484772

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 APPLICATIONS 6

3.0 SAMPLE CASES 9
3.1 VOYAGER 2 10
3.2 MANNED MARS 36
3.3 LUNAR ORBITER 60
3.4 EARTH TO JUPITER (COLLOCATION) 77
3.5 OTHER CASES 118
3.5.1 TRAJECTORY SIMULATION 118
3.5.2 COMPLETE VOYAGER II 120
3.5.3 HOHMANN TRANSFER 125
3.5.4 LOW THRUST TO JUPITER 129

4.0 REFERENCES 136

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.

FEATURE	CAPABILITY
Optimization method	Explicit (Master/subproblems), Implicit (collocation)
Optimization algorithm	NPSOL
Optimization parameter*	ΔV magnitude, mass, time, . . .
Maximum controls	25 (Master), 45 (subproblems), 1700 (collocation)
Control parameters*	Values of event criteria, ΔV, 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 ΔV, 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, J2, 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).

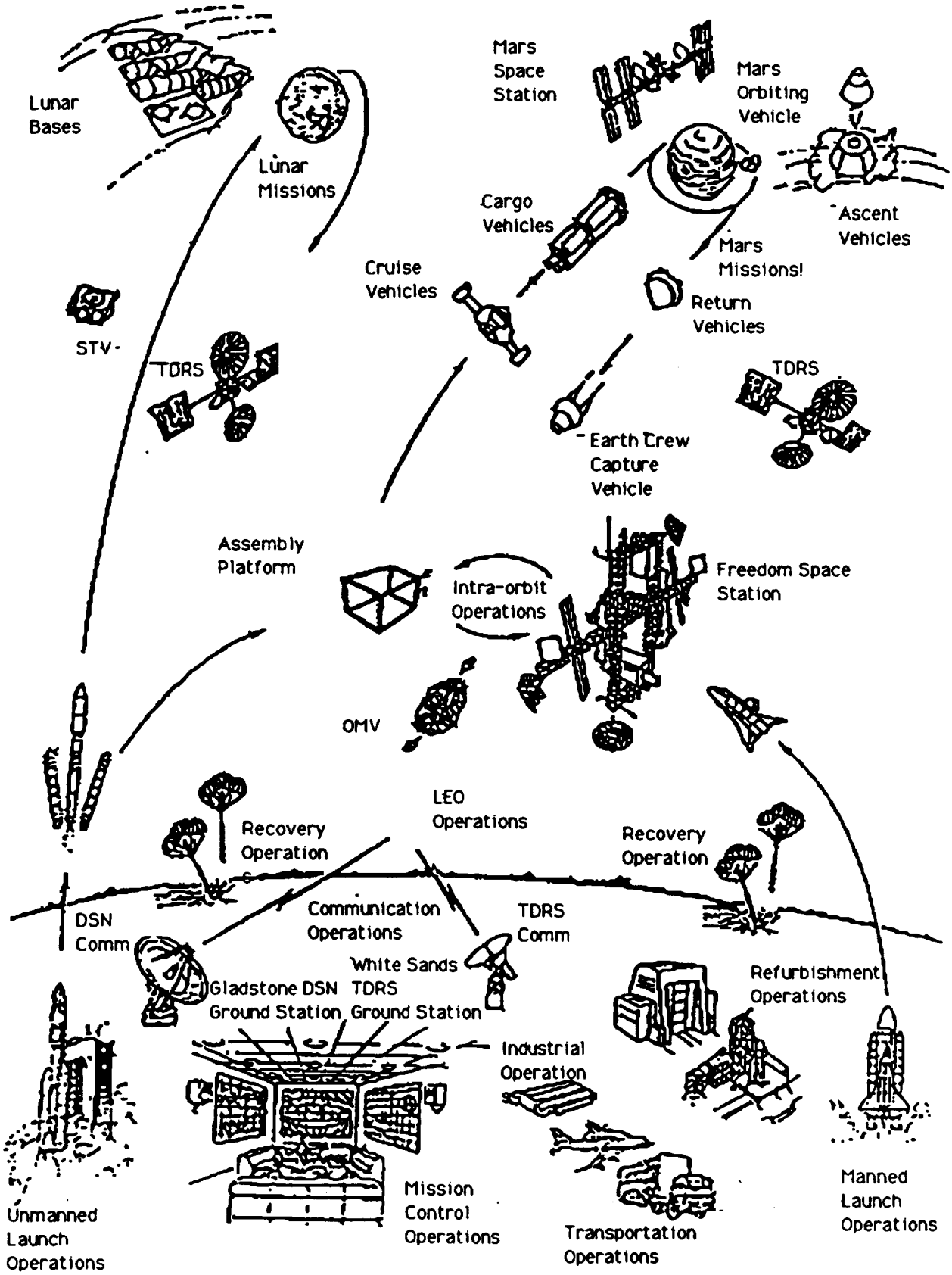


Figure 1 - 1. Space Exploration Infrastructure

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 (ΔV), 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 ΔV (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 ΔV 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 ΔV, Gravity assist	E-J-S, 1 Step, 6 Phases	Minimize to total ΔV, 2 subproblems
GALILEO	4.2 years	Earth Venus Jupiter	Launch, Midcourse ΔV, Gravity assist, Probe	E-V-E-E-J, 1 Step, 9 Phases	Minimize total ΔV, 4 subproblems
LUNAR ORBITER	4 days	Earth Moon (Sun)	Launch, Midcourse ΔV, 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 ΔV, 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 ΔV, Gravity Assist, Flyby, Rendezvous	E-V-A-C, 7 Phases	Minimize total ΔV, 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 ΔV (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 dot T and B dot 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 ΔV components after Jupiter flyby. As in the master problem, important inputs are the control initial guesses (USUB), bounds (INDSLB and INDSUB), and weightings (WGTS).

The constraint or target variables for subproblem 1 are time from periapsis, B dot T and B dot R at Jupiter. For subproblem 2 the constraints are time from periapsis, B dot T and closest approach distance at Saturn. The use of B dot 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 dot T and B dot 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 ΔV 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
p$top
c...  voyager ii earth-jupiter-saturn
  srchm      = 'npsol',
  iprint     = 0,
  ideb = 0,
  iephem     = 1,
  fesn       = 90,
  istm       = 'autopert',
  npad(1)    = 0,
  mxitop     = 30,
  mxitar     = 600,
  ftol       = 1.d-6,
c
c  master controls are jupiter tca, arrival bdt, arrival bdr,
c
  indxi      = 1,2,3,
  indvr      = 'critr','depsvl02','depsvl03',
  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',
  indsph     = 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,
```

```
  depsvl     = -.0001,.180849d7,.129268d6, -.0001,.206130d6,200000.d0,
  depslb     = -.0001,.180849d7,.129268d6, -.0001,.206130d6,199999.d0,
  depsub     = -.0001,.180849d7,.129268d6, -.0001,.206130d6,200001.d0,
  depstl     =  .00005,       .1,       .1, .00005,     100.,     100.,
  wvsnlc     =  1.,    .180849d7,.129268d6,     1.,.206130d6,     .2d6,
c
c objective
c
  optsvr     = 'target','dvmag',
  opts       = -1,-1,
  optsph     = 20,23,
  wopts      = .10,.10,

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

  idfram     = 'ecliptic','mean2000',
  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
c
  event      = 10,
  critr      = 'timrfl',
  value      = 20.,

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

  mantyp     = 'launch',
  ilnch      = 2,

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

 $
p$traj
c  change idbody
c
  event      = 15,
  critr      = 'tdurp',
  value      = 20.,
  ipbody     = 0,5,
  idbody     = 5,
```

```
 $
p$traj
c  jupiter tca
c  7/9/1979
c
  event      = 20,
  critr      = 'timrfl',
  iprop      = 'conic',
  ipbody     = 5,0,

 $
p$traj
c  powered swingby
c
  event      = 23,
  critr      = 'tdurp',
  value      = 1.,
  mantyp     = 'impuls',
  iprop      = 'lstep',
  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      = 'timrfl',
  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
```

table data - 22b 18

16

```
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   0.00000000000D+00   0.00000000000D+00
                 0.00000000000D+00   7.79323386922D+00   0.00000000000D+00
    conic        6.56300000000D+03   0.00000000000D+00   0.00000000000D+00
                 0.00000000000D+00   0.00000000000D+00   0.00000000000D+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       1.00000000000D+10    none            conic
   10.000         timrf1     2.00000000000D+01    launch          1step
   15.000         tdurp      2.00000000000D+01    none            1step
   20.000         timrf1     2.00000000000D+01    none            conic
   23.000         tdurp      1.00000000000D+00    impuls          1step
   25.000         tdurp      3.00000000000D+02    none            1step
   30.000         timrf1     1.48700000000D+03    none            1step
   90.000         tdurp      0.00000000000D+00    none            1step


***targeting/optimization inputs***
master problem optimization parameter   dvsum    at event       90
master problem optimization algorithm - npsol

master prob. control/indep parameters
evtnum          name
   20.000         critr
   20.000         depsvl02
   20.000         depsvl03

master problem  target/dep parameters
evtnum          name
total number of subproblems is   2
subproblem number   1
subproblem controls   vinfxo       vinfyo       vinfzo
          at event       10           10           10
subproblem targets    tfp          bdti         bdri
         at events       20           20           20
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   dvx          dvy          dvz
          at event       23           23           23
subproblem targets    tfp          bdti         rperi
         at events       30           30           30
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      COLD start.............
Variables..............        3      Infinite bound size....  1.00E+20      Crash tolerance........  1.00E-02
Step limit.............  2.00E+00     Infinite step size.....  1.00E+20

Nonlinear constraints..        0      Optimality tolerance...  1.00E-06      Function precision.....  9.90E-14
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      Verify 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      Save frequency.........       31

Difference interval....  1.00E-04     Central diffce 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 Conv
   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 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 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 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+00  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       0.0000000E+00    16.58842       0.0000000E+00       1.050
VARBL  3          FR    1.009167       0.0000000E+00    15.47173       0.0000000E+00       1.009

Exit NPSOL - Current point cannot be improved upon.

Final nonlinear objective value =    7.269194

date    = 7 31 1977  0.00  julian =2443355.50000000  tdurp  =      0.00000000  critr  =   time          propid = conic
primid = earth             secid  = earth            idbody = earth            frame  = ecliptic        epoch  = mean2000
timrfl = 0.000000000E+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  altit  = 0.184860000E+03  period = 0.529132654E+04
lat     = 0.000000000E+00  long   = 0.000000000E+00  longp  = 0.000000000E+00

final conditions for phase   5

date    = 8 20 1977  0.00  julian =2443375.50000000  tdurp  =     20.00000000  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
```

```
execution date and time Fri Oct 23
                                                                                                    page    2

sma    = 0.656300000E+04  eccen  = 0.933848152E-15  inc    = 0.000000000E+00  argp   = 0.000000000E+00  anlong = 0.000000000E+00
meaan  =-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 =2443375.50000000  tdurp  =      20.00000000  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     = 0.341412237E+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  argp   = 0.000000000E+00  anlong = 0.000000000E+00
meaan  =-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  dvy    = 0.000000000E+00  dvz    = 0.000000000E+00  dvmag  = 0.726903802E+01  tburn  = 0.363451901E+05
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.786526125E+06  wprop  = 0.213473875E+06

initial conditions for phase   10 after launch   maneuver

date   = 8 20 1977  0.00  julian =2443375.50000000  tdurp  =       0.00000000  critr  =   timrfl       propid = 1step
primid = sun              secid  = earth            idbody = earth            frame  = ecliptic       epoch  = mean2000
timrfl = 0.200000000E+02
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  argp   = 0.338557485E+03  anlong = 0.346214360E+03
meaan  = 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  vinfx  = 0.845879397E+01  vinfy  = 0.515509334E+01  vinfz  = 0.269756621E+01
bmag   = 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  vinfx  = 0.228372219E+01  vinfy  = 0.930772076E+01  vinfz  = 0.368157486E+01
bmag   = 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     = 0.363332875E+02  vz     = 0.502764333E+01
sma    =-0.764065373E+09  eccen  = 0.119808406E+01  inc    = 0.657694804E+01
argp   = 0.358595914E+03  anlong = 0.327199149E+03  meaan  = 0.826427088E-01

final conditions for phase  10

date   = 9  9 1977  0.00  julian =2443395.50000000  tdurp  =      20.00000000  critr  =   tdurp        propid = 1step
primid = sun              secid  = earth            idbody = earth            frame  = ecliptic       epoch  = mean2000
timrfl = 0.400000000E+02
state relative to idbody: earth
x      = 0.376000157E+07  y      = 0.158739624E+08  z      = 0.624537138E+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  argp   = 0.354658935E+03  anlong = 0.350247545E+03
meaan  = 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  vinfx  = 0.279784107E+01  vinfy  = 0.862309935E+01  vinfz  = 0.344170678E+01
bmag   = 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
altp    = 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
```

```
execution date and time Fri Oct 23                                                                                                  page     3

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  meaan   = 0.149709769E+01

initial conditions for phase   15

date    = 9  9 1977  0.00  julian =2443395.50000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun               secid  = jupiter           idbody = jupiter           frame  = ecliptic         epoch  = mean2000
timrfl = 0.400000000E+02
state relative to idbody: jupiter
x       = 0.489745562E+08  y       =-0.775239332E+09  z       = 0.116229646E+08  radius = 0.776871690E+09  scmass = 0.213473875E+06
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
meaan   =-0.494219226E+06  truan   =-0.545779220E+02  tfp     =-0.176328142E+03  rperi  = 0.450324327E+09  vperi  = 0.415560211E+02
Incoming Asymptote
altp    = 0.450252929E+09  vinfm   = 0.415492509E+02  vinfx   = 0.216174356E+02  vinfy  = 0.353394476E+02  vinfz  = 0.318593345E+01
bmag    = 0.450397705E+09  btheta  =-0.769927828E+01  bdt     = 0.446337319E+09  bdr    =-0.603414482E+08  hypta  = 0.899906647E+02
c3      = 0.172634025E+04  ra      = 0.585455258E+02  dec     = 0.439766997E+01  altit  = 0.776800292E+09
Outgoing Asymptote
altp    = 0.450252929E+09  vinfm   = 0.415492509E+02  vinfx   = 0.216060613E+02  vinfy  = 0.353465658E+02  vinfz  = 0.318412471E+01
bmag    = 0.450397705E+09  btheta  =-0.770070079E+01  bdt     = 0.446335820E+09  bdr    =-0.603525296E+08  hypta  = 0.000000000E+00
c3      = 0.172634025E+04  ra      = 0.585506623E+02  dec     = 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  meaan   = 0.149709769E+01

final conditions for phase  15

date    = 7 12 1979 22.47  julian =2444067.43630849  tdurp  =    671.93630849  critr  =   timrfl         propid = 1step
primid = sun               secid  = jupiter           idbody = jupiter           frame  = ecliptic         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  scmass = 0.213473875E+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
meaan   =-0.169603607E-02  truan   =-0.140507246E-01  tfp     =-0.990053290E-04  rperi  = 0.710156782E+06  vperi  = 0.203590739E+02
Incoming Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.429597088E+00  vinfy  = 0.753775941E+01  vinfz  =-0.840759004E+00
bmag    = 0.190322247E+07  btheta  = 0.393032065E+01  bdt     = 0.189874637E+07  bdr    = 0.130453055E+06  hypta  = 0.409244977E+02
c3      = 0.577092463E+02  ra      = 0.932619112E+02  dec     =-0.635421746E+01  altit  = 0.638758794E+06
Outgoing Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.743241371E+01  vinfy  =-0.143864811E+01  vinfz  = 0.631477984E+00
bmag    = 0.190322247E+07  btheta  = 0.575328899E+01  bdt     = 0.189363550E+07  bdr    = 0.190788873E+06  hypta  = 0.000000000E+00
c3      = 0.577092463E+02  ra      =-0.106626238E+03  dec     = 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      =-0.190899988E+00
sma     =-0.436025897E+09  eccen   = 0.180235266E+01  inc     = 0.206538027E+01
argp    = 0.749073322E+02  anlong  = 0.340181580E+03  meaan   = 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  =   timrfl        propid = conic
primid = jupiter          secid  = sun               idbody = jupiter          frame  = ecliptic        epoch  = mean2000
timrfl = 0.711936308E+03
```

```
execution date and time Fri Oct 23                                                                                                  page    4

state relative to idbody: jupiter
x       = 0.433346698E+06  y       = 0.555192933E+06  z       =-0.910720487E+05  radius = 0.710156794E+06  scmass = 0.213473875E+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
meaan   =-0.169603607E-02  truan   =-0.140507246E-01  tfp     =-0.990053290E-04  rperi  = 0.710156782E+06  vperi  = 0.203590739E+02
Incoming Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.429597088E+00  vinfy  = 0.753775941E+01  vinfz  =-0.840759004E+00
bmag    = 0.190322247E+07  btheta  = 0.393032065E+01  bdt     = 0.189874637E+07  bdr    = 0.130453055E+06  hypta  = 0.409244977E+02
c3      = 0.577092463E+02  ra      = 0.932619112E+02  dec     =-0.635421746E+01  altit  = 0.638758794E+06
Outgoing Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.743241371E+01  vinfy  =-0.143864811E+01  vinfz  = 0.631477984E+00
bmag    = 0.190322247E+07  btheta  = 0.575328899E+01  bdt     = 0.189363550E+07  bdr    = 0.190788873E+06  hypta  = 0.000000000E+00
c3      = 0.577092463E+02  ra      =-0.106626238E+03  dec     = 0.476825608E+01  altit  = 0.638758794E+06
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   = 0.663792506E+02

final conditions for phase  20

date    = 7 13 1979 22.47  julian =2444068.43630849  tdurp  =      1.00000000  critr  =   tdurp          propid = conic
primid = jupiter           secid  = sun               idbody = jupiter          frame  = ecliptic         epoch  = mean2000
timrfl = 0.712936308E+03
state relative to idbody: jupiter
x       =-0.102687501E+07  y       = 0.100077151E+07  z       =-0.508351063E+05  radius = 0.143478225E+07  scmass = 0.213473875E+06
vx      =-0.152561988E+02  vy      = 0.908046614E+00  vz      = 0.851749155E+00  speed  = 0.153069144E+02  fpa    = 0.488279481E+02
sma     =-0.219524281E+07  eccen   = 0.132349806E+01  inc     = 0.746726841E+01  argp   = 0.260688481E+03  anlong = 0.151430683E+03
meaan   = 0.171290593E+02  truan   = 0.834908744E+02  tfp     = 0.999900995E+00  rperi  = 0.710156782E+06  vperi  = 0.203590739E+02
Incoming Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.429597088E+00  vinfy  = 0.753775941E+01  vinfz  =-0.840759004E+00
bmag    = 0.190322247E+07  btheta  = 0.393032065E+01  bdt     = 0.189874637E+07  bdr    = 0.130453055E+06  hypta  = 0.409244977E+02
c3      = 0.577092463E+02  ra      = 0.932619112E+02  dec     =-0.635421746E+01  altit  = 0.136338425E+07
Outgoing Asymptote
altp    = 0.638758782E+06  vinfm   = 0.759666021E+01  vinfx   =-0.743241371E+01  vinfy  =-0.143864811E+01  vinfz  = 0.631477984E+00
bmag    = 0.190322247E+07  btheta  = 0.575328899E+01  bdt     = 0.189363550E+07  bdr    = 0.190788873E+06  hypta  = 0.000000000E+00
c3      = 0.577092463E+02  ra      =-0.106626238E+03  dec     = 0.476825608E+01  altit  = 0.136338425E+07
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   = 0.260368657E+01  inc     = 0.248596821E+01
argp    = 0.338523905E+03  anlong  = 0.119411006E+03  meaan   = 0.485978921E+02

