = 0.302740525E+04  hypata = 0.864419184E+02
c3    = 0.181929299E+04  ra      = -0.403494245E+02  altit = 0.814436176E+07
Outgoing Asymptote
    
```



altp = -0.306685943E+04    vinfm = 0.426531710E+02    vinfz = 0.818761245E+00  
bmeg = 0.352357178E+04    bcheta = 0.120650090E+03    hypba = 0.864419184E+02  
c3 = 0.181929299E+04    ra = -0.424452406E+02    altit = 0.814436176E+07

final conditions for phase 12

```

date = 8 22 1977 5.04 julian =2443377.71000000 tdurp = earth 2.00000000 critr = timrfl
primid = earth secid = earth idbody = earth frame = ecliptic propid = lstep
timrfl = 0.221000000E+01 z = 0.565807241E+07 v = 0.153429146E+06 radius = 0.815073990E+07 scmass = 0.593693257E+01
state relative to idbody: earth z = -0.296162861E+02 vz = 0.818783041E+00 speed = 0.426543175E+02 fpa = 0.899752317E+02
vx = 0.306854362E+02 vy = 0.161133523E+02 inc = 0.120643834E+03 argp = 0.267720382E+03 anlong = 0.316667461E+03
sma = -0.219096367E+03 eccen = 0.935333129E+02 tfp = 0.221128689E+01 rperi = 0.331128057E+04 vperi = 0.453877303E+02
mean = 0.213106951E+07 truan = 0.935333129E+02 tfp = 0.221128689E+01 rperi = 0.331128057E+04 vperi = 0.453877303E+02
Incoming Asymptote
altp = -0.306685943E+04 vinfm = 0.426531710E+02 vinfz = -0.275097949E+02 vinfz = -0.373245976E+01
bmag = 0.352357178E+04 btheta = 0.120774636E+03 bdt = -0.180287980E+04 bdr = 0.302740525E+04 hypta = 0.864419184E+02
c3 = 0.181929299E+04 ra = -0.403494245E+02 dec = -0.502021452E+01 altit = 0.814436176E+07
Outgoing Asymptote
altp = -0.306685943E+04 vinfm = 0.426531710E+02 vinfz = -0.275097949E+02 vinfz = 0.818761245E+00
bmag = 0.352357178E+04 btheta = 0.120650090E+03 bdt = -0.179629473E+04 bdr = 0.303131710E+04 hypta = 0.864419184E+02
c3 = 0.181929299E+04 ra = -0.424452408E+02 dec = 0.109990522E+01 altit = 0.814436176E+07

```

initial conditions for phase 13 before impuls maneuver

```

date = 8 22 1977 5.04 julian =2443377.71000000 tdurp = earth 2.00000000 critr = timrfl
primid = sun secid = earth idbody = earth frame = ecliptic propid = lstep
state relative to idbody: earth z = 0.565807241E+07 v = 0.153429146E+06 radius = 0.815073990E+07 scmass = 0.593693257E+01
vx = 0.586491577E+07 vy = -0.296162861E+02 vz = 0.818783041E+00 speed = 0.426543175E+02 fpa = 0.899752317E+02
sma = -0.219096367E+03 eccen = 0.161133523E+02 inc = 0.120643834E+03 argp = 0.267720382E+03 anlong = 0.316667461E+03
mean = 0.213106950E+07 truan = 0.935333129E+02 tfp = 0.221128689E+01 rperi = 0.331128057E+04 vperi = 0.453877303E+02
impuls maneuver print block
dvx = 0.147739868E+01 dvz = -0.194529550E+01 dtburn = 0.7492771162E-01
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.246410141E+01 wprop = 0.786314180E+06

```

initial conditions for phase 13 after impuls maneuver

```

date = 8 24 1977 12.00 julian =2443379.99999999 tdurp = earth 2.28999999 critr = timrfl
primid = sun secid = earth idbody = earth frame = ecliptic propid = lstep
state relative to idbody: earth z = 0.119284276E+08 v = 0.440315042E+06 radius = 0.171088969E+08 scmass = 0.347283284E+01
vx = 0.122569609E+08 vy = -0.315857611E+02 vz = 0.145292488E+01 speed = 0.451870104E+02 fpa = 0.896011831E+02
sma = -0.195218295E+03 eccen = 0.610034621E+03 inc = 0.112715747E+03 argp = 0.271903668E+03 anlong = 0.316395773E+03
mean = 0.502100332E+07 truan = 0.896951030E+02 tfp = 0.438193565E+01 rperi = 0.118894700E+06 vperi = 0.452606276E+02
Incoming Asymptote
altp = 0.112516560E+06 vinfm = 0.451866494E+02 vinfz = 0.323241174E+02 vinfz = 0.131633258E+01
bmag = 0.119089759E+06 btheta = 0.112725932E+03 bdt = -0.460071768E+05 bdr = 0.109844027E+06 hypta = 0.899060778E+02
c3 = 0.204181931E+04 ra = -0.443032757E+02 dec = 0.166932560E+01 altit = 0.171025188E+08
Outgoing Asymptote
altp = 0.112516560E+06 vinfm = 0.451866494E+02 vinfz = 0.323241174E+02 vinfz = 0.145290996E+01
bmag = 0.119089759E+06 btheta = 0.112728156E+03 bdt = -0.460114420E+05 bdr = 0.109842241E+06 hypta = 0.899060778E+02
c3 = 0.204181931E+04 ra = -0.443377600E+02 dec = 0.184258504E+01 altit = 0.171025188E+08
state relative primary body: sun
x = 0.145179667E+09 y = -0.840380327E+08 z = 0.437030705E+06
vx = 0.459897138E+02 vy = -0.551354886E+01 vz = 0.145402883E+01
sma = -0.234767565E+09 eccen = 0.114150594E+01 inc = 0.420767629E+01
argp = 0.241736323E+03 anlong = 0.327905974E+03 mean = 0.180532107E+02

```

final conditions for phase 13

date = 6 17 1979 3.14 julian = 2444041.63102000 tdurp = 663.92102000 critr = timrf1 propid = lstep  
primid = sun secid = earth idbody = earth frame = ecliptic epoch = mean2000  
timrf1 = 0.666131020E+03

```

state relative to idbody: earth
x = 0.528792935E+09 y = 0.692481418E+09 z = 0.126012838E+08
vx = -0.554066841E+02 vy = 0.260647562E+01 vz = -0.101096878E+01
sma = -0.129511803E+03 eccen = 0.515210557E+07 inc = 0.22041445E+01
meanan = 0.247931494E+09 truan = 0.400266995E+02 tfp = 0.116920439E+03
Incoming Asymptote
altp = 0.567251976E+09 vinfm = 0.554771620E+02 vinfz = 0.260649290E+01
bmag = 0.667258484E+09 btheta = -0.195968910E+01 bdt = 0.666868227E+09
c3 = 0.307771550E+04 ra = 0.177306624E+03 dec = -0.104416674E+01
Outgoing Asymptote
altp = 0.667251976E+09 vinfm = 0.554771620E+02 vinfz = 0.260647140E+01
bmag = 0.667258484E+09 btheta = -0.195968870E+01 bdt = 0.666868227E+09
c3 = 0.307771550E+04 ra = 0.177306646E+03 dec = -0.104416750E+01
state relative primary body: sun
x = 0.540935347E+09 z = 0.125942687E+08
vx = -0.261902913E+02 vy = 0.223474083E+00 vz = -0.100981216E+01
sma = -0.390455646E+09 eccen = 0.219732241E+01 inc = 0.420767629E+01
argp = 0.102782260E+03 anlong = 0.327905974E+03 meanan = 0.670882663E+02

```

initial conditions for phase 17 before impuls maneuver

```

date = 6 17 1979 3.14 julian =2444041.63102000 tdurp = 663.92102000
primid = jupiter secid = earth idbody = jupiter
state relative to idbody: jupiter
x = 0.306159889E+08 y = -0.141746713E+08 z = 0.208687118E+07
vx = -0.169190675E+02 vy = 0.899503266E+01 vz = -0.123539388E+01
sma = -0.350695774E+06 eccen = 0.545090592E+01 inc = 0.51909747E+01
meanan = -0.536628119E+04 truan = 0.400266995E+02 tfp = 0.116920439E+03
impuls maneuver print block
dvx = 0.321533374E-03 dvz = 0.250805969E-03
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.313769080E-03

```

initial conditions for phase 17 after impuls maneuver

```

date = 6 25 1979 12.00 julian =2444049.99999999 tdurp = 8.36897999
primid = jupiter secid = earth idbody = jupiter
state relative to idbody: jupiter
x = 0.186807615E+08 y = -0.764803680E+07 z = 0.118696987E+07
vx = -0.165956126E+02 vy = 0.906121698E+01 vz = -0.125008973E+01
sma = -0.365560370E+06 eccen = 0.632774920E+01 inc = 0.518742040E+01
meanan = -0.304133670E+04 truan = -0.926648783E+02 tfp = -0.120643189E+02
Incoming Asymptote
altp = 0.187621597E+07 vinfm = 0.186159168E+02 vinfz = 0.891779366E+01
bmag = 0.228410620E+07 btheta = 0.354874801E+01 bdt = 0.227972642E+07
c3 = 0.346552357E+03 ra = 0.151308779E+03 dec = -0.378603454E+01
Outgoing Asymptote
altp = 0.187621597E+07 vinfm = 0.186159168E+02 vinfz = 0.891779366E+01
bmag = 0.228410620E+07 btheta = 0.455181100E+01 bdt = 0.227690208E+07
c3 = 0.346552357E+03 ra = 0.168224279E+03 dec = -0.249066353E+01
state relative to secondary body: earth
x = -0.568569496E+09 y = 0.692846601E+09 z = 0.118765607E+08
vx = -0.550133143E+02 vy = -0.159616862E+01 vz = -0.100799717E+01
sma = -0.131550114E+03 eccen = 0.539249635E+07 inc = 0.205774462E+01
argp = 0.120663065E+03 anlong = 0.331015066E+03 meanan = 0.238645951E+09

```

final conditions for phase 17

date = 7 5 1979 3.14 julian = 2444059.63102000 tdurp = 18.00000000 critr = timrfl propid = lstep  
primid = jupiter secid = earth idbody = jupiter frame = ecliptic epoch = mean2000

```

timrf1 = 0.684131020E+03
state relative to idbody: jupiter
  x = 0.400676179E+07  y = -0.639418859E+05  z = 0.118554270E+06
  vx = -0.193168363E+02  vy = 0.917226734E+01  vz = -0.133644213E+01
  sma = -0.320029687E+06  eccen = 0.568932792E+01  inc = 0.518742040E+01
  meanan = -0.616540578E+03  truan = -0.200330331E+01  rperi = 0.150072415E+07
Incoming Asymptote
  altp = 0.142932615E+07  vinfm = 0.198961410E+02  vinfz = 0.177973574E+02
  bmag = 0.179240774E+07  btheta = 0.370213015E+01  bdt = 0.178866738E+07
  c3 = 0.395856425E+03  ra = 0.153678157E+01  dec = -0.363620316E+01
Outgoing Asymptote
  altp = 0.142932615E+07  vinfm = 0.198961410E+02  vinfz = 0.177973574E+02
  bmag = 0.179240774E+07  btheta = 0.473012808E+01  bdt = 0.178630310E+07
  c3 = 0.395856425E+03  ra = 0.173224813E+03  dec = -0.213202986E+01
state relative to secondary body: earth
  x = -0.614919953E+09  y = 0.689535677E+09  z = 0.110087801E+08
  vx = -0.569046839E+02  vy = -0.633027797E+01  vz = -0.109701403E+01
  sma = -0.121546103E+03  eccen = 0.620007279E+07  inc = 0.195356479E+01
  argp = 0.124190309E+03  anlong = 0.332172854E+03  meanan = 0.252008105E+09

```

initial conditions for phase 18 before impuls maneuver

```

date = 7 5 1979 3.14 julian =2444059.63102000  tdurp = 18.00000000
primid = jupiter  secid = earth  idbody = jupiter
state relative to idbody: jupiter
  x = 0.400676179E+07  y = -0.639418859E+05  z = 0.118554270E+06
  vx = -0.193168363E+02  vy = 0.917226734E+01  vz = -0.133644213E+01
  sma = -0.320029687E+06  eccen = 0.568932792E+01  inc = 0.518742040E+01
  meanan = -0.616540578E+03  truan = -0.200330331E+01  rperi = 0.150072415E+07
impuls maneuver print block
dvx = -0.568354464E-04  dvz = -0.262689444E-04  dvmag = 0.135201308E-03
thrust = 0.200000000E+06  spi = 0.480000000E+03  dmass = 0.997512448E-04  wprop = 0.786314179E+06

```

initial conditions for phase 18 after impuls maneuver

```

date = 7 5 1979 12.00 julian =2444059.99999999  tdurp = 0.36897999
primid = jupiter  secid = earth  idbody = jupiter
state relative to idbody: jupiter
  x = 0.338717581E+07  y = 0.230625556E+06  z = 0.756523965E+05
  vx = -0.196128868E+02  vy = 0.919951425E+01  vz = -0.134726611E+01
  sma = -0.319510537E+06  eccen = 0.571986492E+01  inc = 0.518815080E+01
  meanan = -0.503543424E+03  truan = -0.697025889E+02  tfp = -0.163216608E+01
Incoming Asymptote
  altp = 0.143664858E+07  vinfm = 0.199122983E+02  vinfz = 0.177981954E+02
  bmag = 0.179941046E+07  btheta = 0.369726599E+01  bdt = 0.179566534E+07
  c3 = 0.396499624E+03  ra = 0.153590533E+03  dec = -0.364219107E+01
Outgoing Asymptote
  altp = 0.143664858E+07  vinfm = 0.199122983E+02  vinfz = 0.177981954E+02
  bmag = 0.179941046E+07  btheta = 0.472356563E+01  bdt = 0.179329895E+07
  c3 = 0.396499624E+03  ra = 0.173004672E+03  dec = -0.214832454E+01
state relative to secondary body: earth
  x = -0.616737092E+09  y = 0.689333124E+09  z = 0.109735083E+08
  vx = -0.571539629E+02  vy = -0.648503697E+01  vz = -0.110802104E+01
  sma = -0.120428273E+03  eccen = 0.626738812E+07  inc = 0.195626056E+01

```

argp = 0.124345895E+03 anlong = 0.332143100E+03 meaan = 0.254429196E+09  
final conditions for phase 18  
date = 7 6 1979 15.14 julian =2444061.13102000 tdurp = 1.50000000 critr = timrf1 propid = lstep