initial conditions for phase   23 before impuls   maneuver

date    = 7 13 1979 22.47  julian =2444068.43630849  tdurp  =      1.00000000  critr  =   tdurp          propid = 1step
primid = sun               secid  = jupiter           idbody = jupiter          frame  = ecliptic         epoch  = mean2000
state relative to idbody: jupiter
x       =-0.102687501E+07  y       = 0.100077151E+07  z       =-0.508351063E+05  radius = 0.143478225E+07  scmass = 0.213473875E+06
vx      =-0.152561988E+02  vy      = 0.908046614E+00  vz      = 0.851749155E+00  speed  = 0.153069144E+02  fpa    = 0.488279481E+02
sma     =-0.219524281E+07  eccen   = 0.132349806E+01  inc     = 0.746726841E+01  argp   = 0.260688481E+03  anlong = 0.151430683E+03
meaan   = 0.171290593E+02  truan   = 0.834908744E+02  tfp     = 0.999900995E+00  rperi  = 0.710156782E+06  vperi  = 0.203590739E+02

impuls   maneuver print block
dvx     = 0.455302180E-04  dvy     = 0.246251752E-04  dvz     =-0.146724351E-03  dvmag  = 0.155587387E-03  tburn  = 0.166069213E+00
thrust  = 0.200000000E+06  spi     = 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  =      0.00000000  critr  =   tdurp          propid = lstep
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      =-0.508351063E+05  radius = 0.143478225E+07  scmass = 0.213466820E+06
vx     =-0.152561533E+02  vy     = 0.908071239E+00  vz     = 0.851602431E+00  speed  = 0.153068623E+02  fpa    = 0.488281129E+02
sma    =-0.219530346E+07  eccen  = 0.132348641E+01  inc    = 0.746650342E+01  argp   = 0.260686214E+03  anlong = 0.151432351E+03
meaan  = 0.171284271E+02  truan  = 0.834914876E+02  tfp    = 0.999905525E+00  rperi  = 0.710150836E+06  vperi  = 0.203591082E+02
Incoming Asymptote
altp   = 0.638752836E+06  vinfm  = 0.759655526E+01  vinfx  =-0.429428880E+00  vinfy  = 0.753767121E+01  vinfz  =-0.840687472E+00
bmag   = 0.190323603E+07  btheta = 0.392959822E+01  bdt    = 0.189876154E+07  bdr    = 0.130430044E+06  hypta  = 0.409239162E+02
c3     = 0.577076519E+02  ra     = 0.932606748E+02  dec    =-0.635376275E+01  altit  = 0.136338425E+07
Outgoing Asymptote
altp   = 0.638752836E+06  vinfm  = 0.759655526E+01  vinfx  =-0.743231726E+01  vinfy  =-0.143863407E+01  vinfz  = 0.631382611E+00
bmag   = 0.190323603E+07  btheta = 0.575283674E+01  bdt    = 0.189365049E+07  bdr    = 0.190775284E+06  hypta  = 0.000000000E+00
c3     = 0.577076519E+02  ra     =-0.106620240E+03  dec    = 0.476760027E+01  altit  = 0.136338425E+07
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  meaan  = 0.485974250E+02

final conditions for phase  23

date   = 5  8 1980 22.47  julian =2444368.43630849  tdurp  =    300.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = jupiter           idbody = jupiter           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  radius = 0.210937806E+09  scmass = 0.213466820E+06
vx     =-0.824688791E+01  vy     =-0.767464927E+00  vz     = 0.624257848E+00  speed  = 0.830601351E+01  fpa    = 0.870742963E+02
sma    =-0.186883390E+07  eccen  = 0.589728383E+01  inc    = 0.173329246E+03  argp   = 0.399346646E+02  anlong = 0.325193209E+03
meaan  = 0.630628788E+04  truan  = 0.968242418E+02  tfp    = 0.289154191E+03  rperi  = 0.915221005E+07  vperi  = 0.977102314E+01
Incoming Asymptote
altp   = 0.908081205E+07  vinfm  = 0.823338891E+01  vinfx  =-0.743318183E+01  vinfy  =-0.344279315E+01  vinfz  = 0.826847133E+00
bmag   = 0.108614396E+08  btheta =-0.176635948E+03  bdt    =-0.108427236E+08  bdr    =-0.637349842E+06  hypta  = 0.802372049E+02
c3     = 0.677886930E+02  ra     =-0.155148057E+03  dec    = 0.576370769E+01  altit  = 0.210866408E+09
Outgoing Asymptote
altp   = 0.908081205E+07  vinfm  = 0.823338891E+01  vinfx  =-0.817496277E+01  vinfy  =-0.758924362E+00  vinfz  = 0.618636011E+00
bmag   = 0.108614396E+08  btheta =-0.174902994E+03  bdt    =-0.108184903E+08  bdr    =-0.964954632E+06  hypta  = 0.000000000E+00
c3     = 0.677886930E+02  ra     =-0.174170329E+03  dec    = 0.430912103E+01  altit  = 0.210866408E+09
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    = 0.256989943E+01
argp   = 0.351055672E+03  anlong = 0.119694447E+03  meaan  = 0.719129706E+01

initial conditions for phase   25

date   = 5  8 1980 22.47  julian =2444368.43630849  tdurp  =      0.00000000  critr  =   tdurp          propid = 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  radius = 0.454527721E+09  scmass = 0.213466820E+06
vx     =-0.113743257E+02  vy     =-0.288227647E+01  vz     = 0.552717232E+00  speed  = 0.117468421E+02  fpa    =-0.880253179E+02
sma    =-0.275171223E+06  eccen  = 0.569607410E+02  inc    = 0.269841380E+01  argp   = 0.292373562E+01  anlong = 0.102299021E+03
meaan  =-0.944095269E+05  truan  =-0.890306541E+02  tfp    =-0.447017053E+03  rperi  = 0.153987855E+08  vperi  = 0.119476806E+02
Incoming Asymptote
altp   = 0.153387855E+08  vinfm  = 0.117397370E+02  vinfx  =-0.113674760E+02  vinfy  =-0.288041445E+01  vinfz  = 0.552383113E+00
```

```
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      = 0.229413788E+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    = 0.256989943E+01
argp   = 0.351055672E+03  anlong = 0.119694447E+03  meaan  = 0.719129706E+01

final conditions for phase  25

date   = 8 26 1981  0.00  julian =2444842.50000000  tdurp  =    474.06369151  critr  =   timrfl        propid = 1step
primid = sun              secid  = saturn            idbody = saturn            frame  = ecliptic        epoch  = mean2000
timrfl = 0.148700000E+04
state relative to idbody: saturn
x      =-0.135228263E+06  y      = 0.404454447E+05  z      = 0.141744757E+06  radius = 0.200035230E+06  scmass = 0.213466820E+06
vx     =-0.151987656E+02  vy     =-0.117929374E+02  vz     =-0.111465811E+02  speed  = 0.222333560E+02  fpa    =-0.210938786E-01
sma    =-0.329365722E+06  eccen  = 0.160733463E+01  inc    = 0.602120192E+02  argp   = 0.125300170E+03  anlong = 0.184377547E+02
meaan  =-0.100297619E-01  truan  =-0.342173925E-01  tfp    =-0.621887707E-04  rperi  = 0.200035208E+06  vperi  = 0.222333569E+02
Incoming Asymptote
altp   = 0.140035208E+06  vinfm  = 0.107305177E+02  vinfx  =-0.102574128E+02  vinfy  =-0.310866351E+01  vinfz  = 0.515465435E+00
bmag   = 0.414467811E+06  btheta =-0.601741047E+02  bdt    = 0.206142240E+06  bdr    =-0.359567717E+06  hypta  = 0.515268380E+02
c3     = 0.115144010E+03  ra     =-0.163139777E+03  dec    = 0.275339599E+01  altit  = 0.140035230E+06
Outgoing Asymptote
altp   = 0.140035208E+06  vinfm  = 0.107305177E+02  vinfx  =-0.122575319E+01  vinfy  =-0.580408435E+01  vinfz  =-0.894170812E+01
bmag   = 0.414467811E+06  btheta =-0.260199533E+02  bdt    = 0.372457905E+06  bdr    =-0.181820449E+06  hypta  = 0.000000000E+00
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  meaan  = 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  =      0.00000000  critr  =   tdurp         propid = 1step
primid = sun              secid  = saturn            idbody = saturn            frame  = ecliptic        epoch  = mean2000
timrfl = 0.148700000E+04
state relative to idbody: saturn
x      =-0.135228263E+06  y      = 0.404454447E+05  z      = 0.141744757E+06  radius = 0.200035230E+06  scmass = 0.213466820E+06
vx     =-0.151987656E+02  vy     =-0.117929374E+02  vz     =-0.111465811E+02  speed  = 0.222333560E+02  fpa    =-0.210938786E-01
sma    =-0.329365722E+06  eccen  = 0.160733463E+01  inc    = 0.602120192E+02  argp   = 0.125300170E+03  anlong = 0.184377547E+02
meaan  =-0.100297619E-01  truan  =-0.342173925E-01  tfp    =-0.621887707E-04  rperi  = 0.200035208E+06  vperi  = 0.222333569E+02
Incoming Asymptote
altp   = 0.140035208E+06  vinfm  = 0.107305177E+02  vinfx  =-0.102574128E+02  vinfy  =-0.310866351E+01  vinfz  = 0.515465435E+00
bmag   = 0.414467811E+06  btheta =-0.601741047E+02  bdt    = 0.206142240E+06  bdr    =-0.359567717E+06  hypta  = 0.515268380E+02
c3     = 0.115144010E+03  ra     =-0.163139777E+03  dec    = 0.275339599E+01  altit  = 0.140035230E+06
Outgoing Asymptote
altp   = 0.140035208E+06  vinfm  = 0.107305177E+02  vinfx  =-0.122575319E+01  vinfy  =-0.580408435E+01  vinfz  =-0.894170812E+01
bmag   = 0.414467811E+06  btheta =-0.260199533E+02  bdt    = 0.372457905E+06  bdr    =-0.181820449E+06  hypta  = 0.000000000E+00
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  meaan  = 0.216645061E+03
initial conditions for phase   90
```

```
execution date and time Fri Oct 23

esn =   90.000  fesn=   90.000
time=  2.44484250D+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 name	phase	value	residual	constraints name	phase	value	residual	objective function name	phase	value
1	critr	20.0	0.71193631E+03	0.00000000E+00					dvsum	90.0	0.726919361E+01
2	depsvl	20.0	0.18987465E+07	0.12067911-152							
3	depsvl	20.0	0.13045306E+06	0.12067911-152							

total number of iterations = 14
total number of reloaded fn 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.

```
i p o s t - interplanetary post simulation.  version  2.18  , dated 03-05-90.                    problem no.    1
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
  indxsi    = 1,1,1,2,2,2,3,3,3,
  indsvr    = 'vinfxo','vinfyo','vinfzo','dvx','dvy','dvz',
              'vinfxo','vinfyo','vinfzo',
  indsph    = 10,10,10,30,30,30,50,50,50,
  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,
c
c   targets
c
  indxsd    = 1,1,1,2,2,2,3,3,3,
  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.,-600.,-.001,4000.,-.001,5500.,7000.,-.001,17000.,
  depslb    = 9820.,-820.,-.001,3850.,-.001,5150.,6850.,-.001,16400.,
  depsub    = 9720.,-800., .001,3900., .001,5250.,6900., .001,17000.,
  depstl    = 1.,1.,.0001,1.,.0001,1.,1.,.0001,1.,
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.,
 $
p$traj
c
c   earth escape...use launch maneuver
c
  event     = 10,
  critr     = 'timrf1',
  value     = .5,
  mantyp    = 'launch',
  ilnch     = 2,
  inc       = -1.,
  spi       = 480.,
  rperi     = 6878.,
  rapoap    = 6878.,
  iprop     = '1step',
  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
c
  event     = 25,
  critr     = 6htimrf1,
  value     = 168.,
 $
p$traj
c   on the way to mars, do impulse correction
c
  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      = 5htdurp,
  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      = 5htdurp,
  value      = 60.,
  mantyp     = 'launch',
  rapoap     = 36327.,
  rperi      = 3880.,
  inc        = -1.,
  iprop      = '1step',
  ipbody     = 0,4,
 $
p$traj
c   exited mars soi, change secondary, input body
c
  event      = 60,
  critr      = 5htdurp,
  value      = 40.d0,
  ipbody     = 0,3,
  idbody     = 3,
 $
p$traj
c   earth closest approach
c
  event      = 65,
  critr      = 6htimrfl,
  value      = 583.,
 $
p$traj
c   orbit insertion
c
  event      = 70,
  critr      = 5htdurp,
  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                                                                  page    1

**** ipost input summary ****

*** trajectory inputs ***
initial epoch
    julian date ...2455522.0000
    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    6.87800000000D+03   0.00000000000D+00   0.00000000000D+00
                 0.00000000000D+00   7.61268440196D+00   0.00000000000D+00
    conic        6.87800000000D+03   0.00000000000D+00   0.00000000000D+00
                 0.00000000000D+00   0.00000000000D+00   0.00000000000D+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 summary
number          trigger          value            type          propagator
    5.000         time        1.00000000000D+10   none            conic
   10.000         timrfl      5.00000000000D-01   launch          lstep
   20.000         tdurp       4.00000000000D+01   none            lstep
   25.000         timrfl      1.68000000000D+02   none            lstep
   30.000         tdurp       0.00000000000D+00   impuls          lstep
   35.000         tdurp       4.00000000000D+01   none            lstep
   40.000         timrfl      3.23000000000D+02   none            lstep
   45.000         tdurp       0.00000000000D+00   orbins          conic
   50.000         tdurp       6.00000000000D+01   launch          lstep
   60.000         tdurp       4.00000000000D+01   none            lstep
   65.000         timrfl      5.83000000000D+02   none            lstep
   70.000         tdurp       0.00000000000D+00   orbins          lstep
   75.000         tdurp       0.00000000000D+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         bdri         tfp
          at events       25           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          dvy          dvz
           at event       30           30           30
subproblem targets    rperi        tfp          bdti
          at events       40           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
           at event       50           50           50
subproblem targets    rperi        tfp          bdti
          at events       65           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  tdurp  =      0.00000000  critr  =   time          propid = conic
primid = earth            secid  = sun               idbody = earth             frame  = ecliptic        epoch  = mean2000
timrfl = 0.000000000E+00
state relative to idbody: earth
x      = 0.687800000E+04  y      = 0.000000000E+00  z      = 0.000000000E+00  radius = 0.687800000E+04  scmass = 0.100000000E+07
vx     = 0.000000000E+00  vy     = 0.761268440E+01  vz     = 0.000000000E+00  speed  = 0.761268440E+01  fpa    =-0.381666562E-12
sma    = 0.687800000E+04  eccen  = 0.932142818E-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  = 0.687800000E+04  vperi  = 0.761268440E+01
altp   = 0.499860000E+03  alta   = 0.499860000E+03  rapoap = 0.687800000E+04  altit  = 0.499860000E+03  period = 0.567680811E+04
lat    = 0.000000000E+00  long   = 0.000000000E+00  longp  = 0.000000000E+00
state relative to secondary body: sun
x      = 0.763136841E+08  y      = 0.126559269E+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
```

final conditions for phase 5

```
date   =11 22 2010  0.00  julian =2455522.50000000  tdurp  =      0.50000000  critr  =   timrf1        propid = conic
primid = earth            secid  = sun              idbody = earth             frame  = ecliptic        epoch  = mean2000
timrf1 = 0.500000000E+00
state relative to idbody: earth
x      =-0.530206260E+04  y      =-0.438121172E+04  z      = 0.000000000E+00  radius = 0.687800000E+04  scmass = 0.100000000E+07
vx     = 0.484919775E+01  vy     =-0.586841077E+01  vz     = 0.000000000E+00  speed  = 0.761268440E+01  fpa    =-0.356222124E-12
sma    = 0.687800000E+04  eccen  = 0.347400286E-15  inc    = 0.000000000E+00  argp   = 0.000000000E+00  anlong = 0.000000000E+00
meaan  =-0.140432324E+03  truan  =-0.140432324E+03  tfp    =-0.256303804E-01  rperi  = 0.687800000E+04  vperi  = 0.761268440E+01
altp   = 0.499860000E+03  alta   = 0.499860000E+03  rapoap = 0.687800000E+04  altit  = 0.499860000E+03  period = 0.567680811E+04
lat    = 0.000000000E+00  long   =-0.114591559E+03  longp  = 0.000000000E+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  meaan  =-0.157350680E+03
```

initial conditions for phase 10 before launch maneuver

```
date   =11 22 2010  0.00  julian =2455522.50000000  tdurp  =      0.50000000  critr  =   timrf1        propid = 1step
primid = sun              secid  = earth            idbody = earth             frame  = ecliptic        epoch  = mean2000
state relative to idbody: earth
x      =-0.530206260E+04  y      =-0.438121172E+04  z      = 0.000000000E+00  radius = 0.687800000E+04  scmass = 0.100000000E+07
vx     = 0.484919775E+01  vy     =-0.586841077E+01  vz     = 0.000000000E+00  speed  = 0.761268440E+01  fpa    =-0.356222124E-12
sma    = 0.687800000E+04  eccen  = 0.683258405E-12  inc    = 0.000000000E+00  argp   = 0.000000000E+00  anlong = 0.000000000E+00
meaan  =-0.140432324E+03  truan  =-0.140432324E+03  tfp    =-0.256303804E-01  rperi  = 0.687800000E+04  vperi  = 0.761268440E+01

launch   maneuver print block
dvx    = 0.000000000E+00  dvy    = 0.000000000E+00  dvz    = 0.000000000E+00  dvmag  = 0.445280160E+01  tburn  = 0.222640080E+05
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.611692249E+06  wprop  = 0.388307751E+06
```

initial conditions for phase 10 after launch maneuver

```
date   =11 22 2010  0.00  julian =2455522.50000000  tdurp  =      0.00000000  critr  =   timrf1        propid = 1step
primid = sun              secid  = earth            idbody = earth             frame  = ecliptic        epoch  = mean2000
timrf1 = 0.500000000E+00
state relative to idbody: earth
x      =-0.592058832E+04  y      =-0.326417341E+04  z      =-0.126439311E+04  radius = 0.687800000E+04  scmass = 0.388307751E+06
vx     = 0.528086388E+01  vy     =-0.105528008E+02  vz     = 0.251531798E+01  speed  = 0.120654860E+02  fpa    =-0.949077517E-11
sma    =-0.134344506E+05  eccen  = 0.151196734E+01  inc    = 0.161377276E+02  argp   = 0.318594036E+03  anlong = 0.249135596E+03
meaan  =-0.350418797E-11  truan  =-0.151611100E-10  tfp    =-0.174587029E-14  rperi  = 0.687800000E+04  vperi  = 0.120654860E+02
Incoming Asymptote
altp   = 0.499860000E+03  vinfm  = 0.544701982E+01  vinfx  =-0.131297115E+01  vinfy  =-0.528301470E+01  vinfz  = 0.189439804E+00
bmag   = 0.152351957E+05  btheta = 0.160174267E+02  bdt    = 0.146437321E+05  bdr    = 0.420384317E+04  hypta  = 0.485940357E+02
c3     = 0.296700250E+02  ra     =-0.103956777E+03  dec    = 0.199306976E+01  altit  = 0.499860000E+03
Outgoing Asymptote
altp   = 0.499860000E+03  vinfm  = 0.544701982E+01  vinfx  = 0.488927835E+01  vinfy  =-0.186355420E+01  vinfz  = 0.151398411E+01
bmag   = 0.152351957E+05  btheta =-0.179009054E-10  bdt    = 0.152351957E+05  bdr    =-0.475992820E-08  hypta  = 0.000000000E+00
c3     = 0.296700250E+02  ra     =-0.125166693E+03  dec    = 0.161377276E+02  altit  = 0.499860000E+03
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  meaan  =-0.134908160E+03
```