```

primid = jupiter
timrfl = 0.685631020E+03
state relative to idbody: jupiter
x = 0.139164583E+07 y = 0.110761256E+07 z = 0.177951034E+07
vx = -0.215454596E+02 vy = 0.836672893E+01 vz = 0.231511912E+02
sma = -0.321868536E+06 eccen = 0.567226417E+01 inc = 0.518815080E+03
meanan = -0.154107901E+03 truan = -0.351362761E+02 tfp = 0.150385483E+07
Incoming Asymptote
altp = 0.143245683E+07 vinfm = 0.198392258E+02 vinfz = 0.877464073E+01
bmag = 0.179712728E+07 btheta = 0.370377495E+01 bdt = 0.116090292E+06
c3 = 0.393594880E+03 ra = 0.153693088E+01 dec = 0.170811234E+07
Outgoing Asymptote
altp = 0.143245683E+07 vinfm = 0.198392258E+02 vinfz = 0.208210946E+01
bmag = 0.179712728E+07 btheta = 0.473373078E+01 bdt = 0.148308338E+06
c3 = 0.393594880E+03 ra = 0.173309199E+03 dec = 0.170811234E+07
state relative to secondary body: earth
x = -0.622393900E+09 y = 0.688650230E+09 z = 0.108648744E+08
vx = -0.589367333E+02 vy = -0.78736652E+01 vz = -0.109125315E+01
sma = -0.11270333E+03 eccen = 0.679019400E+07 inc = 0.186109955E+01
argp = 0.124402818E+03 anlong = 0.333220656E+03 meanan = 0.267119008E+09

```

initial conditions for phase 19 before impuls maneuver

```

date = 7 6 1979 15.14 julian =2444061.13102000 tdurp = 1.50000000
primid = jupiter secid = earth idbody = jupiter
state relative to idbody: jupiter
x = 0.139164583E+07 y = 0.110761256E+07 z = 0.177951034E+07
vx = -0.215454596E+02 vy = 0.836672893E+01 vz = 0.231511912E+02
sma = -0.321868536E+06 eccen = 0.567226417E+01 inc = 0.518815080E+03
meanan = -0.154107901E+03 truan = -0.351362761E+02 tfp = 0.150385483E+07
impuls maneuver print block
dvx = -0.180804265E-03 dvz = 0.781759852E-04 dvmag = 0.108976392E-03
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.166084969E-03

```

initial conditions for phase 19 after impuls maneuver

```

date = 7 7 1979 3.14 julian =2444061.63102000 tdurp = 0.50000000
primid = jupiter secid = earth idbody = jupiter
state relative to idbody: jupiter
x = 0.432742394E+06 y = 0.143564622E+07 z = 0.150360260E+07
vx = -0.227388911E+02 vy = 0.663415878E+01 vz = -0.121222216E+01
sma = -0.321730253E+06 eccen = 0.567339385E+01 inc = 0.518786447E+01
meanan = -0.154578733E+01 truan = -0.395247039E+00 tfp = 0.150357218E+07
Incoming Asymptote
altp = 0.143217418E+07 vinfm = 0.198434889E+02 vinfz = 0.877538735E+01
bmag = 0.179672442E+07 btheta = 0.370387995E+01 bdt = 0.116068190E+06
c3 = 0.393764051E+03 ra = 0.153696780E+03 dec = 0.143220460E+07
Outgoing Asymptote
altp = 0.143217418E+07 vinfm = 0.198434889E+02 vinfz = 0.20826245E+01
bmag = 0.179672442E+07 btheta = 0.473349896E+01 bdt = 0.148267847E+06
c3 = 0.393764051E+03 ra = 0.173308983E+03 dec = 0.143220460E+07
state relative to secondary body: earth
x = -0.624966617E+09 y = 0.688271391E+09 z = 0.108198206E+08
vx = -0.600608939E+02 vy = -0.987096633E+01 vz = -0.973829305E+00

```



sma    =-0.107564315E+03   eccen   = 0.725837557E+07   inc    = 0.166247563E+01  
argp   = 0.123463937E+03   anlong = 0.335880242E+03   meaan  = 0.268908739E+09  
final conditions for phase 19

```

date = 7 1979 3.14 julian = 2444061.63102000 tdurp = 0.50000000 critr = timrfl propid = 1step
primid = jupiter secid = earth idbody = jupiter epoch = mean2000
timrfl = 0.686131020E+03
state relative to idbody: jupiter
x = 0.432742394E+06 y = 0.143564622E+07 z = 0.111690319E+06 scmass = 0.347292780E+01
vx = -0.227388911E+02 vy = 0.661415878E+01 vz = -0.121222216E+01 fpa = -0.336020078E+00
sma = -0.321730253E+06 eccen = 0.567339385E+01 inc = 0.518786447E+01 arcp = 0.235630953E+03 anlong = 0.198100321E+03
meaan = -0.154578733E+01 truan = -0.395247099E+00 tfp = -0.506275878E-02 rperi = 0.150357218E+07 vperi = 0.237123840E+02
Incoming Asymptote
altp = 0.143217418E+07 vinfm = 0.198434889E+02 vinfz = 0.877538735E+01 vinfz = -0.125809966E+01
bmag = 0.179672442E+07 btheta = 0.370387995E+01 bdt = 0.179297150E+07 bdr = 0.116068190E+06 hypta = 0.798479314E+02
c3 = 0.393764051E+03 ra = 0.153696780E+03 dec = -0.363505538E+01 altit = 0.1432220460E+07
Outgoing Asymptote
altp = 0.143217418E+07 vinfm = 0.198434889E+02 vinfz = 0.208269245E+01 vinfz = -0.736002003E+00
bmag = 0.179672442E+07 btheta = 0.473349896E+01 bdt = 0.179059635E+07 bdr = 0.148267847E+06 hypta = 0.798479314E+02
c3 = 0.393764051E+03 ra = 0.173308983E+03 dec = -0.212560823E+01 altit = 0.1143220460E+07
state relative to secondary body: earth
x = -0.624966617E+09 y = 0.688271391E+09 z = 0.108198206E+08
vx = -0.600608939E+02 vy = -0.987096633E+01 vz = -0.973829305E+00
sma = -0.107564315E+03 eccen = 0.725837557E+07 inc = 0.166247563E+01
argp = 0.123463937E+03 anlong = 0.335880242E+03 meaan = 0.268908739E+09

```

initial conditions for phase 20

```

esn = 20.000 fesh= 20.000
time= 2.44406163D+06
normal termination
cpu = 1.770 seconds

```

execution date and time Thu Oct 29

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\*\*\* n p s o l s u m m a r y o u t p u t \*\*\*

		variables		residual		name		phase		constraints		residual		name		objective function	
		phase	value	value	value	value	name	phase	value	value	value	value	name	phase	value	value	value
1	dvx	10.0	0.24017931E+02	0.0000000E+00	tfp	20.0	-0.50627588E-02	0.78496517E-10	dvsum	20.0	0.519084431E+02						
2	dvy	10.0	-0.42926452E+02	0.0000000E+00	bdti	20.0	0.17929715E+07	0.49024238E-03									
3	dvz	10.0	-0.2752017E+01	0.0000000E+00	bdr	20.0	0.11606819E+06	0.24088510E-03									
4	dvx	11.0	0.28403643E-01	0.0000000E+00	10x	0.0	0.0000000E+00	0.0000000E+00									
5	dvy	11.0	-0.48920737E-01	0.0000000E+00	10y	0.0	0.0000000E+00	0.0000000E+00									
6	dvz	11.0	-0.17783205E-02	0.0000000E+00	10z	0.0	0.0000000E+00	0.0000000E+00									
7	dvx	12.0	0.32747227E-01	0.0000000E+00	10u	0.0	-0.49737992E-13	0.49737992E-13									
8	dvy	12.0	-0.51689409E-01	0.0000000E+00	10v	0.0	0.74251716E-12	0.74251716E-12									
9	dvz	12.0	0.11835729E-02	0.0000000E+00	10w	0.0	0.52707838E-13	0.52707838E-13									
10	dvx	13.0	0.14773987E+01	0.0000000E+00	10m	0.0	0.22309836E-05	0.22309836E-05									
11	dvy	13.0	-0.19452955E+01	0.0000000E+00	11x	0.0	0.0000000E+00	0.0000000E+00									
12	dvz	13.0	0.63577463E+00	0.0000000E+00	11y	0.0	0.0000000E+00	0.0000000E+00									
13	dvx	17.0	0.3215337E-03	0.0000000E+00	11z	0.0	0.0000000E+00	0.0000000E+00									
14	dvy	17.0	-0.25080597E-03	0.0000000E+00	11u	0.0	-0.48814286E-11	0.48814286E-11									
15	dvz	17.0	0.12084323E-03	0.0000000E+00	11v	0.0	-0.37303494E-12	0.37303494E-12									
16	dvx	18.0	-0.56835446E-04	0.0000000E+00	11w	0.0	-0.36248782E-12	0.36248782E-12									
17	dvy	18.0	-0.26286894E-04	0.0000000E+00	11m	0.0	-0.14462317E-05	0.14462317E-05									
18	dvz	18.0	-0.11982539E-03	0.0000000E+00	12x	0.0	0.0000000E+00	0.0000000E+00									
19	dvx	19.0	-0.18080426E-03	0.0000000E+00	12y	0.0	0.26775524E-08	0.26775524E-08									
20	dvy	19.0	-0.78175985E-04	0.0000000E+00	12z	0.0	0.0000000E+00	0.0000000E+00									
21	dvz	19.0	0.10897639E-03	0.0000000E+00	12u	0.0	-0.36699532E-11	0.36699532E-11									
22	e 11x	0.0	0.32171689E+05	0.0000000E+00	12v	0.0	-0.49737992E-13	0.49737992E-13									
23	e 11y	0.0	-0.28904015E+05	0.0000000E+00	12w	0.0	0.33384406E-12	0.33384406E-12									
24	e 11z	0.0	-0.21979214E+04	0.0000000E+00	12m	0.0	-0.15450362E-05	0.15450362E-05									
25	e 11u	0.0	0.31115274E+02	0.0000000E+00	13x	0.0	-0.11026859E-05	0.11026859E-05									
26	e 11v	0.0	-0.29958987E+02	0.0000000E+00	13y	0.0	0.53644180E-06	0.53644180E-06									
27	e 11w	0.0	0.78898505E+00	0.0000000E+00	13z	0.0	0.28812792E-08	0.28812792E-08									
28	e 11m	0.0	0.60873761E+01	0.0000000E+00	13u	0.0	0.30198066E-11	0.30198066E-11									
29	e 11x	0.0	0.56230774E+06	0.0000000E+00	13v	0.0	0.41655568E-12	0.41655568E-12									
30	e 12y	0.0	-0.54021937E+06	0.0000000E+00	13w	0.0	0.12967405E-12	0.12967405E-12									
31	e 12z	0.0	0.11939191E+05	0.0000000E+00	13m	0.0	0.16712238E-05	0.16712238E-05									
32	e 12u	0.0	-0.29579390E+02	0.0000000E+00	17x	0.0	-0.93132257E-07	0.93132257E-07									
33	e 12v	0.0	0.30668081E+02	0.0000000E+00	17y	0.0	0.10617077E-06	0.10617077E-06									
34	e 12w	0.0	0.81793434E+00	0.0000000E+00	17z	0.0	-0.46566129E-09	0.46566129E-09									
35	e 12m	0.0	0.60146247E+01	0.0000000E+00	17u	0.0	0.46824766E-10	0.46824766E-10									
36	e 13x	0.0	0.58649158E+07	0.0000000E+00	17v	0.0	-0.11842971E-10	0.11842971E-10									
37	e 13y	0.0	-0.56580724E+07	0.0000000E+00	17w	0.0	0.11857182E-12	0.11857182E-12									
38	e 13z	0.0	0.15342915E+06	0.0000000E+00	17m	0.0	-0.48732094E-03	0.48732094E-03									
39	e 13u	0.0	0.30685436E+02	0.0000000E+00	18x	0.0	0.0000000E+00	0.0000000E+00									
40	e 13v	0.0	-0.29616286E+02	0.0000000E+00	18y	0.0	0.36379788E-10	0.36379788E-10									
41	e 13w	0.0	0.81878304E+00	0.0000000E+00	18z	0.0	0.43655746E-10	0.43655746E-10									
42	e 13m	0.0	0.59369326E+01	0.0000000E+00	18u	0.0	-0.20197177E-10	0.20197177E-10									
43	e 17x	0.0	-0.54032621E+09	0.0000000E+00	18v	0.0	-0.10516032E-11	0.10516032E-11									
44	e 17y	0.0	0.54093535E+09	0.0000000E+00	18w	0.0	0.28199665E-13	0.28199665E-13									
45	e 17z	0.0	0.12594269E+08	0.0000000E+00	18m	0.0	-0.14710834E-04	0.14710834E-04									
46	e 17u	0.0	-0.26190291E+02	0.0000000E+00	19x	0.0	0.0000000E+00	0.0000000E+00									
47	e 17v	0.0	0.22347408E+00	0.0000000E+00	19y	0.0	0.23283064E-09	0.23283064E-09									
48	e 17w	0.0	-0.10098122E+01	0.0000000E+00	19z	0.0	0.16007107E-09	0.16007107E-09									
49	e 17m	0.0	0.34728328E+01	0.0000000E+00	19u	0.0	-0.20349944E-10	0.20349944E-10									
50	e 18x	0.0	0.40067618E+07	0.0000000E+00	19v	0.0	-0.20792257E-10	0.20792257E-10									

51	e 18y	0.0	-0.63941886E+05	0.00000000E+00	19w	0.0	0.28770319E-11	0.28770319E-11
52	e 18z	0.0	0.11855427E+06	0.00000000E+00	19m	0.0	-0.17253781E-03	0.17253781E-03
53	e 18u	0.0	-0.19316836E+02	0.00000000E+00	20x	0.0	0.58207661E-10	0.58207661E-10
54	e 18v	0.0	0.91722673E+01	0.00000000E+00	20y	0.0	0.00000000E+00	0.00000000E+00
55	e 18w	0.0	-0.13364421E+01	0.00000000E+00	20z	0.0	0.00000000E+00	0.00000000E+00
56	e 18m	0.0	0.34730064E+01	0.00000000E+00	20u	0.0	0.00000000E+00	0.00000000E+00
57	e 19x	0.0	0.13916458E+07	0.00000000E+00	20v	0.0	0.00000000E+00	0.00000000E+00
58	e 19y	0.0	-0.11076126E+07	0.00000000E+00	20w	0.0	-0.44408921E-15	0.44408921E-15
59	e 19z	0.0	-0.56332170E+05	0.00000000E+00	20m	0.0	-0.54667382E-12	0.54667382E-12
60	e 19u	0.0	-0.21545460E+02	0.00000000E+00	10x	0.0	-0.45337246E-09	0.45337246E-09
61	e 19v	0.0	0.83667289E+01	0.00000000E+00	10y	0.0	0.27021499E-10	0.27021499E-10
62	e 19w	0.0	-0.13299131E+01	0.00000000E+00	10z	0.0	-0.72230413E-10	0.72230413E-10
63	e 19m	0.0	0.34729213E+01	0.00000000E+00	10u	0.0	0.10683757E-10	0.10683757E-10
64	e 20x	0.0	0.43274239E+06	0.00000000E+00	10v	0.0	-0.88367952E-13	0.88367952E-13
65	e 20y	0.0	0.14356462E+07	0.00000000E+00	10w	0.0	0.79697396E-12	0.79697396E-12
66	e 20z	0.0	-0.11169032E+06	0.00000000E+00	10m	0.0	0.19555397E-17	0.19555397E-17
67	e 20u	0.0	-0.22738891E+02	0.00000000E+00	11x	0.0	0.90311389E-08	0.90311389E-08
68	e 20v	0.0	0.66141588E+01	0.00000000E+00	11y	0.0	-0.55210914E-09	0.55210914E-09
69	e 20w	0.0	-0.12122222E+01	0.00000000E+00	11z	0.0	0.14364152E-08	0.14364152E-08
70	e 20m	0.0	0.34729278E+01	0.00000000E+00	11u	0.0	0.10959449E-11	0.10959449E-11
71	o 10x	0.0	0.51464903E+04	0.00000000E+00	11v	0.0	-0.72274692E-13	0.72274692E-13
72	o 10y	0.0	-0.28980813E+04	0.00000000E+00	11w	0.0	0.18211349E-12	0.18211349E-12
73	o 10z	0.0	-0.28614212E+04	0.00000000E+00	11m	0.0	0.36131554E-17	0.36131554E-17
74	o 10u	0.0	0.32465288E+02	0.00000000E+00	12x	0.0	0.27375740E-09	0.27375740E-09
75	o 10v	0.0	-0.30807946E+02	0.00000000E+00	12y	0.0	-0.47523691E-10	0.47523691E-10
76	o 10w	0.0	0.16744937E+00	0.00000000E+00	12z	0.0	0.86284301E-10	0.86284301E-10
77	o 10m	0.0	0.60873761E+01	0.00000000E+00	12u	0.0	0.35425356E-14	0.35425356E-14
78	o 11x	0.0	0.32171688E+05	0.00000000E+00	12v	0.0	-0.63258237E-15	0.63258237E-15
79	o 11y	0.0	-0.28904015E+05	0.00000000E+00	12w	0.0	0.11463947E-14	0.11463947E-14
80	o 11z	0.0	-0.21979214E+04	0.00000000E+00	12m	0.0	0.13350473E-19	0.13350473E-19
81	o 11u	0.0	0.31143677E+02	0.00000000E+00	13x	0.0	0.16179162E-08	0.16179162E-08
82	o 11v	0.0	-0.30007908E+02	0.00000000E+00	13y	0.0	0.45337304E-09	0.45337304E-09
83	o 11w	0.0	0.78720673E+00	0.00000000E+00	13z	0.0	0.49462271E-09	0.49462271E-09
84	o 11m	0.0	0.60146247E+01	0.00000000E+00	13u	0.0	-0.79930508E-15	0.79930508E-15
85	o 12x	0.0	-0.56230774E+06	0.00000000E+00	13v	0.0	-0.35392033E-15	0.35392033E-15
86	o 12y	0.0	0.54021937E+06	0.00000000E+00	13w	0.0	-0.12351609E-15	0.12351609E-15
87	o 12z	0.0	0.11939191E+05	0.00000000E+00	13m	0.0	0.33607325E-22	0.33607325E-22
88	o 12u	0.0	0.30700828E+02	0.00000000E+00	17x	0.0	-0.74540668E-09	0.74540668E-09
89	o 12v	0.0	-0.29631080E+02	0.00000000E+00	17y	0.0	-0.32909900E-08	0.32909900E-08
90	o 12w	0.0	0.81911791E+00	0.00000000E+00	17z	0.0	0.64367869E-09	0.64367869E-09
91	o 12m	0.0	0.59369326E+01	0.00000000E+00	17u	0.0	0.23209344E-14	0.23209344E-14
92	o 13x	0.0	0.13597618E+09	0.00000000E+00	17v	0.0	0.46465869E-14	0.46465869E-14
93	o 13y	0.0	-0.14998658E+06	0.00000000E+00	17m	0.0	-0.88215230E-15	0.88215230E-15
94	o 13z	0.0	0.46870577E+02	0.00000000E+00	18x	0.0	-0.57395859E-19	0.57395859E-19
95	o 13u	0.0	-0.60490767E+01	0.00000000E+00	18y	0.0	0.60070486E-09	0.60070486E-09
96	o 13v	0.0	0.14550827E+01	0.00000000E+00	18z	0.0	0.61477538E-09	0.61477538E-09
97	o 13w	0.0	0.34728328E+01	0.00000000E+00	18u	0.0	-0.18669528E-13	0.18669528E-13
98	o 13m	0.0	0.30615989E+08	0.00000000E+00	18v	0.0	0.24789846E-13	0.24789846E-13
99	o 17x	0.0	-0.14174671E+08	0.00000000E+00	18w	0.0	-0.86521453E-14	0.86521453E-14
100	o 17y	0.0	0.20868712E+07	0.00000000E+00	18m	0.0	0.10412817E-19	0.10412817E-19
101	o 17z	0.0	-0.16918746E+02	0.00000000E+00	19x	0.0	-0.61670568E-10	0.61670568E-10
102	o 17u	0.0	0.89947818E+01	0.00000000E+00	19y	0.0	-0.63356962E-10	0.63356962E-10
103	o 17v	0.0	-0.12534730E+01	0.00000000E+00	19z	0.0	-0.52473290E-10	0.52473290E-10
104	o 17w	0.0	0.34730064E+01	0.00000000E+00	19u	0.0	0.42638517E-13	0.42638517E-13
105	o 17m	0.0	0.40067618E+07	0.00000000E+00	19v	0.0	-0.20187614E-13	0.20187614E-13
106	o 18x	0.0	-0.463941886E+05	0.00000000E+00	19w	0.0	-0.26000854E-14	0.26000854E-14
107	o 18y	0.0	0.11855427E+06	0.00000000E+00	19m	0.0	-0.48419687E-17	0.48419687E-17
108	o 18z	0.0	0.11855427E+06	0.00000000E+00	19m	0.0	-0.48419687E-17	0.48419687E-17