final conditions for phase 10

```
date   = 1  1 2011  0.00  julian =2455562.50000000  tdurp  =     40.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrfl = 0.405000000E+02
state relative to idbody: earth
x      = 0.155522723E+08  y      =-0.666837022E+07  z      = 0.481674995E+07  radius = 0.175937891E+08  scmass = 0.388307751E+06
vx     = 0.369097569E+01  vy     =-0.244754059E+01  vz     = 0.112530601E+01  speed  = 0.456947153E+01  fpa    = 0.798838431E+02
sma    =-0.191315145E+05  eccen  = 0.161705292E+03  inc    = 0.162295683E+03  argp   = 0.355741412E+02  anlong = 0.937043641E+02
meaan  = 0.517888522E+05  truan  = 0.802326591E+02  tfp    = 0.438485287E+02  rperi  = 0.307453563E+07  vperi  = 0.459282593E+01
Incoming Asymptote
altp   = 0.306815749E+07  vinfm  = 0.456451077E+01  vinfx  = 0.371500213E+01  vinfy  =-0.239741027E+01  vinfz  = 0.113399371E+01
bmag   = 0.309360799E+07  btheta =-0.169568589E+03  bdt    =-0.304247794E+07  bdr    =-0.560123493E+06  hypta  = 0.896456755E+02
c3     = 0.208347586E+02  ra     =-0.328354531E+02  dec    = 0.143850457E+02  altit  = 0.175874110E+08
Outgoing Asymptote
altp   = 0.306815749E+07  vinfm  = 0.456451077E+01  vinfx  = 0.368674683E+01  vinfy  =-0.244525393E+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    = 0.142556556E+02  altit  = 0.175874110E+08
state relative primary body: sun
x      =-0.101183285E+08  y      = 0.138184253E+09  z      = 0.481316317E+07
vx     =-0.261358954E+02  vy     =-0.775214417E+01  vz     = 0.112458002E+01
sma    = 0.113422157E+09  eccen  = 0.303458560E+00  inc    = 0.347568092E+01
argp   = 0.182890485E+03  anlong = 0.593013863E+02  meaan  =-0.125271215E+03

initial conditions for phase   20

date   = 1  1 2011  0.00  julian =2455562.50000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = venus             idbody = venus             frame  = ecliptic         epoch  = mean2000
timrfl = 0.405000000E+02
state relative to idbody: venus
x      = 0.703826212E+08  y      = 0.671837720E+08  z      =-0.805460103E+06  radius = 0.973037582E+08  scmass = 0.388307751E+06
vx     =-0.284097516E+01  vy     = 0.186940818E+02  vz     = 0.142466850E+00  speed  = 0.189092604E+02  fpa    = 0.350198257E+02
sma    =-0.908560017E+03  eccen  = 0.877080195E+05  inc    = 0.981680549E+00  argp   = 0.296088017E+03  anlong = 0.725561590E+02
meaan  = 0.352130711E+07  truan  = 0.350202006E+02  tfp    = 0.341783161E+02  rperi  = 0.796870912E+08  vperi  = 0.189092994E+02
Incoming Asymptote
altp   = 0.796810392E+08  vinfm  = 0.189090838E+02  vinfx  =-0.284061322E+01  vinfy  = 0.186939582E+02  vinfz  = 0.142460299E+00
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
altp   = 0.796810392E+08  vinfm  = 0.189090838E+02  vinfx  =-0.284103945E+01  vinfy  = 0.186938934E+02  vinfz  = 0.142466933E+00
bmag   = 0.796879997E+08  btheta = 0.881678273E+00  bdt    = 0.796785650E+08  bdr    = 0.122620559E+07  hypta  = 0.000000000E+00
c3     = 0.357553452E+03  ra     = 0.986402305E+02  dec    = 0.431688352E+00  altit  = 0.972977062E+08
state relative primary body: sun
x      =-0.101183285E+08  y      = 0.138184253E+09  z      = 0.481316317E+07
vx     =-0.261358954E+02  vy     =-0.775214417E+01  vz     = 0.112458002E+01
sma    = 0.113422157E+09  eccen  = 0.303458560E+00  inc    = 0.347568092E+01
argp   = 0.182890485E+03  anlong = 0.593013863E+02  meaan  =-0.125271215E+03

final conditions for phase  20

date   = 5  8 2011 12.00  julian =2455690.00000000  tdurp  =    127.50000000  critr  =   timrfl         propid = 1step
primid = sun              secid  = venus             idbody = venus             frame  = ecliptic         epoch  = mean2000
timrfl = 0.168000000E+03
state relative to idbody: venus
x      =-0.939251327E+03  y      =-0.737709393E+04  z      = 0.591387009E+03  radius = 0.746012375E+04  scmass = 0.388307751E+06
vx     = 0.142430687E+02  vy     =-0.167884287E+01  vz     =-0.342414513E+00  speed  = 0.143457578E+02  fpa    =-0.639960672E+00
sma    =-0.273660439E+04  eccen  = 0.372583555E+01  inc    = 0.473446410E+01  argp   = 0.106980891E+03  anlong = 0.156522518E+03
```

```
meaan  =-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  hypta  = 0.744311480E+02
c3     = 0.118708708E+03  ra     =-0.220702583E+02  dec    =-0.116535168E+00  altit  = 0.140612375E+04
Outgoing Asymptote
```

```
execution date and time Fri Oct 23
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                
page 4

altp = 0.140753352E+04 vinfm = 0.108953526E+02 vinfx = 0.107510861E+02 vinfy = 0.169963345E+01 vinfz =-0.483841312E+00
bmag = 0.982202753E+04 btheta =-0.399342539E+01 bdt = 0.979818012E+04 bdr =-0.684025682E+03 hypta = 0.000000000E+00
c3 = 0.118708708E+03 ra = 0.955508898E+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 meaan = 0.274846183E+02

initial conditions for phase 25

subproblem iteration 20 final icnvgd = 1

subp. ind. vars. 1 2 3
4.88927835E+00-1.86355420E+00 1.51398411E+00

subp. dep. vars. 1 2 3
9.78853423E+03-8.10445840E+02-8.52656040E-05
6.65774332E-01-1.51598210E-02 8.52656040E-05
subproblem number 2

initial conditions for phase 25

final conditions for phase 25

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
timrfl = 0.168000000E+03
state relative to idbody: venus
x =-0.939251327E+03 y =-0.737709393E+04 z = 0.591387009E+03 radius = 0.746012375E+04 scmass = 0.388307751E+06
vx = 0.142430687E+02 vy =-0.167884287E+01 vz =-0.342414513E+00 speed = 0.143457578E+02 fpa =-0.639960672E+00
sma =-0.273660439E+04 eccen = 0.372583555E+01 inc = 0.473446410E+01 argp = 0.106980891E+03 anlong = 0.156522518E+03
meaan =-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 hypta = 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 vinfm = 0.108953526E+02 vinfx = 0.107510861E+02 vinfy = 0.169963345E+01 vinfz =-0.483841312E+00
bmag = 0.982202753E+04 btheta =-0.399342539E+01 bdt = 0.979818012E+04 bdr =-0.684025682E+03 hypta = 0.000000000E+00
c3 = 0.118708708E+03 ra = 0.955508898E+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 meaan = 0.274846183E+02

initial conditions for phase 30 before 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
state relative to idbody: venus
x =-0.939251327E+03 y =-0.737709393E+04 z = 0.591387009E+03 radius = 0.746012375E+04 scmass = 0.388307751E+06
vx = 0.142430687E+02 vy =-0.167884287E+01 vz =-0.342414513E+00 speed = 0.143457578E+02 fpa =-0.639960672E+00
sma =-0.273660439E+04 eccen = 0.372583555E+01 inc = 0.473446410E+01 argp = 0.106980891E+03 anlong = 0.156522518E+03
meaan =-0.168050387E+01 truan =-0.811720352E+00 tfp =-0.852656040E-04 rperi = 0.745953352E+04 vperi = 0.143459980E+02
```

```
impuls   maneuver print block
dvx    =-0.145887869E-01  dvy    =-0.302675298E-02  dvz    =-0.518018869E-02  dvmag  = 0.157742921E-01  tburn  = 0.306263995E+02
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.129908194E+04  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 = 0.168000000E+03
state relative to idbody: venus
x      =-0.939251327E+03  y      =-0.737709393E+04  z      = 0.591387009E+03  radius = 0.746012375E+04  scmass = 0.387008669E+06
vx     = 0.142284799E+02  vy     =-0.168186962E+01  vz     =-0.347594702E+00  speed  = 0.143317531E+02  fpa    =-0.622917861E+00
```

```
sma    =-0.274589438E+04  eccen  = 0.371662461E+01  inc    = 0.474105451E+01  argp   = 0.107231532E+03  anlong = 0.156249743E+03
meaan  =-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  vinfm  = 0.108769062E+02  vinfx  = 0.100754007E+02  vinfy  =-0.409789471E+01  vinfz  =-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  vinfm  = 0.108769062E+02  vinfx  = 0.107321883E+02  vinfy  = 0.169986571E+01  vinfz  =-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
argp   = 0.208286225E+03  anlong = 0.638971570E+02  meaan  = 0.275486293E+02

final conditions for phase  30

date   = 6 17 2011 12.00  julian =2455730.00000000  tdurp  =     40.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = venus            idbody = venus             frame  = ecliptic         epoch  = mean2000
timrf1 = 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    = 0.273625023E+01  argp   = 0.192893179E+03  anlong = 0.958880603E+02
meaan  = 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  vinfm  = 0.207474141E+02  vinfx  = 0.196204726E+02  vinfy  = 0.667533188E+01  vinfz  =-0.965500511E+00
bmag   = 0.722790812E+07  btheta = 0.610713378E+00  bdt    = 0.722749753E+07  bdr    = 0.770405191E+05  hypta  = 0.899940176E+02
c3     = 0.430455193E+03  ra     = 0.187894745E+02  dec    =-0.266727651E+01  altit  = 0.498427244E+08
Outgoing Asymptote
altp   = 0.722110148E+07  vinfm  = 0.207474141E+02  vinfx  = 0.196190788E+02  vinfy  = 0.667943389E+01  vinfz  =-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
argp   = 0.221411371E+03  anlong = 0.740056455E+02  meaan  = 0.501923109E+02

initial conditions for phase   35

date   = 6 17 2011 12.00  julian =2455730.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = mars             idbody = mars              frame  = ecliptic         epoch  = mean2000
timrf1 = 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    =-0.829811156E+02
sma    =-0.273666432E+03  eccen  = 0.292804740E+05  inc    = 0.150384887E+03  argp   = 0.270400715E+03  anlong = 0.499118207E+02
meaan  =-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  vinfm  = 0.125099216E+02  vinfx  = 0.811367384E+01  vinfy  = 0.952179516E+01  vinfz  = 0.430245223E-01
bmag   = 0.801308284E+07  btheta = 0.150385483E+03  bdt    =-0.696633183E+07  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  vinfm  = 0.125099216E+02  vinfx  = 0.811423831E+01  vinfy  = 0.952131222E+01  vinfz  = 0.434467758E-01
```

```
bmag   = 0.801308284E+07  btheta = 0.150385495E+03  bdt    =-0.696633264E+07  bdr    = 0.395976087E+07  hypta  = 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
```

```
final conditions for phase  35

date   =10 10 2011 12.00  julian =2455845.00000000  tdurp  =    115.00000000  critr  =   timrfl          propid = 1step
primid = sun              secid  = mars             idbody = mars             frame  = ecliptic          epoch  = mean2000
timrfl = 0.323000000E+03
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
meaan  =-0.655473392E-02  truan  =-0.346415439E-02  tfp    =-0.384028891E-06  rperi  = 0.388086084E+04  vperi  = 0.707171967E+01
Incoming Asymptote
altp   = 0.483660842E+03  vinfm  = 0.528561061E+01  vinfx  = 0.455477922E+01  vinfy  = 0.262769714E+01  vinfz  = 0.535605717E+00
bmag   = 0.519227805E+04  btheta =-0.166719774E+01  bdt    = 0.519008006E+04  bdr    =-0.151064054E+03  hypta  = 0.735510323E+02
c3     = 0.279376795E+02  ra     = 0.299810722E+02  dec    = 0.581592413E+01  altit  = 0.483660847E+03
Outgoing Asymptote
altp   = 0.483660842E+03  vinfm  = 0.528561061E+01  vinfx  = 0.239770784E+01  vinfy  = 0.469619692E+01  vinfz  = 0.366621192E+00
bmag   = 0.519227805E+04  btheta =-0.456169921E+01  bdt    = 0.517583030E+04  bdr    =-0.412955294E+03  hypta  = 0.000000000E+00
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  meaan  = 0.122469476E+03

initial conditions for phase   40

subproblem iteration  32  final     icnvgd =   1

  subp. ind. vars.              4              5              6
                 -1.45887869E-02-3.02675298E-03-5.18018869E-03

  subp. dep. vars.              4              5              6
                  3.88086084E+03-3.84028891E-07 5.19008006E+03
                 -8.60841762E-01 3.84028891E-07-5.87811764E-05
subproblem number  3

initial conditions for phase   40

final conditions for phase  40

date   =10 10 2011 12.00  julian =2455845.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = mars             idbody = mars             frame  = ecliptic          epoch  = mean2000
timrfl = 0.323000000E+03
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
meaan  =-0.655473392E-02  truan  =-0.346415439E-02  tfp    =-0.384028891E-06  rperi  = 0.388086084E+04  vperi  = 0.707171967E+01
Incoming Asymptote
altp   = 0.483660842E+03  vinfm  = 0.528561061E+01  vinfx  = 0.455477922E+01  vinfy  = 0.262769714E+01  vinfz  = 0.535605717E+00
bmag   = 0.519227805E+04  btheta =-0.166719774E+01  bdt    = 0.519008006E+04  bdr    =-0.151064054E+03  hypta  = 0.735510323E+02
c3     = 0.279376795E+02  ra     = 0.299810722E+02  dec    = 0.581592413E+01  altit  = 0.483660847E+03
Outgoing Asymptote
altp   = 0.483660842E+03  vinfm  = 0.528561061E+01  vinfx  = 0.239770784E+01  vinfy  = 0.469619692E+01  vinfz  = 0.366621192E+00
bmag   = 0.519227805E+04  btheta =-0.456169921E+01  bdt    = 0.517583030E+04  bdr    =-0.412955294E+03  hypta  = 0.000000000E+00
```

```
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  meaan  = 0.122469476E+03

initial conditions for phase   45 before orbins   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
```

```
execution date and time Fri Oct 23
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                
page 7

sma =-0.153299371E+04 eccen = 0.353155693E+01 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
meaan =-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 dvy =-0.302675298E-02 dvz =-0.518018869E-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 critr = tdurp propid = conic
primid = mars secid = sun idbody = mars frame = ecliptic epoch = mean2000
timrfl = 0.323000000E+03
state relative to idbody: mars
x = 0.279600081E+04 y =-0.268119410E+04 z = 0.219038125E+03 radius = 0.388000000E+04 scmass = 0.222467576E+06
vx = 0.306261277E+01 vy = 0.322621981E+01 vz = 0.397436432E+00 speed = 0.446609975E+01 fpa =-0.381666562E-12
sma = 0.201035000E+05 eccen = 0.806998781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
meaan = 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
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 meaan = 0.128078496E+03

final conditions for phase 45

date =12 9 2011 12.00 julian =2455905.00000000 tdurp = 60.00000000 critr = tdurp propid = conic
primid = mars secid = sun idbody = mars frame = ecliptic epoch = mean2000
timrfl = 0.383000000E+03
state relative to idbody: mars
x =-0.174242594E+05 y = 0.534144104E+03 z =-0.177839432E+04 radius = 0.175229224E+05 scmass = 0.222467576E+06
vx = 0.129920633E+01 vy =-0.102879184E+01 vz = 0.107327232E+00 speed = 0.166068325E+01 fpa =-0.534531795E+02
sma = 0.201035000E+05 eccen = 0.806998781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
meaan =-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 period = 0.865410237E+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 =-0.131880675E+02 vz = 0.311697669E+00
sma = 0.220101204E+09 eccen = 0.118651171E+00 inc = 0.198999094E+01
argp = 0.235652198E+03 anlong = 0.614189311E+02 meaan =-0.168813507E+03

initial conditions for phase 50 before launch maneuver

date =12 9 2011 12.00 julian =2455905.00000000 tdurp = 60.00000000 critr = tdurp propid = 1step
primid = sun secid = mars idbody = mars frame = ecliptic epoch = mean2000
state relative to idbody: mars
x =-0.174242594E+05 y = 0.534144104E+03 z =-0.177839432E+04 radius = 0.175229224E+05 scmass = 0.222467576E+06
vx = 0.129920633E+01 vy =-0.102879184E+01 vz = 0.107327232E+00 speed = 0.166068325E+01 fpa =-0.534531795E+02
sma = 0.201035000E+05 eccen = 0.806998781E+00 inc = 0.604937751E+01 argp = 0.323901798E+02 anlong = 0.283955165E+03
meaan =-0.351984804E+02 truan =-0.138018007E+03 tfp =-0.979331444E-01 rperi = 0.388000000E+04 vperi = 0.446609975E+01

launch maneuver print block
dvx =-0.145887869E-01 dvy =-0.302675298E-02 dvz =-0.518018869E-02 dvmag = 0.358749107E+01 tburn = 0.399050221E+04
thrust = 0.200000000E+06 spi = 0.480000000E+03 dmass = 0.118648304E+06 wprop = 0.103819271E+06
```

```
initial conditions for phase   50 after launch   maneuver

date   =12  9 2011 12.00  julian =2455905.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = mars             idbody = mars             frame  = ecliptic         epoch  = mean2000
timrfl = 0.383000000E+03
state relative to idbody: mars
x      =-0.302691118E+04  y      =-0.242577039E+04  z      =-0.885817392E+02  radius = 0.388000000E+04  scmass = 0.103819271E+06
vx     = 0.499077110E+01  vy     =-0.625959852E+01  vz     = 0.877470951E+00  speed  = 0.805359082E+01  fpa    =-0.172131619E-09
sma    =-0.100103773E+04  eccen  = 0.487597776E+01  inc    = 0.639142809E+01  argp   = 0.348165404E+03  anlong = 0.230471824E+03
meaan  =-0.651497419E-09  truan  =-0.206957351E-09  tfp    =-0.201412605E-13  rperi  = 0.388000000E+04  vperi  = 0.805359082E+01
Incoming Asymptote
altp   = 0.482800000E+03  vinfm  = 0.654093942E+01  vinfx  = 0.292071129E+01  vinfy  =-0.581451596E+01  vinfz  = 0.666886960E+00
bmag   = 0.477728509E+04  btheta = 0.257483466E+01  bdt    = 0.477246193E+04  bdr    = 0.214615796E+03  hypta  = 0.781654038E+02
c3     = 0.427838885E+02  ra     =-0.633289928E+02  dec    = 0.585180749E+01  altit  = 0.482800000E+03
Outgoing Asymptote
altp   = 0.482800000E+03  vinfm  = 0.654093942E+01  vinfx  = 0.501374565E+01  vinfy  =-0.413715562E+01  vinfz  = 0.728139046E+00
bmag   = 0.477728509E+04  btheta =-0.215388652E-10  bdt    = 0.477728509E+04  bdr    =-0.179589667E-08  hypta  = 0.000000000E+00
c3     = 0.427838885E+02  ra     =-0.547790228E+02  dec    = 0.639142809E+01  altit  = 0.482800000E+03
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
sma    = 0.240662237E+09  eccen  = 0.297775446E+00  inc    = 0.383356774E+01
argp   = 0.139186832E+03  anlong = 0.980212618E+02  meaan  =-0.771008284E+02

final conditions for phase  50

date   = 1 18 2012 12.00  julian =2455945.00000000  tdurp  =     40.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = mars             idbody = mars             frame  = ecliptic         epoch  = mean2000
timrfl = 0.423000000E+03
state relative to idbody: mars
x      = 0.178913628E+08  y      =-0.149251718E+08  z      = 0.242582832E+07  radius = 0.234253337E+08  scmass = 0.103819271E+06
vx     = 0.555762988E+01  vy     =-0.464809298E+01  vz     = 0.645548932E+00  speed  = 0.727384023E+01  fpa    = 0.891446927E+02
sma    =-0.809530476E+03  eccen  = 0.431968600E+03  inc    = 0.947842140E+02  argp   = 0.847578617E+02  anlong = 0.139665486E+03
meaan  = 0.165755640E+07  truan  = 0.892773168E+02  tfp    = 0.372663101E+02  rperi  = 0.348882216E+06  vperi  = 0.729044665E+01
Incoming Asymptote
altp   = 0.345485016E+06  vinfm  = 0.727358887E+01  vinfx  = 0.555690279E+01  vinfy  =-0.464380902E+01  vinfz  = 0.678943538E+00
bmag   = 0.349690810E+06  btheta =-0.948052429E+02  bdt    =-0.292932592E+05  bdr    =-0.348461716E+06  hypta  = 0.898673611E+02
c3     = 0.529050951E+02  ra     =-0.398849297E+02  dec    = 0.535599592E+01  altit  = 0.234219365E+08
Outgoing Asymptote
altp   = 0.345485016E+06  vinfm  = 0.727358887E+01  vinfx  = 0.555743786E+01  vinfy  =-0.464793259E+01  vinfz  = 0.645524762E+00
bmag   = 0.349690810E+06  btheta =-0.948032116E+02  bdt    =-0.292809055E+05  bdr    =-0.348462754E+06  hypta  = 0.000000000E+00
c3     = 0.529050951E+02  ra     =-0.399099546E+02  dec    = 0.509165016E+01  altit  = 0.234219365E+08
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
sma    = 0.211970237E+09  eccen  = 0.286340551E+00  inc    = 0.352537246E+01
argp   = 0.167354273E+03  anlong = 0.953199762E+02  meaan  =-0.868798376E+02

initial conditions for phase   60

date   = 1 18 2012 12.00  julian =2455945.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = earth            idbody = earth            frame  = ecliptic         epoch  = mean2000
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
```

```
vx     = 0.190043391E+02  vy     =-0.818599076E+01  vz     = 0.610586295E+00  speed  = 0.207014049E+02  fpa    =-0.666317000E+02
sma    =-0.930133391E+03  eccen  = 0.488496640E+05  inc    = 0.174136625E+02  argp   = 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  vinfy  =-0.818595464E+01  vinfz  = 0.610591689E+00
bmag   = 0.454367036E+08  btheta =-0.173339706E+02  bdt    = 0.433731647E+08  bdr    =-0.135374523E+08  hypta  = 0.899988271E+02
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  = 0.190044983E+02  vinfy  =-0.818521453E+01  vinfz  = 0.610339279E+00
bmag   = 0.454367036E+08  btheta =-0.173340367E+02  bdt    = 0.433731491E+08  bdr    =-0.135375023E+08  hypta  = 0.000000000E+00
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     =-0.788523682E+01  vy     =-0.221008314E+02  vz     = 0.609935752E+00
sma    = 0.211970237E+09  eccen  = 0.286340551E+00  inc    = 0.352537246E+01
argp   = 0.167354273E+03  anlong = 0.953199762E+02  meaan  =-0.868798376E+02

final conditions for phase  60

date   = 6 26 2012 12.00  julian =2456105.00000000  tdurp  =    160.00000000  critr  =   timrfl         propid = 1step
primid = sun              secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrfl = 0.583000000E+03
state relative to idbody: earth
x      = 0.302481089E+04  y      =-0.586397149E+04  z      =-0.194506645E+04  radius = 0.687887535E+04  scmass = 0.103819271E+06
vx     = 0.935566338E+01  vy     = 0.608449291E+01  vz     =-0.379163000E+01  speed  = 0.117866853E+02  fpa    =-0.368042702E-02
sma    =-0.173042955E+05  eccen  = 0.139752415E+01  inc    = 0.253602065E+02  argp   = 0.221319779E+03  anlong = 0.788281155E+02
meaan  =-0.102203474E-02  truan  =-0.631396077E-02  tfp    =-0.744374105E-06  rperi  = 0.687887532E+04  vperi  = 0.117866853E+02
Incoming Asymptote
altp   = 0.500735324E+03  vinfm  = 0.479945529E+01  vinfx  = 0.417156720E+01  vinfy  =-0.119651454E+01  vinfz  =-0.204967097E+01
bmag   = 0.168934043E+05  btheta =-0.206774582E+01  bdt    = 0.168824044E+05  bdr    =-0.609533276E+03  hypta  = 0.443116145E+02
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  vinfy  = 0.465823139E+01  vinfz  =-0.107291524E+00
bmag   = 0.168934043E+05  btheta = 0.253299735E+02  bdt    = 0.152692531E+05  bdr    = 0.722751805E+04  hypta  = 0.000000000E+00
c3     = 0.230347710E+02  ra     = 0.481547288E+02  dec    =-0.128095029E+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  meaan  =-0.106296698E+01

initial conditions for phase   65

subproblem iteration  31  final     icnvgd =   1

  subp. ind. vars.              7              8              9
                 5.01374565E+00-4.13715562E+00 7.28139046E-01

  subp. dep. vars.              7              8              9
                 6.87887532E+03-7.44374105E-07 1.68824044E+04
                -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          propid = 1step
primid = sun              secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrfl = 0.583000000E+03
state relative to idbody: earth
```

```
x       = 0.302481089E+04  y       =-0.586397149E+04  z       =-0.194506645E+04  radius = 0.687887535E+04  scmass = 0.103819271E+06
vx      = 0.935566338E+01  vy      = 0.608449291E+01  vz      =-0.379163000E+01  speed  = 0.117866853E+02  fpa    =-0.368042702E-02
sma     =-0.173042955E+05  eccen   = 0.139752415E+01  inc     = 0.253602065E+02  argp   = 0.221319779E+03  anlong = 0.788281155E+02
meaan   =-0.102203474E-02  truan   =-0.631396077E-02  tfp     =-0.744374105E-06  rperi  = 0.687887532E+04  vperi  = 0.117866853E+02
Incoming Asymptote
altp    = 0.500735324E+03  vinfm   = 0.479945529E+01  vinfx   = 0.417156720E+01  vinfy  =-0.119651454E+01  vinfz  =-0.204967097E+01
bmag    = 0.168934043E+05  btheta  =-0.206774582E+01  bdt     = 0.168824044E+05  bdr    =-0.609533276E+03  hypta  = 0.443116145E+02
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  vinfy  = 0.465823139E+01  vinfz  =-0.107291524E+00
bmag    = 0.168934043E+05  btheta  = 0.253299735E+02  bdt     = 0.152692531E+05  bdr    = 0.722751805E+04  hypta  = 0.000000000E+00
c3      = 0.230347710E+02  ra      = 0.481547288E+02  dec     =-0.128095029E+01  altit  = 0.500735349E+03
```

```
execution date and time Fri Oct 23                                                                                                  page   10

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  meaan  =-0.106296698E+01

initial conditions for phase   70 before orbins   maneuver

date   = 6 26 2012 12.00  julian =2456105.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = earth            idbody = earth             frame  = ecliptic         epoch  = mean2000
state relative to idbody: earth
x      = 0.302481089E+04  y      =-0.586397149E+04  z      =-0.194506645E+04  radius = 0.687887535E+04  scmass = 0.103819271E+06
vx     = 0.935566338E+01  vy     = 0.608449291E+01  vz     =-0.379163000E+01  speed  = 0.117866853E+02  fpa    =-0.368042702E-02
sma    =-0.173042955E+05  eccen  = 0.139752415E+01  inc    = 0.253602065E+02  argp   = 0.221319779E+03  anlong = 0.788281155E+02
meaan  =-0.102203474E-02  truan  =-0.631396077E-02  tfp    =-0.744374105E-06  rperi  = 0.687800000E+04  vperi  = 0.117866853E+02

orbins   maneuver print block
dvx    =-0.145887869E-01  dvy    =-0.302675298E-02  dvz    =-0.518018869E-02  dvmag  = 0.146671222E+01  tburn  = 0.761357577E+03
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.277942906E+05  wprop  = 0.760249809E+05

initial conditions for phase   70 after orbins   maneuver

final conditions for phase  70

date   = 6 26 2012 12.00  julian =2456105.00000000  tdurp  =      0.00000000  critr  =   tdurp          propid = 1step
primid = sun              secid  = earth            idbody = earth             frame  = ecliptic         epoch  = mean2000
timrfl = 0.583000000E+03
state relative to idbody: earth
x      = 0.302502760E+04  y      =-0.586283403E+04  z      =-0.194506277E+04  radius = 0.687800000E+04  scmass = 0.760249809E+05
vx     = 0.819185986E+01  vy     = 0.532814871E+01  vz     =-0.331991825E+01  speed  = 0.103207361E+02  fpa    = 0.578097619E-10
sma    = 0.424570000E+05  eccen  = 0.838000801E+00  inc    = 0.253602065E+02  argp   = 0.221319779E+03  anlong = 0.788281155E+02
meaan  = 0.613834713E-11  truan  = 0.206760636E-10  tfp    = 0.171818575E-13  rperi  = 0.687800000E+04  vperi  = 0.103207361E+02
altp   = 0.499860000E+03  alta   = 0.716578600E+05  rapoap = 0.780360000E+05  altit  = 0.499860000E+03  period = 0.870632575E+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    = 0.500277705E+01
argp   = 0.196592887E+03  anlong = 0.951215847E+02  meaan  =-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
```