```

109 o 18u0 0.0 -0.19316893E+02 0.00000000E+00
110 o 18v0 0.0 0.91722411E+01 0.00000000E+00
111 o 18w0 0.0 -0.13365620E+01 0.00000000E+00
112 o 18m0 0.0 0.34729213E+01 0.00000000E+00
113 o 19x0 0.0 0.13916458E+07 0.00000000E+00
114 o 19y0 0.0 0.11076126E+07 0.00000000E+00
115 o 19z0 0.0 -0.56332170E+05 0.00000000E+00
116 o 19u0 0.0 -0.21545640E+02 0.00000000E+00
117 o 19v0 0.0 0.83666507E+01 0.00000000E+00
118 o 19w0 0.0 -0.13298041E+01 0.00000000E+00
119 o 19m0 0.0 0.34729278E+01 0.00000000E+00
120 o 20x0 0.0 0.43274239E+06 0.00000000E+00
121 o 20y0 0.0 0.14356462E+07 0.00000000E+00
122 o 20z0 0.0 -0.11169032E+06 0.00000000E+00
123 o 20u0 0.0 -0.22738891E+02 0.00000000E+00
124 o 20v0 0.0 0.66141588E+01 0.00000000E+00
125 o 20w0 0.0 -0.12122222E+01 0.00000000E+00
126 o 20m0 0.0 0.34729278E+01 0.00000000E+00

```