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 ΔV.

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 ΔV to achieve desired hyperbolic conditions (closest approach distance, inclination, time from periapsis) at lunar arrival. The second subproblem varies lunar insertion ΔV, 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 ΔV was 3.968 km/s, reduced from 4.058 km/s for the initial guess. Note that the iteration summaries display the <u>weighted</u> 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.

```
i p o s t - interplanetary post simulation.  version  2.18  , dated 03-05-90.                    problem no.    1
p$top
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,
  mxitop    = 50,
  mxitar    = 200,
  iephem    = 1,
  istm      = 'autopert',
  npad(1)   = 0,

c  master problem controls
c vary initial velocity at loi from leo

  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   minimize the delta-v at the soi

  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
  indxsi    = 1,1,1, 2,2,2,
  indsvr    = 'dvx','dvy','dvz','dvx','dvy','dvz',
  indsph    = 3*15, 3*32,
c  usub      = .029158, -.007079, -.007728, .442687,-.790124,-.090804,
  usub      = .029158, -.007079, -.007728, .0, -1.0,0.,
  indslb    = 6*-2.,
  indsub    = 6*2.,
  pertsb    =  6*1.d-5,
  wvus      = 6*2.,
c
c targets
```

```
c
  indxsd     = 1,1,1, 2,2,2,
  depsvr     = 'rperi','inc','tfp','rperi','rapoap','inc'
  depsph     = 3*30,3*35,
  depsvl     = 1838.,16.,-0.00001,1838.,1838.,16.,
  depslb     = 1838.,16.,-0.00001,1838.,1838.,16.,
  depsub     = 1838.,16.,-0.00001,1838.,1838.,16.,
  depstl     = .01,.01,.00001,.01,.01,.01,
  wvsnlc     = 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',
  iepoch     = '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, ecliptic
                  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           timrfl      1.00000000000D+10    impuls          conic
   20.000           tdurp       0.00000000000D+00    none            conic
   30.000           timrfl      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***
master problem optimization parameter   dvsum    at event       75
master problem optimization algorithm - npsol

master prob. control/indep parameters
evtnum            name
    1.000           dvx
    1.000           dvy
    1.000           dvz
   15.000           critr
   30.000           critr

master problem  target/dep parameters
evtnum            name
total number of subproblems is   2
subproblem number   1
subproblem controls   dvx           dvy           dvz
          at event       15            15            15
subproblem targets    rperi         inc           tfp
         at events       30            30            30
subproblem values      0.18380E+04  0.16000E+02 -0.10000E-04
     with tolerance    0.10000E-01  0.10000E-01  0.10000E-04
subproblem number   2
subproblem controls   dvx           dvy           dvz
          at event       32            32            32
subproblem targets    rperi         rapoap        inc
         at events       35            35            35
subproblem values      0.18380E+04  0.18380E+04  0.16000E+02
     with tolerance    0.10000E-01  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      COLD start.............
Variables..............        5      Infinite bound size....  1.00E+20      Crash tolerance........  1.00E-02
Step limit.............  2.00E+00     Infinite step size.....  1.00E+20

Nonlinear constraints..        0      Optimality tolerance...  1.00E-06      Function precision.....  9.90E-14
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      Verify 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      Save frequency.........       51

Difference interval....  1.00E-04     Central diffce 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 ItQP      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*

   1    4  1.8E-03     7  4.051820E-01   4   0   1  1.1E+01  1.1E+01  4.E+05  1.E+00  0.E+00 T FF
   2    4  0.0E+00    14  4.051820E-01   4   0   1  6.3E+01  6.3E+01  1.E+06  1.E+00  0.E+00 T FF  C
   3    2  2.1E-03    20  4.043624E-01   3   0   2  1.8E+01  1.8E+01  3.E+06  4.E+01  0.E+00 T FF  C
   4    4  1.4E-01    23  4.043346E-01   2   0   3  5.4E+00  5.4E+00  4.E+06  4.E+03  0.E+00 F FF  C
   5    2  4.3E-01    25  4.000760E-01   1   0   4  1.1E+01  1.1E+01  1.E+07  3.E+04  0.E+00 F FF  C
   6    1  1.6E-01    27  3.998416E-01   1   0   4  3.6E+00  3.6E+00  1.E+06  1.E+04  0.E+00 F FF  C
   7    4  1.0E+00    28  3.996655E-01   0   0   5  2.2E+01  2.2E+01  6.E+04  6.E+04  0.E+00 F FT  C
   8    2  1.0E+00    29  3.982310E-01   1   0   4  8.2E+00  8.2E+00  6.E+04  3.E+04  0.E+00 F FF  C
   9    2  1.0E+00    31  3.975420E-01   2   0   3  7.8E+00  7.8E+00  6.E+05  4.E+03  0.E+00 F FFM C
  10    1  1.0E+00    32  3.970350E-01   2   0   3  3.8E+00  3.8E+00  7.E+05  3.E+03  0.E+00 F FT  C
  11    1  1.0E+00    33  3.968211E-01   2   0   3  2.9E-01  2.9E-01  7.E+05  5.E+03  0.E+00 F FT  C
  12    1  1.0E+00    34  3.968006E-01   2   0   3  1.5E+00  1.5E+00  8.E+05  5.E+03  0.E+00 F FT  C
  13    1  1.0E+00    35  3.967914E-01   2   0   3  3.0E-02  3.0E-02  7.E+05  4.E+03  0.E+00 T FT  C
  14    1  7.2E-03    39  3.967914E-01   2   0   3  3.0E-02  3.0E-02  7.E+05  2.E+02  0.E+00 T FTM C
  15    1  1.2E+02    43  3.967908E-01   2   0   3  6.3E-02  6.3E-02  1.E+06  5.E+02  0.E+00 T FT  C

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   0.3333333E-01   0.1000000       0.0000000E+00      0.1783E-01
VARBL  2          FR   0.6660273E-01   0.2500000E-01   0.1000000       0.0000000E+00      0.3340E-01
VARBL  3          FR   0.6100295E-01   0.2500000E-01   0.1000000       0.0000000E+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          propid = conic
primid = earth             secid  = moon              idbody = earth             frame  = eartheq         epoch  = mean2000
state relative to idbody: earth
x       = 0.370962000E+04  y      =-0.560324000E+04  z      =-0.146603000E+04  radius = 0.000000000E+00  scmass = 0.100000000E+07
vx      = 0.609961300E+01  vy     = 0.318670600E+01  vz     = 0.325462600E+01  speed  = 0.000000000E+00  fpa    = 0.000000000E+00
sma     = 0.687799119E+04  eccen  = 0.673340314E-06  inc    = 0.285362330E+02  argp   = 0.000000000E+00  anlong = 0.327159590E+03
meaan   =-0.264989909E+02  truan  = 0.000000000E+00  tfp    = 0.000000000E+00  rperi  = 0.000000000E+00  vperi  = 0.000000000E+00

impuls   maneuver print block
dvx     = 0.246509293E+01  dvy    = 0.133205456E+01  dvz    = 0.122005899E+01  dvmag  = 0.305607534E+01  tburn  = 0.305607534E+04
thrust  = 0.100000000E+07  spi    = 0.100000000E+07  dmass  = 0.311584404E+03  wprop  = 0.999688416E+06

date    =10 13 1995 19.20  julian =2450004.30000000  tdurp  =      0.00000000  critr  =   time          propid = conic
```

```
execution date and time Thu Oct 29                                                                                    page    2

primid = earth            secid  = moon             idbody = earth            frame  = eartheq          epoch  = mean2000
timrf1 = 0.000000000E+00
state relative to idbody: earth
x      = 0.370962000E+04  y      =-0.560324000E+04  z      =-0.146603000E+04  radius = 0.687799557E+04  scmass = 0.999688416E+06
vx     = 0.856470593E+01  vy     = 0.451876056E+01  vz     = 0.447468499E+01  speed  = 0.106675297E+02  fpa    =-0.842734370E-01
sma    = 0.188927030E+06  eccen  = 0.963594514E+00  inc    = 0.280496717E+02  argp   = 0.333217561E+03  anlong = 0.327676481E+03
meaan  =-0.851281492E-03  truan  =-0.171730805E+00  tfp    =-0.223670677E-04  rperi  = 0.687798040E+04  vperi  = 0.106675417E+02
altp   = 0.499840405E+03  alta   = 0.364597940E+06  rapoap = 0.370976080E+06  altit  = 0.499855566E+03  period = 0.817244684E+06
lat    = 0.000000000E+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  meaan  =-0.389913692E+06

final conditions for phase   1

date   =10 15 1995  7.20  julian =2450005.80000000  tdurp  =      1.50000000  critr  =   timrf1         propid = conic
primid = earth            secid  = moon             idbody = earth            frame  = eartheq          epoch  = mean2000
timrf1 = 0.150000000E+01
state relative to idbody: earth
x      =-0.940651529E+05  y      = 0.218931354E+06  z      = 0.717762941E+05  radius = 0.248859453E+06  scmass = 0.999688416E+06
vx     =-0.641943429E+00  vy     = 0.805702796E+00  vz     = 0.179884081E+00  speed  = 0.104575649E+01  fpa    = 0.736246009E+02
sma    = 0.188927030E+06  eccen  = 0.963594514E+00  inc    = 0.280496717E+02  argp   = 0.333217561E+03  anlong = 0.327676481E+03
meaan  = 0.570885381E+02  truan  = 0.168950122E+03  tfp    = 0.149997763E+01  rperi  = 0.687798040E+04  vperi  = 0.106675417E+02
altp   = 0.499840405E+03  alta   = 0.364597940E+06  rapoap = 0.370976080E+06  altit  = 0.242481313E+06  period = 0.817244684E+06
lat    = 0.000000000E+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     = 0.897772776E+00  vz     = 0.252849089E+00
sma    =-0.535511541E+04  eccen  = 0.264422074E+01  inc    = 0.535655879E+02
argp   = 0.310765779E+03  anlong = 0.592438130E+02  meaan  =-0.177537257E+04

initial conditions for phase   15 before impuls   maneuver

date   =10 15 1995  7.20  julian =2450005.80000000  tdurp  =      1.50000000  critr  =   timrf1         propid = conic
primid = earth            secid  = moon             idbody = earth            frame  = eartheq          epoch  = mean2000
state relative to idbody: earth
x      =-0.940651529E+05  y      = 0.218931354E+06  z      = 0.717762941E+05  radius = 0.248859453E+06  scmass = 0.999688416E+06
vx     =-0.641943429E+00  vy     = 0.805702796E+00  vz     = 0.179884081E+00  speed  = 0.104575649E+01  fpa    = 0.736246009E+02
sma    = 0.188927030E+06  eccen  = 0.963594514E+00  inc    = 0.280496717E+02  argp   = 0.333217561E+03  anlong = 0.327676481E+03
meaan  = 0.570885381E+02  truan  = 0.168950122E+03  tfp    = 0.149997763E+01  rperi  = 0.687798040E+04  vperi  = 0.106675417E+02

impuls   maneuver print block
dvx    =-0.274819515E-01  dvy    =-0.214944086E-01  dvz    = 0.382630952E-01  dvmag  = 0.517815770E-01  tburn  = 0.517654427E+02
thrust = 0.100000000E+07  spi    = 0.100000000E+07  dmass  = 0.527859218E+01  wprop  = 0.999683137E+06

initial conditions for phase   15 after impuls   maneuver

final conditions for phase  15

date   =10 15 1995  7.20  julian =2450005.80000000  tdurp  =      0.00000000  critr  =   tdurp          propid = conic
primid = earth            secid  = moon             idbody = earth            frame  = eartheq          epoch  = mean2000
timrf1 = 0.150000000E+01
state relative to idbody: earth
x      =-0.940651529E+05  y      = 0.218931354E+06  z      = 0.717762941E+05  radius = 0.248859453E+06  scmass = 0.999683137E+06
```

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

```
execution date and time Thu Oct 29                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                page    3

sma    = 0.190470310E+06  eccen  = 0.958785506E+00  inc    = 0.215995786E+02  argp   = 0.320308678E+03  anlong = 0.342787237E+03
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    = 0.000000000E+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     = 0.289568155E+00  vy     = 0.876278367E+00  vz     = 0.291112184E+00
sma    =-0.556159178E+04  eccen  = 0.133048215E+01  inc    = 0.282013955E+02
argp   = 0.358243518E+03  anlong = 0.356805098E+02  meaan  =-0.167144329E+04

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
timrfl = 0.150000000E+01
state relative to idbody: moon
x      = 0.120175771E+06  y      = 0.131335948E+06  z      = 0.138631727E+05  radius = 0.178559611E+06  scmass = 0.999683137E+06
vx     =-0.668965723E+00  vy     =-0.694433710E+00  vz     =-0.818931114E-01  speed  = 0.967708529E+00  fpa    =-0.884802786E+02
sma    =-0.556159178E+04  eccen  = 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  =-0.795543808E-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 = 0.297525920E+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      =-0.247290328E+06  z      =-0.213371395E+05
vx     = 0.240181669E+00  vy     =-0.102001655E+01  vz     =-0.112162056E+00
sma    = 0.190470310E+06  eccen  = 0.958785506E+00  inc    = 0.682936048E+01
argp   = 0.580306402E+02  anlong = 0.399059132E+02  meaan  = 0.565958086E+02

final conditions for phase  20

date   =10 17 1995  7.20  julian =2450007.80000000  tdurp  =      2.00000000  critr  =   timrfl         propid = conic
primid = moon             secid  = earth             idbody = moon              frame  = bodyeq           epoch  = mean2000
timrfl = 0.350000000E+01
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  = 0.133048215E+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  vinfy  =-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  vinfy  =-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   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
timrfl = 0.350000000E+01
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  = 0.133048215E+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  vinfy  =-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  vinfy  =-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  = 0.133048215E+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  dvy    = 0.850095765E+00  dvz    =-0.121638038E+00  dvmag  = 0.860051331E+00  tburn  = 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
timrfl = 0.350000000E+01
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  vy     =-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
```

```
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             secid  = earth            idbody = moon             frame  = bodyeq           epoch  = mean2000
timrfl = 0.350000000E+01
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  vy     =-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

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 name	phase	value	residual	constraints name	phase	value	residual	objective function name	phase	value
1	dvx	1.0	0.24650929E+01	0.00000000E+00					dvsum	75.0	0.396790824E+01
2	dvy	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 ΔV maneuver is placed at this first event (ideally the ΔV should be zero), and at every event except the final event.

The next event (#11) occurs 14 minutes later (.01 days), where another impulsive ΔV 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 ΔV 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.

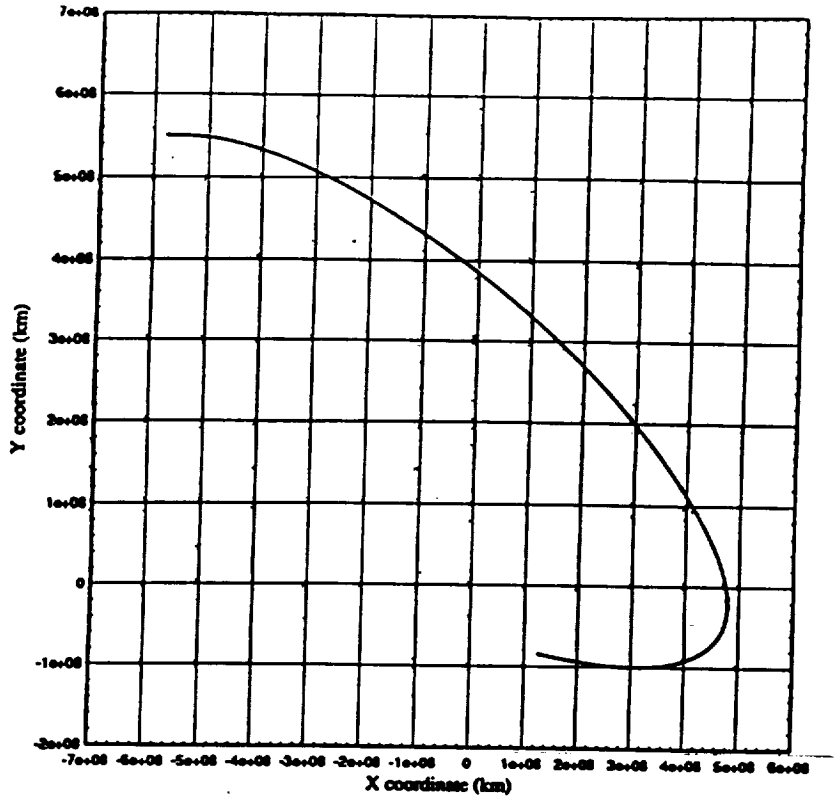
The next iteration takes place and the resultant independent and dependent parameter values are displayed after the iteration 1 summary. Noteworthy items include the Jacobian condition of 40000 (a significant worsening), norm of the nonlinear constraints of 8.84 (also degraded), and an objective (total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

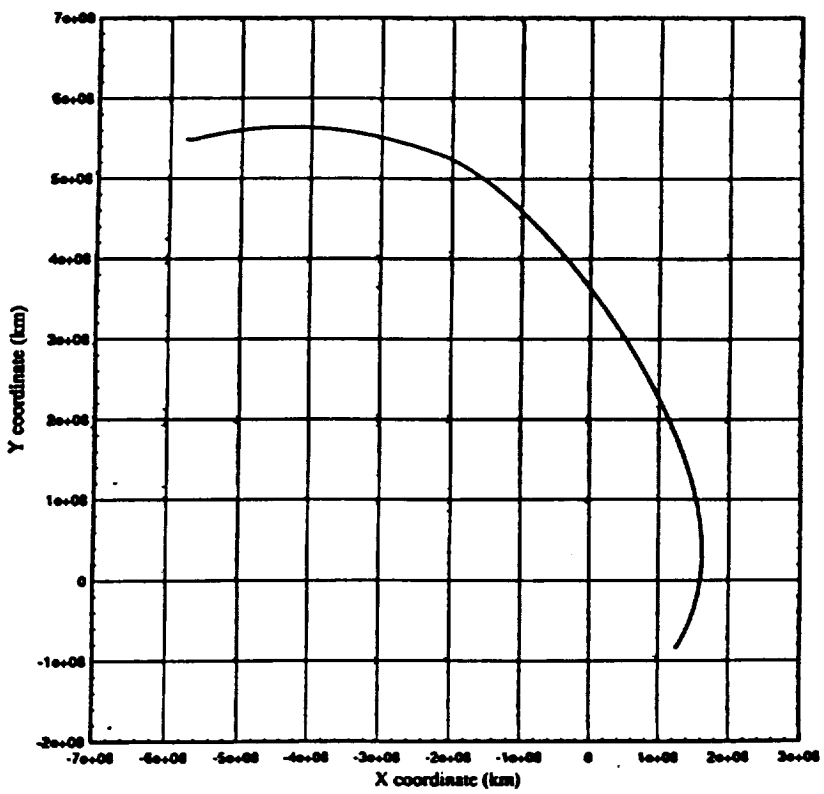
The final solution is displayed after convergence. In this case, a whopping 51.9 km/s total ΔV is required. This large ΔV indicates an aberrant solution. Figure 3 - 1a is an x-y plot of the final trajectory. This points out an interesting phenomenon. Even though NPSOL has found an optimal, and a "feasible", 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 ΔV 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, $\Delta V = 52$km/s



b) 2 Segments/Phase, $\Delta V = 14$ 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.                    problem no.    1
p$top
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,
  iprint    = 0,
  ipro      =-1,
  fesn      = 20,
  istm      = 'autopert',
  npad(1)   = 0,
  mxitop    = 0,150,-1,
c mxitop    = 50,-1,
c mxitop    = 0,0,-1,
c mxitop    = 0,-1,
c mxitop    = -1,
c
c
c  minimize delta-v for total mission
c
c
c  earth escape
c
c  event     = 10,
c
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  radius = 0.656300000e+04  scm
  optvar    = 5hdvsum,
c  dvsum    30.0  0.726729002e+01
  opt       = -1,
  optph     = 20,
  wopt      = 10.,
  etanl     = .5,
c
c controls
c
  indxi(1) = 1,2,3,
  indvr(1) = 'dvx','dvy','dvz',
  indph(1) = 3*10,
  u(1) = 3*0.,
  wvu(1) = 3*0.01,
c
  indxi(4) = 4,5,6,
  indvr(4) = 'dvx','dvy','dvz',
  indph(4) = 3*11,
  u(4) = 3*0.,
  wvu(4) = 3*0.01,
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
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
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
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
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
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
c  event     = 19 timrf1 = 0.68563102e+03,
c
         -0.570000000e+09,0.552000000e+09,0.109000000e+08,
         -0.324878541e+02,-0.719277290e+01,-0.642151228e+00,
          0.213689293e+06,
c
c  jupiter tca
c  7/9/1979
c
c  event     = 20,
c
         -0.578709476e+09,0.549420928e+09,0.107814976e+08,
         -0.324878541e+02,-0.719277290e+01,-0.642151228e+00,
          0.213689293e+06,
c event 20
c  date   = 7  7 1979  0.00  julian =2444061.50000000  tdurp  =    666.00000000  critr  =   timrf1         pr
c timrf1 = 0.706000000e+03
c state relative to idbody: jupiter
c x      =-0.227252336e+06  y      = 0.462397775e+06  z      =-0.544681248e+05  radius = 0.518094686e+06  scm
c state relative primary body: sun
c x      =-0.578709476e+09  y      = 0.549420928e+09  z      = 0.107814976e+08
c vx     =-0.324878541e+02  vy     =-0.719277290e+01  vz     =-0.642151228e+00
c
c targets
c
  indxd(1)    = 1,2,3,
  depvr(1)     = 3htfp,4hbdti,4hbdri,
  depph(1)     = 3*20,
  depvlb(1) =    -0.50627587e-02,0.17929715e+07,0.11606819e+06,
                 -0.15230666e-02,0.46892684e+06,-0.17137332e+05,
  depvub(1) =    -0.50627587e-02,0.17929715e+07,0.11606819e+06,
                 -0.15230666e-02,0.46892684e+06,-0.17137332e+05,
c  depvlb(1)     = -.011,.05d7,.05d6,
c  depvub(1)     =  .000,.30d7,.30d6,
  wvnlc(1) = 1.e+3,2*1.e+9,
c
c*include 'excu3e'
 $
p$traj
c
c  earth escape
c
  event      = 10,
  iepoch     = 'calend',
  date       = 1977,8,20,
  idfram     = 'ecliptic',
  icbody     = 0,
  ipbody(1)  = 3,
  iforce(1)  = 0,
  npert      = 3,5,
  dt         = 10.d0,
  prnc       = 10.0d0,
  mantyp     = 'impuls',
  ilnch      = 2,
  rperi      = 6563.,
  rapoap     = 6563.,
  inc        = 28.5,
```

```
c  pinc = 2.,
c  prnc = 2.,
  conode = 'float',
  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
  thrust    = 2.d5,
  spi       = 480.,
  scmass = 0.213689293e+06,
  inputx    = 'cartes',
  idbody    = 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     = 5htdurp,
  value     = 0.01,
  mantyp    = 'impuls',
  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
 $
p$traj
c
c
  event     = 12,
  critr     = 6htimrfl,
  value     = 0.21,
  mantyp    = 'impuls',
  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
 $
p$traj
c
c
  event     = 13,
  critr     = 6htimrfl,
  value     = 2.21,
  ipbody(1) = 0,
  mantyp    = 'impuls',
  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 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,
  nsgph0     = 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,
  nsgph0     = 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,
  nsgph0     = 0,
  nsgpwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
 $
p$traj
c
c  jupiter tca
c  7/9/1979
c
  event      = 20,
  ipbody     = 5,
  idbody     = 5,
  critr      = 6htimrfl,
  value      = 686.13102,
  nsegph     = 1,
  nsgph0     = 0,
  namlst     = 'none',
```