```

total number of iterations = 150
total number of reloaded fn evals = 19739
total number of function evaluations = 19313
total cpu time = 8195.620 seconds

```

## **3.5 OTHER CASES**

The following cases contain only the IPOST input, and related discussion. The input corresponds to executable IPOST runs, and are shown to expand the envelope of IPOST usage.

### **3.5.1 TRAJECTORY SIMULATION**

The input file described here performs explicit trajectory propagation. A Cowell, or numerical integration of the equations of motion, is emphasized. There is no targeting or optimization. This rather simple case can be used to compare propagators or effects of forces, to perform sensitivity analyses, to generate initial guesses, such as for collocation runs, or to debug a simulation.

```

p$stop
c test of cowell trajectory propagation

srchm = 'none',
fesn = 90,
iephem = 1,

$
p$traj
event = 5,
iePOCH = 'calend',
date = 1977,7,31,
idfram = 'eartheq','mean2000',
ipbody = 3,10,
ibody = 3,
iprop = 'cowell',
dt = .001,
iforce(1) = 1,
npert(1) = 10,
inputx = 'conic',
x = 10000.d0, .1d0, 28.5d0, 0.d0, 0.d0, 0.d0, 0.d0,

$
p$traj
c end trajectory

event = 20,
critr = 'timrfl',
value = .1d0,

$
p$traj
c Let's quit

event = 90,
critr = 'tdurp',
value = 0.,
namlst = 'none',
$

```



### **3.5.2 COMPLETE VOYAGER II**

This case is an extension of the Voyager 2 case (Section 3.1). The mission continues beyond Saturn, and includes flybys of Uranus and Neptune. In addition, the Newton-Raphson full rank subproblem targeting is replaced by NPSOL optimization for each subproblem. The master problem remains the same, although central differencing with input perturbation values is used to form the Jacobian.

In the subproblem setup MODEL T is set to 'SUBOPT' for each subproblem. Each subproblem still has 3 controls and 3 constraints, but now target error is minimized except for the first subproblem where  $\Delta V$  is minimized.

```

P$top
c... Galileo 1989 VEGA trajectory
srchm = 'npsol',
iprint = 0,
ipro = 0,
fesn = 90,
istm = 'forward',
npad(1) = 0,
ideb = 1,
isub = 1,1,1,1,
mxitop = 10,
mxitar = 300,
ftol = 1.d-6,

c master controls are Jupiter TCA, arrival BDT, arrival BDR,
c
c
indxi = 1,2,3,4,
indvr = 5hcritr,8hdepsv102,8hdepsv103,5hcritr,
indph = 3*20,30,
u = 706.,.175565d7,.121609d6,1487.,
indplb = 650.,.88d6,.6d5,1300.,
indpub = 800.,.26d7,.182d6,1600.,
pert = .001,.001,.001,.001,
wvu = .708,.175565d6,.121609d6,1.487,

c
indxi(5) = 5,6,7,8,9,10
indvr(5) = 8hdepsv105,8hdepsv106,5hcritr,8hdepsv108,8hdepsv109,5hcritr,
indph(5) = 30,30,40,40,40,50,
u(5) = .359699d6,-.178342d5,3099.,.137566d6,.275594d5,4486.,
indplb(5) = .18d6,-.34d5,2800.,.65d5,.14d5,4000.,
indpub(5) = .71d6,-.85d4,3500.,.27d6,.55d5,5000.,
pert(5) = .001,.001,.001,.001,.001,
wvu(5) = .359699d6,.178342d5,3.099,.137566d6,.275594d5,4.486,

c minimize delta-v for total mission
c
optvar = 5hdvsum,
opt = -1,
optph = 90,
wopt = 8.,
etanl = .5,

c subproblem setup
c
modelt = 'nraph','nraph','nraph','nraph',
spfesn = 20,30,40,50,
tolf = 1.0d0,
tolu = 1.0d0,
npi = 8,

c controls
c
indxi = 1,1,1,2,2,2,
indsvr = Shvinfz,Shvinfy,Shvinfz,3hdvx,3hdvy,3hdvz,
indsph = 3*10,3*23,
usub = 2.38521,9.44533,3.19406,3*0.,
peretsb = 3*1.d-7,3*1.d-5,

```

```

indxsi(7) = 3,3,3, 4,4,4,
indsvr(7) = 3hdvx,3hdvy,3hdvz, 3hdvx,3hdvy,3hdvz,
indsph(7) = 3*33, 3*43,
usub(7) = 3*0., 3*0.,
pertsb(7) = 3*1.d-6, 3*1.d-5,
c
c targets
c
c
indxsd = 1,1,1, 2,2,2,
depsvr = 3htfp,3hbdt,3hbdr, 3htfp,3hbdt,3hbdr,
depsph = 3*20, 3*30,
depsvl = -.0001,.175565d7,.121609d6, -.0001,.359627d6, -.178304d5,
depstl = .00001,.01,.01, .0001,.1,.1,
c
indxsd(7) = 3,3,3, 4,4,
depsvr(7) = 3htfp,3hbdt,3hbdr, 3htfp,5hrperi,
depsph(7) = 3*40, 2*50,
depsvl(7) = -.0001,.137566d6,.275594d5, -.0001,.66936d5,
depstl(7) = .00001,1.,1., .00001,10.,
$
c
p$traj
event = 5,
iePOCH = 'calend',
date = 1977,7,31,
idfram = 'ecliptic',
ipbody = 3,
ibody = 3,
iprop = 'conic',
scmass = 1.d6,
thrust = 2.d5,
spi = 480.,
inputx = 'conic',
x = 6563.,0.,0.,0.,0.,0.,
$
p$traj
c earth escape
c
event = 10,
critr = 6htimrfl,
value = 20.,
iprop = 'lstep',
ipbody = 0,3,
mantyp = 'launch',
ilnch = 2,
rperi = 6563.,
rapoap = 6563.,
inc = 28.5,
$
p$traj
c change ibody
c

```

```

event = 15,
critr = 5htdurp,
value = 20.,
ipbody = 0,5,
ibbody = 5,
$
cp$traj
c event = 18,
c critr = 6htimrf1,
c value = 690.,
c $
p$traj
c Jupiter TCA
c 7/9/1979
c
event = 20,
critr = 6htimrf1,
value = 708.,
$
p$traj
c powered swingby
c
event = 23,
critr = 5htdurp,
value = 70.,
mantyp = 'impuls',
dvx = 3*0.,
$
p$traj
c change ibbody
c
event = 25,
critr = 5htdurp,
value = 0.,
ipbody = 0,6,
ibbody = 6,
$
p$traj
c Saturn TCA
c 8/25/1981
c
event = 30,
critr = 6htimrf1,
value = 1487.,
$
p$traj
c
event = 33,
critr = 5htdurp,
value = 100.,
mantyp = 'impuls',
dvx = 3*0.d0,
$
p$traj
c
event = 35,
critr = 5htdurp,
value = 0.d0,
ipbody = 0,7,

```