$

```
*** 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                                                                                    page    1

**** 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       -3.78644734676D+03   2.73328700933D+00   4.97418836903D-01
                 5.89490535761D-01   5.13082127711D+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          timrf1      2.10000000000D-01    impuls          none
   13.000          timrf1      2.21000000000D+00    impuls          none
   17.000          timrf1      6.66131020000D+02    impuls          none
   18.000          timrf1      6.84131020000D+02    impuls          none
   19.000          timrf1      6.85631020000D+02    impuls          none
   20.000          timrf1      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          dvy
   10.000          dvz
   11.000          dvx
   11.000          dvy
   11.000          dvz
   12.000          dvx
   12.000          dvy
   12.000          dvz
   13.000          dvx
   13.000          dvy
   13.000          dvz
   17.000          dvx
   17.000          dvy
   17.000          dvz
   18.000          dvx
   18.000          dvy
   18.000          dvz
   19.000          dvx
   19.000          dvy
   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          -1           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           0
 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           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
EPS (machine precision)  3.55E-15        Derivative level.......        0       Verify level...........        0

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        0       Save frequency.........        1

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           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           0
 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           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// NFIXED LINACT NLNACT
//NPCRSH//      0      0    108

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

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

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

//NPMRT //         SCALE        RHONRM        GRDALF
//NPMRT //      1.00E+00      1.06E+02     -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    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	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 2	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 3	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 4	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 5	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 6	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 7	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 8	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 9	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 10	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 11	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 12	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 13	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 14	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 15	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 16	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 17	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 18	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 19	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 20	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 21	FR	0.0000000E+00	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 22	FR	-0.5479069	-37515.49	37515.49	0.0000000E+00	0.3751E+05
VARBL 23	FR	-0.8365333	-37515.49	37515.49	0.0000000E+00	0.3751E+05
VARBL 24	FR	0.3160850E-02	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 25	FR	0.3444482	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 26	FR	0.8843830	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 27	FR	0.3149954	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 28	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 29	FR	-0.5620824	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 30	FR	-0.8264678	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 31	FR	0.3184858E-01	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 32	FR	0.3515340	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 33	FR	0.8814330	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 34	FR	0.3154356	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 35	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 36	FR	-0.5581288	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 37	FR	-0.1312844	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 38	FR	0.8193025	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 39	FR	0.4222132	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 40	FR	0.8487467	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 41	FR	0.3183788	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 42	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 43	FR	-0.6809658	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 44	FR	0.7321513	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 45	FR	0.1549543E-01	-130.3108	130.3108	0.0000000E+00	130.3
VARBL 46	FR	-0.9761752	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 47	FR	-0.2161241	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 48	FR	-0.1929497E-01	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 49	FR	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 50	FR	0.8782371	-3488.120	3488.120	0.0000000E+00	3487.
VARBL 51	FR	0.4780978	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 52	FR	0.1105206E-01	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 53	FR	-0.9963593	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 54	FR	0.7658641E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 55	FR	-0.3745247E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 56	FR	1.000000	-467969.2	467969.2	0.0000000E+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	1.000000	-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	1.000000	-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	1.000000	-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	1.000000	-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	1.000000	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 92	FR	0.8586801	-662.6572	662.6572	0.0000000E+00	661.8
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	1.000000	-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	1.000000	-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	1.000000	-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

Nonlnr 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	0.0000000E+00	0.0000000E+00	0.0000000E+00	195947.5	0.0000E+00
NLCON 5	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-6881.528	0.0000E+00
NLCON 6	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-133743.5	0.0000E+00
NLCON 7	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	643451.4	0.0000E+00
NLCON 8	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1529933.	0.0000E+00
NLCON 9	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-74890.30	0.0000E+00
NLCON 10	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-67.19727	0.0000E+00
NLCON 11	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	160313.7	0.0000E+00
NLCON 12	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-37385.66	0.0000E+00
NLCON 13	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	6321.098	0.0000E+00
NLCON 14	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	548505.0	0.0000E+00
NLCON 15	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1305610.	0.0000E+00
NLCON 16	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-63943.70	0.0000E+00
NLCON 17	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-64.48641	0.0000E+00
NLCON 18	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	148154.1	0.0000E+00
NLCON 19	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-34463.45	0.0000E+00
NLCON 20	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	5827.568	0.0000E+00
NLCON 21	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	534395.2	0.0000E+00
NLCON 22	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1300678.	0.0000E+00
NLCON 23	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-64380.00	0.0000E+00
NLCON 24	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-59.06284	0.0000E+00
NLCON 25	EQ	0.1569469E-13	0.0000000E+00	0.0000000E+00	59070.21	0.1569E-13
NLCON 26	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-14601.25	0.0000E+00
NLCON 27	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	1883.499	0.0000E+00
NLCON 28	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	395068.8	0.0000E+00
NLCON 29	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1257839.	0.0000E+00
NLCON 30	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-68313.29	0.0000E+00
NLCON 31	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-50.89077	0.0000E+00
NLCON 32	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	942729.4	0.0000E+00
NLCON 33	EQ	0.1213614E-17	0.0000000E+00	0.0000000E+00	-785671.5	0.1214E-17
NLCON 34	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-23909.25	0.0000E+00
NLCON 35	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	81383.59	0.0000E+00
NLCON 36	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-88633.62	0.0000E+00
NLCON 37	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1344.681	0.0000E+00
NLCON 38	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-39.60854	0.0000E+00
NLCON 39	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	35129.92	0.0000E+00
NLCON 40	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-29597.88	0.0000E+00
NLCON 41	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-899.9141	0.0000E+00
NLCON 42	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	12767.25	0.0000E+00

NLCON 43	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-25045.32	0.0000E+00
NLCON 44	EQ	0.4716660E-17	0.0000000E+00	0.0000000E+00	193.8782	0.4717E-17
NLCON 45	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-28.31639	0.0000E+00
NLCON 46	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	24776.43	0.0000E+00
NLCON 47	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-20878.24	0.0000E+00
NLCON 48	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-633.9319	0.0000E+00
NLCON 49	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	9037.652	0.0000E+00
NLCON 50	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-21914.11	0.0000E+00
NLCON 51	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	289.8587	0.0000E+00
NLCON 52	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-17.00319	0.0000E+00
NLCON 53	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	15444.44	0.0000E+00
NLCON 54	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-13001.97	0.0000E+00
NLCON 55	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-394.5868	0.0000E+00
NLCON 56	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	7792.764	0.0000E+00
NLCON 57	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-20868.30	0.0000E+00
NLCON 58	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	321.8631	0.0000E+00
NLCON 59	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-5.667729	0.0000E+00
NLCON 60	EQ	-169.5702	0.0000000E+00	0.0000000E+00	-521.5694	-169.6
NLCON 61	EQ	-257.9558	0.0000000E+00	0.0000000E+00	121.6738	-258.0
NLCON 62	EQ	0.9253491	0.0000000E+00	0.0000000E+00	-20.57026	0.9253
NLCON 63	EQ	-0.1495380	0.0000000E+00	0.0000000E+00	-849836.4	-0.1495
NLCON 64	EQ	-0.6740589E-01	0.0000000E+00	0.0000000E+00	2021763.	-0.6741E-01
NLCON 65	EQ	0.2752391E-01	0.0000000E+00	0.0000000E+00	98991.67	0.2752E-01
NLCON 66	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	37.92490	0.0000E+00
NLCON 67	EQ	-0.2117614E-04	0.0000000E+00	0.0000000E+00	-8908.316	-0.2118E-04
NLCON 68	EQ	-0.1445640E-05	0.0000000E+00	0.0000000E+00	2074.920	-0.1446E-05
NLCON 69	EQ	-0.2999026E-06	0.0000000E+00	0.0000000E+00	-350.8710	-0.2999E-06
NLCON 70	EQ	0.1179009	0.0000000E+00	0.0000000E+00	-30093.92	0.1179
NLCON 71	EQ	-0.7655084E-01	0.0000000E+00	0.0000000E+00	72429.43	-0.7655E-01
NLCON 72	EQ	0.2116185E-05	0.0000000E+00	0.0000000E+00	3566.167	0.2116E-05
NLCON 73	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	711.6437	0.0000E+00
NLCON 74	EQ	0.1945117E-03	0.0000000E+00	0.0000000E+00	-90408.51	0.1945E-03
NLCON 75	EQ	-0.2888520E-03	0.0000000E+00	0.0000000E+00	20675.00	-0.2889E-03
NLCON 76	EQ	-0.6039392E-03	0.0000000E+00	0.0000000E+00	-3050.345	-0.6039E-03
NLCON 77	EQ	0.1083490	0.0000000E+00	0.0000000E+00	-280585.2	0.1083
NLCON 78	EQ	-0.6984803E-01	0.0000000E+00	0.0000000E+00	772078.7	-0.6985E-01
NLCON 79	EQ	0.2065037E-02	0.0000000E+00	0.0000000E+00	40149.74	0.2065E-02
NLCON 80	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	6333.328	0.0000E+00
NLCON 81	EQ	0.7014296	0.0000000E+00	0.0000000E+00	-795515.6	0.7014
NLCON 82	EQ	-0.6649538	0.0000000E+00	0.0000000E+00	2675134.	-0.6650
NLCON 83	EQ	-0.4977200E-01	0.0000000E+00	0.0000000E+00	148189.3	-0.4977E-01
NLCON 84	EQ	-0.3625388E-02	0.0000000E+00	0.0000000E+00	-0.1190997E+08	-0.3625E-02
NLCON 85	EQ	-0.1280159	0.0000000E+00	0.0000000E+00	0.1850429E+08	-0.1280
NLCON 86	EQ	-0.7617111E-02	0.0000000E+00	0.0000000E+00	819215.9	-0.7617E-02
NLCON 87	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	1730431.	0.0000E+00
NLCON 88	EQ	0.5417286	0.0000000E+00	0.0000000E+00	-29600.17	0.5417
NLCON 89	EQ	0.1790756	0.0000000E+00	0.0000000E+00	24817.51	0.1791
NLCON 90	EQ	0.1273526E-01	0.0000000E+00	0.0000000E+00	755.9454	0.1274E-01
NLCON 91	EQ	-0.8743459E-02	0.0000000E+00	0.0000000E+00	-17205.37	-0.8743E-02
NLCON 92	EQ	0.2336671E-01	0.0000000E+00	0.0000000E+00	21456.08	0.2337E-01
NLCON 93	EQ	0.6252573E-03	0.0000000E+00	0.0000000E+00	185.7961	0.6253E-03
NLCON 94	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	35212.28	0.0000E+00
NLCON 95	EQ	-2.846881	0.0000000E+00	0.0000000E+00	-2492.744	-2.847
NLCON 96	EQ	-1.016844	0.0000000E+00	0.0000000E+00	2100.508	-1.017
NLCON 97	EQ	-0.1065906	0.0000000E+00	0.0000000E+00	63.82689	-0.1066
NLCON 98	EQ	0.2469226E-02	0.0000000E+00	0.0000000E+00	-773.1290	0.2469E-02
NLCON 99	EQ	0.2009735E-01	0.0000000E+00	0.0000000E+00	1664.927	0.2010E-01
NLCON100	EQ	0.3092034E-03	0.0000000E+00	0.0000000E+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.............
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
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        0       Save frequency.........      151

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           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           0
 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           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// NFIXED LINACT NLNACT
//NPCRSH//      0      0    108

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

//NPFEAS//  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//        RFROBN         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

//NPFEAS//  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
   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

//NPFEAS//  The maximum violation is       6.67E-08 in constraint  196

//NPMRT //        QPCURV        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

//NPFEAS//  The maximum violation is       1.95E-08 in constraint  196

//NPMRT //        QPCURV        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

//NPFEAS//  The maximum violation is       3.54E-08 in constraint  196

//NPMRT //        QPCURV        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

//NPFEAS//  The maximum violation is       9.18E-09 in constraint  196

//NPMRT //        QPCURV        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  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

//NPFEAS//  The maximum violation is       2.28E-09 in constraint  164

//NPMRT //        QPCURV        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  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	FR	-275.2018	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 4	FR	2.840364	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 5	FR	-4.892074	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 6	FR	-0.1778320	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 7	FR	3.274723	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 8	FR	-5.168941	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 9	FR	0.1183573	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 10	FR	147.7399	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 11	FR	-194.5295	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 12	FR	63.57746	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 13	FR	0.3215334E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 14	FR	-0.2508060E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 15	FR	0.1208432E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 16	FR	-0.5683545E-02	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 17	FR	-0.2628689E-02	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 18	FR	-0.1198254E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 19	FR	-0.1808043E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 20	FR	-0.7817599E-02	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 21	FR	0.1089764E-01	-0.1000000E+14	0.1000000E+14	0.0000000E+00	0.1000E+14
VARBL 22	FR	0.1206937E-01	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 23	FR	-0.1084348E-01	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 24	FR	-0.8245610E-03	-37515.49	37515.49	0.0000000E+00	0.3752E+05
VARBL 25	FR	2.421128	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 26	FR	-2.331155	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 27	FR	0.6139215E-01	-0.7781155E+10	0.7781155E+10	0.0000000E+00	0.7781E+10
VARBL 28	FR	0.2848704E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 29	FR	0.2284917	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 30	FR	-0.2195162	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 31	FR	0.4851446E-02	-40634.63	40634.63	0.0000000E+00	0.4063E+05
VARBL 32	FR	2.389676	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 33	FR	-2.304844	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 34	FR	0.6373395E-01	-0.7792062E+10	0.7792062E+10	0.0000000E+00	0.7792E+10
VARBL 35	FR	0.2814659E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 36	FR	6.177240	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 37	FR	-5.959381	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 38	FR	0.1615997	-105325.3	105325.3	0.0000000E+00	0.1053E+06
VARBL 39	FR	2.413518	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 40	FR	-2.329426	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 41	FR	0.6440019E-01	-0.7865354E+10	0.7865354E+10	0.0000000E+00	0.7865E+10
VARBL 42	FR	0.2778301E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 43	FR	-0.7041034	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 44	FR	0.7048972	-130.3108	130.3108	0.0000000E+00	129.6
VARBL 45	FR	0.1641169E-01	-130.3108	130.3108	0.0000000E+00	130.3
VARBL 46	FR	-0.7869499	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 47	FR	0.6714813E-02	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 48	FR	-0.3034222E-01	-0.3004739E+10	0.3004739E+10	0.0000000E+00	0.3005E+10
VARBL 49	FR	0.1625179E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 50	FR	0.1397607	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 51	FR	-0.2230370E-02	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 52	FR	0.4135316E-02	-3488.120	3488.120	0.0000000E+00	3488.
VARBL 53	FR	-0.8206544	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 54	FR	0.3896736	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 55	FR	-0.5677726E-01	-0.4248389E+10	0.4248389E+10	0.0000000E+00	0.4248E+10
VARBL 56	FR	0.1625260E-04	-467969.2	467969.2	0.0000000E+00	0.4680E+06
VARBL 57	FR	0.6887782E-01	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 58	FR	0.5481994E-01	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 59	FR	-0.2788092E-02	-4949.378	4949.378	0.0000000E+00	4949.
VARBL 60	FR	-0.9145105	-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	7949.
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	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.2098225	0.0000E+00
NLCON 5	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.5181035E-01	0.0000E+00
NLCON 6	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1551691	0.0000E+00
NLCON 7	EQ	-0.3303124E-14	0.0000000E+00	0.0000000E+00	0.8943637	-0.3303E-14
NLCON 8	EQ	0.4931092E-13	0.0000000E+00	0.0000000E+00	-1.286776	0.4931E-13
NLCON 9	EQ	0.3500353E-14	0.0000000E+00	0.0000000E+00	0.8019190E-01	0.3500E-14
NLCON 10	EQ	0.1044032E-10	0.0000000E+00	0.0000000E+00	0.4029980E-09	0.1044E-10
NLCON 11	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	6.373173	0.0000E+00
NLCON 12	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-4.276942	0.0000E+00
NLCON 13	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.7959879	0.0000E+00
NLCON 14	EQ	-0.3798315E-12	0.0000000E+00	0.0000000E+00	0.7218794	-0.3798E-12
NLCON 15	EQ	-0.2902643E-13	0.0000000E+00	0.0000000E+00	-1.070901	-0.2903E-13
NLCON 16	EQ	-0.2820574E-13	0.0000000E+00	0.0000000E+00	0.7493854E-01	-0.2821E-13
NLCON 17	EQ	-0.6767918E-11	0.0000000E+00	0.0000000E+00	0.6919382E-10	-0.6768E-11
NLCON 18	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.2819703	0.0000E+00
NLCON 19	EQ	0.1088014E-14	0.0000000E+00	0.0000000E+00	-0.6630108E-01	0.1088E-14
NLCON 20	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	-0.1597573E-01	0.0000E+00
NLCON 21	EQ	-0.2859650E-12	0.0000000E+00	0.0000000E+00	0.6942502	-0.2860E-12
NLCON 22	EQ	-0.3875615E-14	0.0000000E+00	0.0000000E+00	-1.062504	-0.3876E-14
NLCON 23	EQ	0.2601334E-13	0.0000000E+00	0.0000000E+00	0.7629208E-01	0.2601E-13
NLCON 24	EQ	-0.7230293E-11	0.0000000E+00	0.0000000E+00	0.8599938E-11	-0.7230E-11
NLCON 25	EQ	-0.7307027E-14	0.0000000E+00	0.0000000E+00	16.71425	-0.7307E-14
NLCON 26	EQ	0.3554770E-14	0.0000000E+00	0.0000000E+00	-3.627170	0.3555E-14
NLCON 27	EQ	0.1909300E-16	0.0000000E+00	0.0000000E+00	-0.9740813	0.1909E-16
NLCON 28	EQ	0.1494355E-14	0.0000000E+00	0.0000000E+00	70.62834	0.1494E-14
NLCON 29	EQ	0.2061330E-15	0.0000000E+00	0.0000000E+00	-158.9018	0.2061E-15
NLCON 30	EQ	0.6416934E-16	0.0000000E+00	0.0000000E+00	14.26755	0.6417E-16
NLCON 31	EQ	-0.7820812E-11	0.0000000E+00	0.0000000E+00	0.9418140E-11	-0.7821E-11
NLCON 32	EQ	-0.1213614E-15	0.0000000E+00	0.0000000E+00	3.313150	-0.1214E-15
NLCON 33	EQ	0.1383520E-15	0.0000000E+00	0.0000000E+00	-6.233249	0.1384E-15
NLCON 34	EQ	-0.6068070E-18	0.0000000E+00	0.0000000E+00	0.7410129	-0.6068E-18
NLCON 35	EQ	0.1406962E-11	0.0000000E+00	0.0000000E+00	0.2271528	0.1407E-11
NLCON 36	EQ	-0.3558504E-12	0.0000000E+00	0.0000000E+00	-0.4895646	-0.3559E-12
NLCON 37	EQ	0.3562774E-14	0.0000000E+00	0.0000000E+00	0.5703453E-01	0.3563E-14
NLCON 38	EQ	-0.2280512E-08	0.0000000E+00	0.0000000E+00	0.1622285E-10	-0.2281E-08
NLCON 39	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.1049116	0.0000E+00
NLCON 40	EQ	0.1268971E-17	0.0000000E+00	0.0000000E+00	-0.2634199	0.1269E-17
NLCON 41	EQ	0.1522765E-17	0.0000000E+00	0.0000000E+00	0.3027199E-01	0.1523E-17
NLCON 42	EQ	-0.8580547E-12	0.0000000E+00	0.0000000E+00	0.8340031E-02	-0.8581E-12
NLCON 43	EQ	-0.4467620E-13	0.0000000E+00	0.0000000E+00	-0.4853620E-01	-0.4468E-13
NLCON 44	EQ	0.1198032E-14	0.0000000E+00	0.0000000E+00	0.5060694E-02	0.1198E-14
NLCON 45	EQ	-0.6884216E-10	0.0000000E+00	0.0000000E+00	0.1922204E-10	-0.6884E-10
NLCON 46	EQ	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.9229450E-01	0.0000E+00

NLCON 47	EQ	0.1152367E-16	0.0000000E+00	0.0000000E+00	-0.1980286	0.1152E-16
NLCON 48	EQ	0.7922523E-17	0.0000000E+00	0.0000000E+00	0.2316926E-01	0.7923E-17
NLCON 49	EQ	-0.8637661E-12	0.0000000E+00	0.0000000E+00	-0.3179505E-02	-0.8638E-12
NLCON 50	EQ	-0.8825403E-12	0.0000000E+00	0.0000000E+00	-0.1921239E-01	-0.8825E-12
NLCON 51	EQ	0.1221174E-12	0.0000000E+00	0.0000000E+00	0.1701638E-02	0.1221E-12
NLCON 52	EQ	-0.8074238E-09	0.0000000E+00	0.0000000E+00	0.1451955E-10	-0.8074E-09
NLCON 53	EQ	0.4627254E-17	0.0000000E+00	0.0000000E+00	0.7051934E-01	0.4627E-17
NLCON 54	EQ	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	0.1351957E-01	0.0000E+00
NLCON 56	EQ	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	-0.9739340E-02	0.0000E+00
NLCON 58	EQ	-0.1884398E-16	0.0000000E+00	0.0000000E+00	0.5582426E-03	-0.1884E-16
NLCON 59	EQ	-0.2558265E-17	0.0000000E+00	0.0000000E+00	0.4839108E-11	-0.2558E-17
NLCON 60	EQ	-0.9796890E-13	0.0000000E+00	0.0000000E+00	-9.948297	-0.9797E-13
NLCON 61	EQ	0.5839055E-14	0.0000000E+00	0.0000000E+00	6.561916	0.5839E-14
NLCON 62	EQ	-0.1560821E-13	0.0000000E+00	0.0000000E+00	1.559511	-0.1561E-13
NLCON 63	EQ	0.4086797E-09	0.0000000E+00	0.0000000E+00	-0.8660916	0.4087E-09
NLCON 64	EQ	-0.3380289E-11	0.0000000E+00	0.0000000E+00	1.268229	-0.3380E-11
NLCON 65	EQ	0.3048619E-10	0.0000000E+00	0.0000000E+00	-0.8488208E-01	0.3049E-10
NLCON 66	EQ	0.5271162E-20	0.0000000E+00	0.0000000E+00	-0.2355974E-09	0.5271E-20
NLCON 67	EQ	0.3903064E-10	0.0000000E+00	0.0000000E+00	-0.3199563	0.3903E-10
NLCON 68	EQ	-0.2386095E-11	0.0000000E+00	0.0000000E+00	0.8290975E-01	-0.2386E-11
NLCON 69	EQ	0.6207880E-11	0.0000000E+00	0.0000000E+00	0.1752628E-01	0.6208E-11
NLCON 70	EQ	0.9823930E-09	0.0000000E+00	0.0000000E+00	-0.7082692	0.9824E-09
NLCON 71	EQ	-0.6478620E-10	0.0000000E+00	0.0000000E+00	1.067233	-0.6479E-10
NLCON 72	EQ	0.1632446E-09	0.0000000E+00	0.0000000E+00	-0.7567317E-01	0.1632E-09
NLCON 73	EQ	0.1947854E-18	0.0000000E+00	0.0000000E+00	-0.3884263E-10	0.1948E-18
NLCON 74	EQ	0.1281493E-10	0.0000000E+00	0.0000000E+00	-0.2726684	0.1281E-10
NLCON 75	EQ	-0.2224481E-11	0.0000000E+00	0.0000000E+00	0.5922492E-01	-0.2224E-11
NLCON 76	EQ	0.4039331E-11	0.0000000E+00	0.0000000E+00	0.1588634E-01	0.4039E-11
NLCON 77	EQ	0.3179708E-10	0.0000000E+00	0.0000000E+00	-0.5714162	0.3180E-10
NLCON 78	EQ	-0.5677519E-11	0.0000000E+00	0.0000000E+00	1.035958	-0.5678E-11
NLCON 79	EQ	0.1029282E-10	0.0000000E+00	0.0000000E+00	-0.8343251E-01	0.1029E-10
NLCON 80	EQ	0.7197246E-20	0.0000000E+00	0.0000000E+00	-0.6118851E-11	0.7197E-20
NLCON 81	EQ	0.1067503E-11	0.0000000E+00	0.0000000E+00	-28.42415	0.1068E-11
NLCON 82	EQ	0.2991362E-12	0.0000000E+00	0.0000000E+00	64.58139	0.2991E-12
NLCON 83	EQ	0.3263528E-12	0.0000000E+00	0.0000000E+00	-5.402213	0.3264E-12
NLCON 84	EQ	-0.1739308E-10	0.0000000E+00	0.0000000E+00	-148.7270	-0.1739E-10
NLCON 85	EQ	-0.5111264E-11	0.0000000E+00	0.0000000E+00	407.6527	-0.5111E-11
NLCON 86	EQ	-0.2850572E-11	0.0000000E+00	0.0000000E+00	-26.64372	-0.2851E-11
NLCON 87	EQ	0.6014369E-20	0.0000000E+00	0.0000000E+00	-0.1290097E-10	0.6014E-20
NLCON 88	EQ	-0.1581111E-10	0.0000000E+00	0.0000000E+00	-0.2033717	-0.1581E-10
NLCON 89	EQ	-0.6985054E-10	0.0000000E+00	0.0000000E+00	0.3972709	-0.6985E-10
NLCON 90	EQ	0.1366210E-10	0.0000000E+00	0.0000000E+00	-0.4706942E-01	0.1366E-10
NLCON 91	EQ	0.1021474E-09	0.0000000E+00	0.0000000E+00	-0.8333832E-01	0.1021E-09
NLCON 92	EQ	0.2047434E-09	0.0000000E+00	0.0000000E+00	0.1974207	0.2047E-09
NLCON 93	EQ	-0.3887419E-10	0.0000000E+00	0.0000000E+00	-0.2267330E-01	-0.3887E-10
NLCON 94	EQ	-0.2784792E-18	0.0000000E+00	0.0000000E+00	-0.1775063E-10	-0.2785E-18
NLCON 95	EQ	0.1810348E-11	0.0000000E+00	0.0000000E+00	-0.1082311	0.1810E-11
NLCON 96	EQ	0.1852775E-11	0.0000000E+00	0.0000000E+00	0.2757409	0.1853E-11
NLCON 97	EQ	0.1402341E-12	0.0000000E+00	0.0000000E+00	-0.3158128E-01	0.1402E-12
NLCON 98	EQ	-0.6846581E-10	0.0000000E+00	0.0000000E+00	-0.2699478E-02	-0.6847E-10
NLCON 99	EQ	0.9091204E-10	0.0000000E+00	0.0000000E+00	0.3415759E-01	0.9091E-10
NLCON100	EQ	-0.3173042E-10	0.0000000E+00	0.0000000E+00	-0.3412408E-02	-0.3173E-10
NLCON101	EQ	0.4210166E-20	0.0000000E+00	0.0000000E+00	-0.1683780E-10	0.4210E-20
NLCON102	EQ	-0.8790632E-13	0.0000000E+00	0.0000000E+00	-0.1047093	-0.8791E-13
NLCON103	EQ	-0.9031034E-13	0.0000000E+00	0.0000000E+00	0.1881095	-0.9031E-13
NLCON104	EQ	-0.7479671E-13	0.0000000E+00	0.0000000E+00	-0.2269984E-01	-0.7480E-13

```
NLCON105          EQ  -0.5210694E-10   0.0000000E+00   0.0000000E+00   0.5715803E-02     -0.5211E-10
NLCON106          EQ  -0.2467057E-10   0.0000000E+00   0.0000000E+00   0.1436729E-01     -0.2467E-10
NLCON107          EQ  -0.3177492E-11   0.0000000E+00   0.0000000E+00  -0.1123698E-02     -0.3177E-11
NLCON108          EQ  -0.6525769E-18   0.0000000E+00   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 = 1step
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
meaan  =-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  dvy    =-0.429264518E+02  dvz    =-0.275201773E+01  dvmag  = 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
              33std  profil made by kent       pid   3583executed 10/30/92 00:32:55using   ipost  loaded  on 10-1
  -9         as config vs-3.0
        time       x          y          z          vx         vy         vz         sma        eccen      inc
        anlong     argp       meaan      truan      rperi      vperi      tfp        rapoap     period     radius
        speed      btheti     vinfxi     vinfyi     vinfzi     bdti       bdri       hypta      c3i        rai
        deci       btheto     vinfxo
```

```
date   = 8 20 1977  0.24  julian =2443375.51000000  tdurp  =      0.01000000  critr  =   timrfl        propid = 1step
primid = earth            secid  = earth             idbody = earth             frame  = ecliptic        epoch  = mean2000
timrfl = 0.999999978E-02
state relative to idbody: earth
x      = 0.321716882E+05  y      =-0.289040146E+05  z      =-0.219792140E+04  radius = 0.433046238E+05  scmass = 0.608737610E+01
vx     = 0.311152739E+02  vy     =-0.299589875E+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  argp   = 0.267502949E+03  anlong = 0.316607533E+03
meaan  = 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  vinfx  = 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  vinfx  = 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  =      0.01000000  critr  =   tdurp         propid = 1step
primid = earth            secid  = earth             idbody = earth             frame  = ecliptic        epoch  = mean2000
timrfl = 0.999999978E-02
state relative to idbody: earth
x      = 0.321716882E+05  y      =-0.289040146E+05  z      =-0.219792140E+04  radius = 0.433046238E+05  scmass = 0.608737610E+01
vx     = 0.311152739E+02  vy     =-0.299589875E+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  argp   = 0.267502949E+03  anlong = 0.316607533E+03
meaan  = 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  vinfx  = 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  vinfx  = 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  =      0.01000000  critr  =   tdurp         propid = 1step
primid = earth            secid  = earth             idbody = earth             frame  = ecliptic        epoch  = mean2000
state relative to idbody: earth
x      = 0.321716882E+05  y      =-0.289040146E+05  z      =-0.219792140E+04  radius = 0.433046238E+05  scmass = 0.608737610E+01
vx     = 0.311152739E+02  vy     =-0.299589875E+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  argp   = 0.267502949E+03  anlong = 0.316607533E+03
meaan  = 0.113391336E+05  truan  = 0.892444914E+02  tfp    = 0.114936638E-01  rperi  = 0.314696796E+04  vperi  = 0.458392633E+02

impuls   maneuver print block
dvx    = 0.284036426E-01  dvy    =-0.489207367E-01  dvz    =-0.177832047E-02  dvmag  = 0.565965354E-01  tburn  = 0.172262198E-02
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.727528200E-01  wprop  = 0.786316722E+06

initial conditions for phase   11 after impuls   maneuver

date   = 8 20 1977  5.04  julian =2443375.71000000  tdurp  =      0.20000000  critr  =   tdurp         propid = 1step
primid = earth            secid  = earth             idbody = earth             frame  = ecliptic        epoch  = mean2000
timrfl = 0.210000000E+00
```

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

```
execution date and time Thu Oct 29                                                                                                  page    3

altp    =-0.319583806E+04  vinfm  = 0.426042049E+02  vinfx  = 0.321904344E+02  vinfy  =-0.276078065E+02  vinfz  =-0.408695791E+01
bmag    = 0.339480698E+04  btheta = 0.116941799E+03  bdt    =-0.153813676E+04  bdr    = 0.302635915E+04  hypta  = 0.862988577E+02
c3      = 0.181511828E+04  ra     =-0.406177133E+02  dec    =-0.550476362E+01  altit  = 0.773474094E+06
Outgoing Asymptote
altp    =-0.319583806E+04  vinfm  = 0.426042049E+02  vinfx  = 0.306594399E+02  vinfy  =-0.295710727E+02  vinfz  = 0.817727397E+00
bmag    = 0.339480698E+04  btheta = 0.116812917E+03  bdt    =-0.153132531E+04  bdr    = 0.302981142E+04  hypta  = 0.862988577E+02
c3      = 0.181511828E+04  ra     =-0.425714892E+02  dec    = 0.109977890E+01  altit  = 0.773474094E+06

final conditions for phase  11

date    = 8 20 1977  5.04  julian =2443375.71000000  tdurp  =      0.20000000  critr  =   timrf1         propid = 1step
primid = earth             secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrf1 = 0.210000000E+00
state relative to idbody: earth
x       = 0.562307739E+06  y      =-0.540219371E+06  z      = 0.119391909E+05  radius = 0.779852234E+06  scmass = 0.601462472E+01
vx      = 0.306680807E+02  vy     =-0.295793904E+02  vz     = 0.817934336E+00  speed  = 0.426162002E+02  fpa    = 0.897506528E+02
sma     =-0.219600282E+03  eccen  = 0.154913381E+02  inc    = 0.116807583E+03  argp   = 0.267531086E+03  anlong = 0.316591022E+03
meaan   = 0.203175025E+06  truan  = 0.934517600E+02  tfp    = 0.211550656E+00  rperi  = 0.318230194E+04  vperi  = 0.454491921E+02
Incoming Asymptote
altp    =-0.319583806E+04  vinfm  = 0.426042049E+02  vinfx  = 0.321904344E+02  vinfy  =-0.276078065E+02  vinfz  =-0.408695791E+01
bmag    = 0.339480698E+04  btheta = 0.116941799E+03  bdt    =-0.153813676E+04  bdr    = 0.302635915E+04  hypta  = 0.862988577E+02
c3      = 0.181511828E+04  ra     =-0.406177133E+02  dec    =-0.550476362E+01  altit  = 0.773474094E+06
Outgoing Asymptote
altp    =-0.319583806E+04  vinfm  = 0.426042049E+02  vinfx  = 0.306594399E+02  vinfy  =-0.295710727E+02  vinfz  = 0.817727397E+00
bmag    = 0.339480698E+04  btheta = 0.116812917E+03  bdt    =-0.153132531E+04  bdr    = 0.302981142E+04  hypta  = 0.862988577E+02
c3      = 0.181511828E+04  ra     =-0.425714892E+02  dec    = 0.109977890E+01  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  =   timrf1         propid = 1step
primid = earth             secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
state relative to idbody: earth
x       = 0.562307739E+06  y      =-0.540219371E+06  z      = 0.119391909E+05  radius = 0.779852234E+06  scmass = 0.601462472E+01
vx      = 0.306680807E+02  vy     =-0.295793904E+02  vz     = 0.817934336E+00  speed  = 0.426162002E+02  fpa    = 0.897506528E+02
sma     =-0.219600282E+03  eccen  = 0.154913381E+02  inc    = 0.116807583E+03  argp   = 0.267531086E+03  anlong = 0.316591022E+03
meaan   = 0.203175025E+06  truan  = 0.934517600E+02  tfp    = 0.211550656E+00  rperi  = 0.318230194E+04  vperi  = 0.454491921E+02

impuls   maneuver print block
dvx     = 0.327472271E-01  dvy    =-0.516894090E-01  dvz    = 0.118357286E-02  dvmag  = 0.612011171E-01  tburn  = 0.184050876E-02
thrust = 0.200000000E+06  spi    = 0.480000000E+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  =   timrf1         propid = 1step
primid = earth             secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrf1 = 0.221000000E+01
state relative to idbody: earth
x       = 0.586491577E+07  y      =-0.565807241E+07  z      = 0.153429146E+06  radius = 0.815073990E+07  scmass = 0.593693257E+01
vx      = 0.306854362E+02  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
meaan   = 0.213106950E+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  vinfx  = 0.323817146E+02  vinfy  =-0.275097491E+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  vinfx  = 0.306846113E+02  vinfy  =-0.296154901E+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     =-0.424452406E+02  dec    = 0.109990522E+01  altit  = 0.814436176E+07

final conditions for phase  12
```

```
date   = 8 22 1977  5.04  julian =2443377.71000000  tdurp  =      2.00000000  critr  =   timrf1         propid = 1step
primid = earth            secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrf1 = 0.221000000E+01
state relative to idbody: earth
x      = 0.586491577E+07  y      =-0.565807241E+07  z      = 0.153429146E+06  radius = 0.815073990E+07  scmass = 0.593693257E+01
vx     = 0.306854362E+02  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
meaan  = 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  vinfx  = 0.323817146E+02  vinfy  =-0.275097491E+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  vinfx  = 0.306846113E+02  vinfy  =-0.296154901E+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     =-0.424452406E+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  =      2.00000000  critr  =   timrf1         propid = 1step
primid = sun              secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
state relative to idbody: earth
x      = 0.586491577E+07  y      =-0.565807241E+07  z      = 0.153429146E+06  radius = 0.815073990E+07  scmass = 0.593693257E+01
vx     = 0.306854362E+02  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
meaan  = 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  dvy    =-0.194529550E+01  dvz    = 0.635774631E+00  dvmag  = 0.252410198E+01  tburn  = 0.749271162E-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  =      2.28999999  critr  =   timrf1         propid = 1step
primid = sun              secid  = earth             idbody = earth             frame  = ecliptic         epoch  = mean2000
timrf1 = 0.449999999E+01
state relative to idbody: earth
x      = 0.122569609E+08  y      =-0.119284276E+08  z      = 0.440315042E+06  radius = 0.171088969E+08  scmass = 0.347283284E+01
vx     = 0.322814902E+02  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
meaan  = 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  = 0.451864948E+02  vinfx  = 0.323241174E+02  vinfy  =-0.315473931E+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  = 0.451864948E+02  vinfx  = 0.322811214E+02  vinfy  =-0.315854012E+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   = 0.241736329E+03  anlong = 0.327905974E+03  meaan  = 0.180532107E+02
```

```
final conditions for phase  13

date   = 6 17 1979  3.14  julian =2444041.63102000  tdurp  =    663.92102000  critr  =   timrfl        propid = 1step
primid = sun              secid  = earth            idbody = earth            frame  = ecliptic        epoch  = mean2000
timrfl = 0.666131020E+03
```

```
state relative to idbody: earth
x      =-0.528792935E+09  y      = 0.692481418E+09  z      = 0.126012838E+08  radius = 0.871384688E+09  scmass = 0.347283284E+01
vx     =-0.554066841E+02  vy     = 0.260647562E+01  vz     =-0.101096878E+01  speed  = 0.554771702E+02  fpa    = 0.400266924E+02
sma    =-0.129511803E+03  eccen  = 0.515210557E+07  inc    = 0.222041445E+01  argp   = 0.118056982E+03  anlong = 0.329267512E+03
meaan  = 0.247931494E+09  truan  = 0.400266995E+02  tfp    = 0.116920439E+03  rperi  = 0.667258354E+09  vperi  = 0.554771728E+02
Incoming Asymptote
altp   = 0.667251976E+09  vinfm  = 0.554771620E+02  vinfx  =-0.554066751E+02  vinfy  = 0.260649290E+01  vinfz  =-0.101096802E+01
bmag   = 0.667258484E+09  btheta =-0.195968910E+01  bdt    = 0.666868227E+09  bdr    =-0.228178105E+08  hypta  = 0.899999889E+02
c3     = 0.307771550E+04  ra     = 0.177306624E+03  dec    =-0.104416674E+01  altit  = 0.871378309E+09
Outgoing Asymptote
altp   = 0.667251976E+09  vinfm  = 0.554771620E+02  vinfx  =-0.554066761E+02  vinfy  = 0.260647140E+01  vinfz  =-0.101096876E+01
bmag   = 0.667258484E+09  btheta =-0.195968870E+01  bdt    = 0.666868227E+09  bdr    =-0.228178058E+08  hypta  = 0.899999889E+02
c3     = 0.307771550E+04  ra     = 0.177306646E+03  dec    =-0.104416750E+01  altit  = 0.871378309E+09
state relative primary body: sun
x      =-0.540326210E+09  y      = 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  meaan  = 0.670882663E+02

initial conditions for phase   17 before impuls   maneuver

date   = 6 17 1979  3.14  julian =2444041.63102000  tdurp  =    663.92102000  critr  =   timrf1          propid = 1step
primid = jupiter          secid  = earth             idbody = jupiter           frame  = ecliptic          epoch  = mean2000
state relative to idbody: jupiter
x      = 0.306159889E+08  y      =-0.141746713E+08  z      = 0.208687118E+07  radius = 0.871384688E+09  scmass = 0.347283284E+01
vx     =-0.169190675E+02  vy     = 0.899503265E+01  vz     =-0.125359388E+01  speed  = 0.554771702E+02  fpa    = 0.400266924E+02
sma    =-0.350695774E+06  eccen  = 0.545090592E+01  inc    = 0.519097747E+01  argp   = 0.234372329E+03  anlong = 0.198067566E+03
meaan  =-0.536628119E+04  truan  = 0.400266995E+02  tfp    = 0.116920439E+03  rperi  = 0.667258354E+09  vperi  = 0.554771728E+02

impuls   maneuver print block
dvx    = 0.321533374E-03  dvy    =-0.250805969E-03  dvz    = 0.120843234E-03  dvmag  = 0.425312158E-03  tburn  = 0.738519014E-05
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.313769080E-03  wprop  = 0.786314180E+06

initial conditions for phase   17 after impuls   maneuver

date   = 6 25 1979 12.00  julian =2444049.99999999  tdurp  =      8.36897999  critr  =   timrf1          propid = 1step
primid = jupiter          secid  = earth             idbody = jupiter           frame  = ecliptic          epoch  = mean2000
timrf1 = 0.674500000E+03
state relative to idbody: jupiter
x      = 0.186807615E+08  y      =-0.764803680E+07  z      = 0.118696987E+07  radius = 0.202205889E+08  scmass = 0.347300639E+01
vx     =-0.165956126E+02  vy     = 0.906121698E+01  vz     =-0.125008973E+01  speed  = 0.189494785E+02  fpa    =-0.836287051E+02
sma    =-0.365560370E+06  eccen  = 0.632774920E+01  inc    = 0.518742040E+01  argp   = 0.232179956E+03  anlong = 0.198104300E+03
meaan  =-0.304133670E+04  truan  =-0.926648783E+02  tfp    =-0.120643189E+02  rperi  = 0.194761397E+07  vperi  = 0.218322171E+02
Incoming Asymptote
altp   = 0.187621597E+07  vinfm  = 0.186159168E+02  vinfx  =-0.162946104E+02  vinfy  = 0.891779366E+01  vinfz  =-0.122922185E+01
bmag   = 0.228410620E+07  btheta = 0.354874801E+01  bdt    = 0.227972642E+07  bdr    = 0.141381020E+06  hypta  = 0.809071946E+02
c3     = 0.346552357E+03  ra     = 0.151308779E+03  dec    =-0.378603454E+01  altit  = 0.201491909E+08
Outgoing Asymptote
altp   = 0.187621597E+07  vinfm  = 0.186159168E+02  vinfx  =-0.182854823E+02  vinfy  = 0.339691602E+01  vinfz  =-0.808984256E+00
bmag   = 0.228410620E+07  btheta = 0.455181100E+01  bdt    = 0.227690208E+07  bdr    = 0.181267921E+06  hypta  = 0.809071946E+02
c3     = 0.346552357E+03  ra     = 0.168224279E+03  dec    =-0.249066353E+01  altit  = 0.201491909E+08
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  = 0.539249615E+07  inc    = 0.205774462E+01
argp   = 0.120663065E+03  anlong = 0.331015066E+03  meaan  = 0.238645951E+09
```

```
final conditions for phase  17

date   = 7  5 1979  3.14  julian =2444059.63102000  tdurp  =     18.00000000  critr  =   timrfl        propid = 1step
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  radius = 0.400902528E+07  scmass = 0.347300639E+01
vx     =-0.193168363E+02  vy     = 0.917226734E+01  vz     =-0.133644213E+01  speed  = 0.214256092E+02  fpa    =-0.654695124E+02
sma    =-0.320029687E+06  eccen  = 0.568932792E+01  inc    = 0.518742040E+01  argp   = 0.235579637E+03  anlong = 0.198104300E+03
meaan  =-0.616540578E+03  truan  =-0.746707772E+02  tfp    =-0.200330331E+01  rperi  = 0.150072415E+07  vperi  = 0.237631927E+02
Incoming Asymptote
altp   = 0.142932615E+07  vinfm  = 0.198961410E+02  vinfx  =-0.177973574E+02  vinfy  = 0.880444576E+01  vinfz  =-0.126183563E+01
bmag   = 0.179240774E+07  btheta = 0.370213015E+01  bdt    = 0.178866738E+07  bdr    = 0.115734708E+06  hypta  = 0.798766643E+02
c3     = 0.395856425E+03  ra     = 0.153678157E+03  dec    =-0.363620316E+01  altit  = 0.393762728E+07
Outgoing Asymptote
altp   = 0.142932615E+07  vinfm  = 0.198961410E+02  vinfx  =-0.197696209E+02  vinfy  = 0.211438961E+01  vinfz  =-0.740183280E+00
bmag   = 0.179240774E+07  btheta = 0.473012806E+01  bdt    = 0.178630310E+07  bdr    = 0.147806537E+06  hypta  = 0.798766643E+02
c3     = 0.395856425E+03  ra     = 0.173224813E+03  dec    =-0.213202986E+01  altit  = 0.393762728E+07
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  meaan  = 0.252008105E+09

initial conditions for phase   18 before impuls   maneuver

date   = 7  5 1979  3.14  julian =2444059.63102000  tdurp  =     18.00000000  critr  =   timrf1         propid = 1step
primid = jupiter          secid  = earth            idbody = jupiter           frame  = ecliptic         epoch  = mean2000
state relative to idbody: jupiter
x      = 0.400676179E+07  y      =-0.639418859E+05  z      = 0.118554270E+06  radius = 0.400902528E+07  scmass = 0.347300639E+01
vx     =-0.193168363E+02  vy     = 0.917226734E+01  vz     =-0.133644213E+01  speed  = 0.214256092E+02  fpa    =-0.654695124E+02
sma    =-0.320029687E+06  eccen  = 0.568932792E+01  inc    = 0.518742040E+01  argp   = 0.235579637E+03  anlong = 0.198104300E+03
meaan  =-0.616540578E+03  truan  =-0.746707772E+02  tfp    =-0.200330331E+01  rperi  = 0.150072415E+07  vperi  = 0.237631927E+02

impuls   maneuver print block
dvx    =-0.568354464E-04  dvy    =-0.262868944E-04  dvz    =-0.119825393E-03  dvmag  = 0.135201308E-03  tburn  = 0.234777502E-05
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  critr  =   timrf1         propid = 1step
primid = jupiter          secid  = earth            idbody = jupiter           frame  = ecliptic         epoch  = mean2000
timrf1 = 0.684500000E+03
state relative to idbody: jupiter
x      = 0.338717581E+07  y      = 0.230625560E+06  z      = 0.756523965E+05  radius = 0.339586092E+07  scmass = 0.347292135E+01
vx     =-0.196128868E+02  vy     = 0.919951425E+01  vz     =-0.134726611E+01  speed  = 0.217051035E+02  fpa    =-0.609143874E+02
sma    =-0.319510537E+06  eccen  = 0.571986492E+01  inc    = 0.518815080E+01  argp   = 0.235440158E+03  anlong = 0.198101505E+03
meaan  =-0.503543424E+03  truan  =-0.697025889E+02  tfp    =-0.163216608E+01  rperi  = 0.150804658E+07  vperi  = 0.237594770E+02
Incoming Asymptote
altp   = 0.143664858E+07  vinfm  = 0.199122983E+02  vinfx  =-0.177981954E+02  vinfy  = 0.883876677E+01  vinfz  =-0.126493716E+01
bmag   = 0.179941046E+07  btheta = 0.369726599E+01  bdt    = 0.179566534E+07  bdr    = 0.116034426E+06  hypta  = 0.799312752E+02
c3     = 0.396499624E+03  ra     = 0.153590533E+03  dec    =-0.364219107E+01  altit  = 0.332446292E+07
Outgoing Asymptote
altp   = 0.143664858E+07  vinfm  = 0.199122983E+02  vinfx  =-0.197780979E+02  vinfy  = 0.218387031E+01  vinfz  =-0.746443395E+00
bmag   = 0.179941046E+07  btheta = 0.472356563E+01  bdt    = 0.179329895E+07  bdr    = 0.148178602E+06  hypta  = 0.799312752E+02
c3     = 0.396499624E+03  ra     = 0.173004672E+03  dec    =-0.214832454E+01  altit  = 0.332446292E+07
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  =   timrfl        propid = 1step
```