```

idbody = 7,
$
p$traj
c
event = 40,
critr = 6htimrfl,
value = 3099.,
$
p$traj
c
event = 43,
critr = 5htdurp,
value = 100.,
mantyp = 'impuls',
dvx = 3*0.d0,
$
p$traj
c
event = 45,
critr = 5htdurp,
value = 0.d0,
ipbody = 0,8,
idbody = 8,
$
p$traj
c
event = 50,
critr = 6htimrfl,
value = 4486.,
$
p$traj
c This is the end
c
event = 90,
critr = 5htdurp,
value = 0.,
namlst = 'none',
$

```

### **3.5.3 HOHMANN TRANSFER**

The Hohmann transfer problem is a classic orbital mechanics solution: The optimal two impulse solution for transferring from one circular orbit to another circular orbit in the same plane is to perform the impulses 180° apart in the direction of travel (for raising an orbit).

This case uses finite burns and collocation. Although the case assumes a low enough thrust such that "impulse" is not a good approximation, and only one segment per phase is assumed, the Hohmann transfer solution in principle is validated.

The first burn occurs in the phase between the first event (# 10) and the second event (# 20), followed by a coasting phase, and then the second burn starting at event 30 and ending at the last event (# 40). Simple thrust tables are input, in this case constant thrust (5000 newtons).

There are 7 mission controls: Thrust direction relative to velocity, throttle, and stop time of the first burn, and start time, thrust direction relative to velocity, throttle, and stop time of the second burn. Invalid guesses of the states are input at each event. There are a total of 49 additional, collocation introduced controls. The constraints are Cartesian position at the end of the second burn. Final mass is maximized.

```

p$stop
c
c hohmann transfer orbit test case
c
fesn = 40,
srchm = 'colloc',
irscl = 2,
istm = 'autopert',
mxitop = 50,-1,
ipro = 0,
ideb = 0,
optvar = 'scmass',
opt = 1,
optph = 40.,
wopt = 10000.,
etanl = .5,

indxi = 1, 2, 3, 4, 5, 6, 7,
indvr = 'yaw0','thl0','critr','critr','yaw0','thl0','critr',
indph = 10,10, 20, 30,30,30, 40,
u = 0.,1.,.007,.035,0.,1.,.007,
wvu = 180.,1.,.01,.07,180.,1.,.01,
indplb = -180.,0.,.0001,.01,-180.,0.,.0001,
indpub = 180.,1.,.01,.07,180.,1.,.01,

depvr = 'x2','y2','z2',
depph = 40,40,40,
indxd = 1,2,3,
depvlb = -0.733663153E+04,-0.521113415E+04,0.,
depvub = -0.733663153E+04,-0.521113415E+04,0.,
wnlcl(1) = 1.,1.,1.,
namlst = 'traj',

c initial conditions for phase 10
c
c date = 7 1 1992 0.22 julian =2448804.50920918 tdurp = 0.00920918
c state relative to ibody: earth
c
c u(8) = 0.57790518E+04,
0.56101708E+04,
-0.1180584E-14,
-0.49046907E+01,
0.53057448E+01,
-0.80100503E-18,
0.19999984E+05,
---
c initial conditions for phase 20
c
c date = 7 1 1992 1.09 julian =2448804.54558686 tdurp = 0.03637768
c state relative to ibody: earth
c
c -0.58963384E+04,
0.61478585E+04,
-0.10105050E-14,
-0.50762013E+01,
-0.46307005E+01,
0.10379708E-17,
0.199999950E+05,

```

```

---
c initial conditions for phase 30
c
c date = 7 1 1992 1.29 julian =2448804.55390736 tdurp = 0.00832050
c state relative to ibody: earth
c
-0.73366315E+04,
-0.52111341E+04,
0.0000000E+00,
0.35904416E+01,
-0.53670536E+01,
-0.57761545E-17,
0.19999915E+05,
$
p$traj
event = 10,
epoch = 'calend',
date = 1992, 7, 1,
tol = 1.d-8,
idfram = 'ecliptic',
ibody = 3,
ibody = 3,
scmass = 20000.,
spi = 320.,
inputx = 'conic',
x = 8000., 0., 0., 0., 0., 0.,
wprop = 10000.,
icord = 3,
iforce(5) = 1,
pitch0 = 0.,
yaw0 = 90.,
thl0 = 1.d0,
namlst = 'table',
nsegph = 1,
nsgph0 = 0,
nsgpwd = 0,
nsgpwl = 0,
cointp = 'linear',
$
p$stab
table = 'thrstt', 0., 5000.,
namlst = 'traj',
$
p$traj
event = 20.,
critr = 'tdurp',
value = .007,
iforce(5) = 0,
nsegph = 1,
nsgph0 = 0,
nsgpwd = 0,
nsgpwl = 0,
cointp = 'linear',
$
p$traj
event = 30.,

```



```
critr = 'tdurp',
value = .028,
iforce(5) = 1,
pitch0 = 0.,
namlst = 'table',

nsegph = 1,
nsgph0 = 0,
nsgpwd = 0,
nsgpwi = 0,
cointp = 'linear',
$
p$stab
table = 'thrstt', 0., 5000.,
namlst = 'traj',
$
p$traj
event = 40.,
critr = 'tdurp',
value = .007,
iforce(5) = 0,
namlst = 'none',
$
```

### **3.5.4 LOW THRUST TO JUPITER**

This case illustrates a nuclear powered low thrust mission from Earth to Jupiter. There is one long continuous burn. The control parameters are thrust throttle level, and pitch and yaw thrust directions (UVW relative). Constraints are TFP, and closest approach distance at Jupiter arrival. S/C mass at arrival is maximized.

```

p$stop
c... Galileo 1989 VEGA trajectory
  srchm = 'npsol',
  iprint = 0,
  ipro = 0,
  fesn = 90,
  istm = 'central',
  rpad(1) = 0,
  mxitop = 30,
  ftol = 1.d-6,

  indxi = 1,2,3,
  indvr = 'pitch0','yaw0','thl0',
  indph = 3*15,
  u = 0.d0, 90.d0, .05d0,
  indplb = -90.d0, -179.999999d0, 0.d0,
  indpub = 90.d0, 180.d0, 1.d0,
  pert = 1.1.,.1,
  wvu = 180.,180.,1.,

c maximize s/c mass at the end
c
  optvar = 6hscmass,
  opt = 1,
  optph = 90,
  wopt = 2.d5,
  etanl = .5,

c targets
c
  indxd = 1,2,3,
  depvr = 'tfp','rperi',
  depvh = 3*20,
  depvib = -1.d0,1.0d6,
  depvub = 1.d0,2.0d6,
  wvnlc = 1.d0,2.0d6,
  $

c
p$traj
event = 5,
iePOCH = 'calend',
date = 1977,7,31,
idfram = 'ecliptic','mean2000',
ipbody = 3,
idbody = 3,
iprop = 'conic',

scmass = 1.5d5,
thrust = 2.d5,
spi = 480.,

inputx = 'conic',
x = 6563.,0.,0.,0.,0.,0.,0.,
$
p$traj
c earth escape
c
event = 10,

```

```

critr = 6htimrfl,
value = 20.,
iprop = '1step',
ipbody = 0,3,
mantyp = 'launch',
ilnch = 2,
vlnfx = 2.26374,
vlnfy = 9.45391,
vlnfz = 3.16241,
rperi = 6563.,
rapoap = 6563.,
inc = -1.,
$
p$traj
c change idbody
c
event = 15,
critr = 5htdurp,
value = 20.,
ipbody = 0,5,
idbody = 5,
iprop = 'encke',
iforce(5) = 3,
icoord = 3,
spi = 4000.,
prpdat(9) = 1.,0.,30000.,0.,0.,0.,0.,0.,0.,
dt = .5d0,
$
p$traj
event = 18,
critr = 6htimrfl,
value = 608.,
iforce(5) = 0,
iprop = '1step',
$
p$traj
c Jupiter TCA
c 7/9/1979
c
event = 20,
critr = 6htimrfl,
value = 711.,
$
p$traj
c This is the end
c
event = 90,
critr = 5htdurp,
value = 0.,
namlst = 'none',
$

```

```

p$top
c... Galileo 1989 VEEGA trajectory
srchm = 'npsol',
iprint = 0,
ipro = 0,
fesn = 90,
istm = 'forward',
npad(1) = 0,
ideb = 1,
isub = 1,1,1,1,
mxitop = 10,
mxitar = 300,
ftol = 1.d-6,

c master controls are Jupiter TCA, arrival BDT, arrival BDR,
c
c
indxi = 1,2,3,4,
indvr = 5hcritr,8hdepsv102,8hdepsv103,5hcritr,
indph = 3*20,30,
u = 706.,.175565d7,.121609d6,1487.,
indplb = 650.,.88d6,.6d5,1300.,
indpub = 800.,.26d7,.182d6,1600.,
pert = .001,.001,.001,.001,
wvu = .708,.175565d6,.121609d6,1.487,

c
indxi(5) = 5,6,7,8,9,10,
indvr(5) = 8hdepsv105,8hdepsv106,5hcritr,8hdepsv108,8hdepsv109,5hcritr,
indph(5) = 30,30,40,40,40,50,
u(5) = .359699d6,-.178342d5,3099.,.137566d6,.275594d5,4486.,
indplb(5) = .18d6,-.34d5,2800.,.65d5,.14d5,4000.,
indpub(5) = .71d6,-.85d4,3500.,.27d6,.55d5,5000.,
pert(5) = .001,.001,.001,.001,.001,
wvu(5) = .359699d6,.178342d5,3.099,.137566d6,.275594d5,4.486,

c minimize delta-v for total mission
c
optvar = 5hdvsum,
opt = -1,
optph = 90,
wopt = 8,
etanl = .5,

c subproblem setup
c
c
modelt = 'nraph','nraph','nraph','nraph',
spfesn = 20,30,40,50,
tolf = 1.0d0,
tolu = 1.0d0,
npi = 8,

c controls
c
indxsi = 1,1,1,2,2,2,
indsvr = 5hvinfx,5hvinfy,5hvinfz,3hdvx,3hdvy,3hdvz,
indspth = 3*10,3*23,
usub = 2.38521,9.44533,3.19406,3*0.,
pertsb = 3*1.d-7,3*1.d-5,

c
indxsi(7) = 3,3,3,4,4,4,
indsvr(7) = 3hdvx,3hdvy,3hdvz,3hdvx,3hdvy,3hdvz,

```

```

indsph(7) = 3*33, 3*43,
usub(7) = 3*0., 3*0.,
pertsb(7) = 3*1.d-6, 3*1.d-5,
c targets
c
c
indxsd = 1,1,1, 2,2,2,
depsvr = 3htfp,3hbd,3hbdr, 3htfp,3hbd,3hbdr,
depsph = 3*20, 3*30,
depsvl = -.0001,.175565d7,.121609d6, -.0001,.359627d6,-.178304d5,
depstl = .00001,.01,.01, .0001,.1,.1,
c
indxsd(7) = 3,3,3, 4,4,
depsvr(7) = 3htfp,3hbd,3hbdr, 3htfp,5hrperi,
depsph(7) = 3*40, 2*50,
depsvl(7) = -.0001,.137566d6,.275594d5, -.0001,.66936d5,
depstl(7) = .00001,1.,1., .00001,10.,
$
c
p$traj
event = 5,
lepoch = 'calend',
date = 1977,7,31,
idfram = 'ecliptic',
ipbody = 3,
idbody = 3,
iprop = 'conic',
scmass = 1.d6,
thrust = 2.d5,
spi = 480.,
inputx = 'conic',
x = 6563.,0.,0.,0.,0.,0.,
$
p$traj
c earth escape
event = 10,
critr = 6htimrfl,
value = 20.,
iprop = '1step',
ipbody = 0,3,
mantyp = 'launch',
ilnch = 2,
rperi = 6563.,
rapoap = 6563.,
inc = 28.5,
$
p$traj
c change idbody
event = 15,
critr = 5htdurp,
value = 20.,
ipbody = 0,5,

```

```

tbody = 5,
$
cp$traj
c event = 18,
c critr = 6htimrfl,
c value = 690.,
c $
p$traj
c Jupiter TCA
c 7/9/1979
c
event = 20,
critr = 6htimrfl,
value = 708.,
$
p$traj
c powered swingby
c
event = 23,
critr = 5htdurp,
value = 70.,
mantyp = 'impuls',
dvx = 3*0.,
$
p$traj
c change tbody
c
event = 25,
critr = 5htdurp,
value = 0.,
tbody = 0,6,
tbody = 6,
$
p$traj
c Saturn TCA
c 8/25/1981
c
event = 30,
critr = 6htimrfl,
value = 1487.,
$
p$traj
c
event = 33,
critr = 5htdurp,
value = 100.,
mantyp = 'impuls',
dvx = 3*0.d0,
$
p$traj
event = 35,
critr = 5htdurp,
value = 0.d0,
tbody = 0,7,
tbody = 7,
$
p$traj
event = 40,
critr = 6htimrfl,

```

```

value = 3099.,
$
p$traj
c
event = 43,
critr = Shtdurp,
value = 100.,
mantyp = 'impuls',
dvx = 3*0.d0,
$
p$traj
c
event = 45,
critr = Shtdurp,
value = 0.d0,
ipbody = 0.8,
idbody = 8,
$
p$traj
c
event = 50,
critr = 6htimrfl,
value = 4486.,
$
p$traj
c This is the end
c
event = 90,
critr = Shtdurp,
value = 0.,
namlst = 'none',
$

```



## **4.0 REFERENCES**

1. "Interplanetary Program to Optimize Simulated Trajectories," Final Report, Volumes I, II, III, Fitzgerald, Hong, Kent, Milleur, and Olson, Martin Marietta Corporation, March 1990.

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<b>13. ABSTRACT (Maximum 200 words)</b>  IPOST is intended to support many analysis phases, from early interplanetary feasibility studies through spacecraft development and operations. The IPOST output provides information for sizing and understanding mission impacts related to propulsion, guidance, communications, sensor/actuators, payload, and other dynamic and geometric environments. IPOST models three degree of freedom trajectory events, such as launch/ascent, orbital coast, propulsive maneuvering (impulsive and finite burn), gravity assist, and atmospheric entry. Trajectory propagation is performed using a choice of Cowell, Encke, Multiconic, Onestep, or Conic methods. The user identifies a desired sequence of trajectory events, and selects which parameters are independent (controls) and dependent (targets), as well as other constraints and the cost function. Targeting and optimization is performed using the Stanford NPSOL algorithm. IPOST structure allows sub-problems within a master optimization problem to aid in the general constrained parameter optimization solution. An alternate optimization method uses implicit simulation and collocation techniques.
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