```
primid = jupiter          secid  = earth            idbody = jupiter          frame  = ecliptic         epoch  = mean2000
timrf1 = 0.685631020E+03
state relative to idbody: jupiter
x      = 0.139164583E+07  y      = 0.110761256E+07  z      =-0.563321704E+05  radius = 0.177951034E+07  scmass = 0.347292135E+01
vx     =-0.215454596E+02  vy     = 0.836672893E+01  vz     =-0.132991307E+01  speed  = 0.231511912E+02  fpa    =-0.300686698E+02
sma    =-0.321868536E+06  eccen  = 0.567226417E+01  inc    = 0.518815080E+01  argp   = 0.235628108E+03  anlong = 0.198101505E+03
meaan  =-0.154107901E+03  truan  =-0.351362761E+02  tfp    =-0.505059258E+00  rperi  = 0.150385483E+07  vperi  = 0.237081486E+02
Incoming Asymptote
altp   = 0.143245683E+07  vinfm  = 0.198392258E+02  vinfx  =-0.177487458E+02  vinfy  = 0.877464073E+01  vinfz  =-0.125800774E+01
bmag   = 0.179712728E+07  btheta = 0.370377496E+01  bdt    = 0.179337373E+07  bdr    = 0.116090929E+06  hypta  = 0.798458881E+02
c3     = 0.393594880E+03  ra     = 0.153693088E+03  dec    =-0.363557154E+01  altit  = 0.170811234E+07
Outgoing Asymptote
altp   = 0.143245683E+07  vinfm  = 0.198392258E+02  vinfx  =-0.197159362E+02  vinfy  = 0.208210946E+01  vinfz  =-0.735907290E+00
bmag   = 0.179712728E+07  btheta = 0.473373078E+01  bdt    = 0.179099723E+07  bdr    = 0.148308338E+06  hypta  = 0.798458881E+02
c3     = 0.393594880E+03  ra     = 0.173309199E+03  dec    =-0.212579147E+01  altit  = 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     =-0.787366652E+01  vz     =-0.109125315E+01
sma    =-0.112703333E+03  eccen  = 0.679019400E+07  inc    = 0.186109955E+01
argp   = 0.124402818E+03  anlong = 0.333220656E+03  meaan  = 0.267119008E+09

initial conditions for phase   19 before impuls   maneuver

date   = 7  6 1979 15.14  julian =2444061.13102000  tdurp  =      1.50000000  critr  =   timrf1         propid = 1step
primid = jupiter          secid  = earth            idbody = jupiter          frame  = ecliptic         epoch  = mean2000
state relative to idbody: jupiter
x      = 0.139164583E+07  y      = 0.110761256E+07  z      =-0.563321704E+05  radius = 0.177951034E+07  scmass = 0.347292135E+01
vx     =-0.215454596E+02  vy     = 0.836672893E+01  vz     =-0.132991307E+01  speed  = 0.231511912E+02  fpa    =-0.300686698E+02
sma    =-0.321868536E+06  eccen  = 0.567226417E+01  inc    = 0.518815080E+01  argp   = 0.235628108E+03  anlong = 0.198101505E+03
meaan  =-0.154107901E+03  truan  =-0.351362761E+02  tfp    =-0.505059258E+00  rperi  = 0.150385483E+07  vperi  = 0.237081486E+02

impuls   maneuver print block
dvx    =-0.180804265E-03  dvy    =-0.781759852E-04  dvz    = 0.108976392E-03  dvmag  = 0.225116683E-03  tburn  = 0.390906267E-05
thrust = 0.200000000E+06  spi    = 0.480000000E+03  dmass  = 0.166084969E-03  wprop  = 0.786314179E+06

initial conditions for phase   19 after impuls   maneuver

date   = 7  7 1979  3.14  julian =2444061.63102000  tdurp  =      0.50000000  critr  =   timrf1         propid = 1step
primid = jupiter          secid  = earth            idbody = jupiter          frame  = ecliptic         epoch  = mean2000
timrf1 = 0.686131020E+03
state relative to idbody: jupiter
x      = 0.432742394E+06  y      = 0.143564622E+07  z      =-0.111690319E+06  radius = 0.150360260E+07  scmass = 0.347292780E+01
vx     =-0.227388911E+02  vy     = 0.661415878E+01  vz     =-0.121222216E+01  speed  = 0.237123121E+02  fpa    =-0.336020078E+00
sma    =-0.321730253E+06  eccen  = 0.567339385E+01  inc    = 0.518786447E+01  argp   = 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  vinfx  =-0.177531353E+02  vinfy  = 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  = 0.143220460E+07
Outgoing Asymptote
altp   = 0.143217418E+07  vinfm  = 0.198434889E+02  vinfx  =-0.197201609E+02  vinfy  = 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  = 0.143220460E+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  7 1979  3.14  julian =2444061.63102000  tdurp  =      0.50000000  critr  =   timrf1         propid = 1step
primid = jupiter          secid  = earth            idbody = jupiter          frame  = ecliptic         epoch  = mean2000
timrf1 = 0.686131020E+03
state relative to idbody: jupiter
x      = 0.432742394E+06  y      = 0.143564622E+07  z      =-0.111690319E+06  radius = 0.150360260E+07  scmass = 0.347292780E+01
vx     =-0.227388911E+02  vy     = 0.661415878E+01  vz     =-0.121222216E+01  speed  = 0.237123121E+02  fpa    =-0.336020078E+00
sma    =-0.321730253E+06  eccen  = 0.567339385E+01  inc    = 0.518786447E+01  argp   = 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  vinfx  =-0.177531353E+02  vinfy  = 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  = 0.143220460E+07
Outgoing Asymptote
altp   = 0.143217418E+07  vinfm  = 0.198434889E+02  vinfx  =-0.197201609E+02  vinfy  = 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  = 0.143220460E+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

initial conditions for phase   20

esn =   20.000  fesn=   20.000
time=  2.44406163D+06
normal termination
cpu =    1.770 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	value	residual	name	phase	value
1	dvx	10.0	0.24017931E+02	0.00000000E+00	tfp	20.0	-0.50627588E-02	0.78496517E-10	dvsum	20.0	0.519084431E+02
2	dvy	10.0	-0.42926452E+02	0.00000000E+00	bdti	20.0	0.17929715E+07	0.49024238E-03			
3	dvz	10.0	-0.27520177E+01	0.00000000E+00	bdri	20.0	0.11606819E+06	0.24088510E-03			
4	dvx	11.0	0.28403643E-01	0.00000000E+00	e 10x	0.0	0.00000000E+00	0.00000000E+00			
5	dvy	11.0	-0.48920737E-01	0.00000000E+00	e 10y	0.0	0.00000000E+00	0.00000000E+00			
6	dvz	11.0	-0.17783205E-02	0.00000000E+00	e 10z	0.0	0.00000000E+00	0.00000000E+00			
7	dvx	12.0	0.32747227E-01	0.00000000E+00	e 10u	0.0	-0.49737992E-13	0.49737992E-13			
8	dvy	12.0	-0.51689409E-01	0.00000000E+00	e 10v	0.0	0.74251716E-12	0.74251716E-12			
9	dvz	12.0	0.11835729E-02	0.00000000E+00	e 10w	0.0	0.52707838E-13	0.52707838E-13			
10	dvx	13.0	0.14773987E+01	0.00000000E+00	e 10m	0.0	0.22309836E-05	0.22309836E-05			
11	dvy	13.0	-0.19452955E+01	0.00000000E+00	e 11x	0.0	0.00000000E+00	0.00000000E+00			
12	dvz	13.0	0.63577463E+00	0.00000000E+00	e 11y	0.0	0.00000000E+00	0.00000000E+00			
13	dvx	17.0	0.32153337E-03	0.00000000E+00	e 11z	0.0	0.00000000E+00	0.00000000E+00			
14	dvy	17.0	-0.25080597E-03	0.00000000E+00	e 11u	0.0	-0.48814286E-11	0.48814286E-11			
15	dvz	17.0	0.12084323E-03	0.00000000E+00	e 11v	0.0	-0.37303494E-12	0.37303494E-12			
16	dvx	18.0	-0.56835446E-04	0.00000000E+00	e 11w	0.0	-0.36248782E-12	0.36248782E-12			
17	dvy	18.0	-0.26286894E-04	0.00000000E+00	e 11m	0.0	-0.14462317E-05	0.14462317E-05			
18	dvz	18.0	-0.11982539E-03	0.00000000E+00	e 12x	0.0	0.00000000E+00	0.00000000E+00			
19	dvx	19.0	-0.18080426E-03	0.00000000E+00	e 12y	0.0	0.26775524E-08	0.26775524E-08			
20	dvy	19.0	-0.78175985E-04	0.00000000E+00	e 12z	0.0	0.00000000E+00	0.00000000E+00			
21	dvz	19.0	0.10897639E-03	0.00000000E+00	e 12u	0.0	-0.36699532E-11	0.36699532E-11			
22	e 11x	0.0	0.32171688E+05	0.00000000E+00	e 12v	0.0	-0.49737992E-13	0.49737992E-13			
23	e 11y	0.0	-0.28904015E+05	0.00000000E+00	e 12w	0.0	0.33384406E-12	0.33384406E-12			
24	e 11z	0.0	-0.21979214E+04	0.00000000E+00	e 12m	0.0	-0.15450362E-05	0.15450362E-05			
25	e 11u	0.0	0.31115274E+02	0.00000000E+00	e 13x	0.0	-0.11026859E-05	0.11026859E-05			
26	e 11v	0.0	-0.29958987E+02	0.00000000E+00	e 13y	0.0	0.53644180E-06	0.53644180E-06			
27	e 11w	0.0	0.78898505E+00	0.00000000E+00	e 13z	0.0	0.28812792E-08	0.28812792E-08			
28	e 11m	0.0	0.60873761E+01	0.00000000E+00	e 13u	0.0	0.30198066E-11	0.30198066E-11			
29	e 12x	0.0	0.56230774E+06	0.00000000E+00	e 13v	0.0	0.41655568E-12	0.41655568E-12			
30	e 12y	0.0	-0.54021937E+06	0.00000000E+00	e 13w	0.0	0.12967405E-12	0.12967405E-12			
31	e 12z	0.0	0.11939191E+05	0.00000000E+00	e 13m	0.0	-0.16712238E-05	0.16712238E-05			
32	e 12u	0.0	0.30668081E+02	0.00000000E+00	e 17x	0.0	-0.93132257E-07	0.93132257E-07			
33	e 12v	0.0	-0.29579390E+02	0.00000000E+00	e 17y	0.0	0.10617077E-06	0.10617077E-06			
34	e 12w	0.0	0.81793434E+00	0.00000000E+00	e 17z	0.0	-0.46566129E-09	0.46566129E-09			
35	e 12m	0.0	0.60146247E+01	0.00000000E+00	e 17u	0.0	0.46824766E-10	0.46824766E-10			
36	e 13x	0.0	0.58649158E+07	0.00000000E+00	e 17v	0.0	-0.11842971E-10	0.11842971E-10			
37	e 13y	0.0	-0.56580724E+07	0.00000000E+00	e 17w	0.0	0.11857182E-12	0.11857182E-12			
38	e 13z	0.0	0.15342915E+06	0.00000000E+00	e 17m	0.0	-0.48732094E-03	0.48732094E-03			
39	e 13u	0.0	0.30685436E+02	0.00000000E+00	e 18x	0.0	0.00000000E+00	0.00000000E+00			
40	e 13v	0.0	-0.29616286E+02	0.00000000E+00	e 18y	0.0	0.36379788E-10	0.36379788E-10			
41	e 13w	0.0	0.81878304E+00	0.00000000E+00	e 18z	0.0	0.43655746E-10	0.43655746E-10			
42	e 13m	0.0	0.59369326E+01	0.00000000E+00	e 18u	0.0	-0.20197177E-10	0.20197177E-10			
43	e 17x	0.0	-0.54032621E+09	0.00000000E+00	e 18v	0.0	-0.10516032E-11	0.10516032E-11			
44	e 17y	0.0	0.54093535E+09	0.00000000E+00	e 18w	0.0	0.28199665E-13	0.28199665E-13			
45	e 17z	0.0	0.12594269E+08	0.00000000E+00	e 18m	0.0	-0.14710834E-04	0.14710834E-04			
46	e 17u	0.0	-0.26190291E+02	0.00000000E+00	e 19x	0.0	0.00000000E+00	0.00000000E+00			
47	e 17v	0.0	0.22347408E+00	0.00000000E+00	e 19y	0.0	0.23283064E-09	0.23283064E-09			
48	e 17w	0.0	-0.10098122E+01	0.00000000E+00	e 19z	0.0	0.16007107E-09	0.16007107E-09			
49	e 17m	0.0	0.34728328E+01	0.00000000E+00	e 19u	0.0	-0.20349944E-10	0.20349944E-10			
50	e 18x	0.0	0.40067618E+07	0.00000000E+00	e 19v	0.0	-0.20792257E-10	0.20792257E-10			

51	e	18y	0.0	-0.63941886E+05	0.00000000E+00e	19w	0.0	0.28770319E-11	0.28770319E-11
52	e	18z	0.0	0.11855427E+06	0.00000000E+00e	19m	0.0	-0.17253781E-03	0.17253781E-03
53	e	18u	0.0	-0.19316836E+02	0.00000000E+00e	20x	0.0	0.58207661E-10	0.58207661E-10
54	e	18v	0.0	0.91722673E+01	0.00000000E+00e	20y	0.0	0.00000000E+00	0.00000000E+00
55	e	18w	0.0	-0.13364421E+01	0.00000000E+00e	20z	0.0	0.00000000E+00	0.00000000E+00
56	e	18m	0.0	0.34730064E+01	0.00000000E+00e	20u	0.0	0.00000000E+00	0.00000000E+00
57	e	19x	0.0	0.13916458E+07	0.00000000E+00e	20v	0.0	0.00000000E+00	0.00000000E+00
58	e	19y	0.0	0.11076126E+07	0.00000000E+00e	20w	0.0	-0.44408921E-15	0.44408921E-15
59	e	19z	0.0	-0.56332170E+05	0.00000000E+00e	20m	0.0	-0.54667382E-12	0.54667382E-12
60	e	19u	0.0	-0.21545460E+02	0.00000000E+00d	10x0	0.0	-0.45337246E-09	0.45337246E-09
61	e	19v	0.0	0.83667289E+01	0.00000000E+00d	10y0	0.0	0.27021499E-10	0.27021499E-10
62	e	19w	0.0	-0.13299131E+01	0.00000000E+00d	10z0	0.0	-0.72230413E-10	0.72230413E-10
63	e	19m	0.0	0.34729213E+01	0.00000000E+00d	10u0	0.0	0.10683757E-10	0.10683757E-10
64	e	20x	0.0	0.43274239E+06	0.00000000E+00d	10v0	0.0	-0.88367952E-13	0.88367952E-13
65	e	20y	0.0	0.14356462E+07	0.00000000E+00d	10w0	0.0	0.79697396E-12	0.79697396E-12
66	e	20z	0.0	-0.11169032E+06	0.00000000E+00d	10m0	0.0	0.19555397E-17	0.19555397E-17
67	e	20u	0.0	-0.22738891E+02	0.00000000E+00d	11x0	0.0	0.90311389E-08	0.90311389E-08
68	e	20v	0.0	0.66141588E+01	0.00000000E+00d	11y0	0.0	-0.55210914E-09	0.55210914E-09
69	e	20w	0.0	-0.12122222E+01	0.00000000E+00d	11z0	0.0	0.14364152E-08	0.14364152E-08
70	e	20m	0.0	0.34729278E+01	0.00000000E+00d	11u0	0.0	0.10959449E-11	0.10959449E-11
71	o	10x0	0.0	0.51464903E+04	0.00000000E+00d	11v0	0.0	-0.72274692E-13	0.72274692E-13
72	o	10y0	0.0	-0.28980813E+04	0.00000000E+00d	11w0	0.0	0.18211349E-12	0.18211349E-12
73	o	10z0	0.0	-0.28614212E+04	0.00000000E+00d	11m0	0.0	0.36131554E-17	0.36131554E-17
74	o	10u0	0.0	0.32465288E+02	0.00000000E+00d	12x0	0.0	0.27375740E-09	0.27375740E-09
75	o	10v0	0.0	-0.30807946E+02	0.00000000E+00d	12y0	0.0	-0.47523691E-10	0.47523691E-10
76	o	10w0	0.0	0.16744937E+00	0.00000000E+00d	12z0	0.0	0.86284301E-10	0.86284301E-10
77	o	10m0	0.0	0.60873761E+01	0.00000000E+00d	12u0	0.0	0.35425356E-14	0.35425356E-14
78	o	11x0	0.0	0.32171688E+05	0.00000000E+00d	12v0	0.0	-0.63258237E-15	0.63258237E-15
79	o	11y0	0.0	-0.28904015E+05	0.00000000E+00d	12w0	0.0	0.11463947E-14	0.11463947E-14
80	o	11z0	0.0	-0.21979214E+04	0.00000000E+00d	12m0	0.0	0.13350473E-19	0.13350473E-19
81	o	11u0	0.0	0.31143677E+02	0.00000000E+00d	13x0	0.0	0.16179162E-08	0.16179162E-08
82	o	11v0	0.0	-0.30007908E+02	0.00000000E+00d	13y0	0.0	0.45337304E-09	0.45337304E-09
83	o	11w0	0.0	0.78720673E+00	0.00000000E+00d	13z0	0.0	0.49462271E-09	0.49462271E-09
84	o	11m0	0.0	0.60146247E+01	0.00000000E+00d	13u0	0.0	-0.79930508E-15	0.79930508E-15
85	o	12x0	0.0	0.56230774E+06	0.00000000E+00d	13v0	0.0	-0.35392033E-15	0.35392033E-15
86	o	12y0	0.0	-0.54021937E+06	0.00000000E+00d	13w0	0.0	-0.12351609E-15	0.12351609E-15
87	o	12z0	0.0	0.11939191E+05	0.00000000E+00d	13m0	0.0	0.33607325E-22	0.33607325E-22
88	o	12u0	0.0	0.30700828E+02	0.00000000E+00d	17x0	0.0	-0.74540668E-09	0.74540668E-09
89	o	12v0	0.0	-0.29631080E+02	0.00000000E+00d	17y0	0.0	-0.32909900E-08	0.32909900E-08
90	o	12w0	0.0	0.81911791E+00	0.00000000E+00d	17z0	0.0	0.64367869E-09	0.64367869E-09
91	o	12m0	0.0	0.59369326E+01	0.00000000E+00d	17u0	0.0	0.23209344E-14	0.23209344E-14
92	o	13x0	0.0	0.13597618E+09	0.00000000E+00d	17v0	0.0	0.46465869E-14	0.46465869E-14
93	o	13y0	0.0	-0.82871490E+08	0.00000000E+00d	17w0	0.0	-0.88215230E-15	0.88215230E-15
94	o	13z0	0.0	0.14998658E+06	0.00000000E+00d	17m0	0.0	-0.57395859E-19	0.57395859E-19
95	o	13u0	0.0	0.46870577E+02	0.00000000E+00d	18x0	0.0	0.60070486E-09	0.60070486E-09
96	o	13v0	0.0	-0.60490767E+01	0.00000000E+00d	18y0	0.0	0.61477538E-09	0.61477538E-09
97	o	13w0	0.0	0.14550827E+01	0.00000000E+00d	18z0	0.0	0.46531308E-10	0.46531308E-10
98	o	13m0	0.0	0.34728328E+01	0.00000000E+00d	18u0	0.0	-0.18669528E-13	0.18669528E-13
99	o	17x0	0.0	0.30615989E+08	0.00000000E+00d	18v0	0.0	0.24789846E-13	0.24789846E-13
100	o	17y0	0.0	-0.14174671E+08	0.00000000E+00d	18w0	0.0	-0.86521453E-14	0.86521453E-14
101	o	17z0	0.0	0.20868712E+07	0.00000000E+00d	18m0	0.0	0.10412817E-19	0.10412817E-19
102	o	17u0	0.0	-0.16918746E+02	0.00000000E+00d	19x0	0.0	-0.61670568E-10	0.61670568E-10
103	o	17v0	0.0	0.89947818E+01	0.00000000E+00d	19y0	0.0	-0.63356962E-10	0.63356962E-10
104	o	17w0	0.0	-0.12534730E+01	0.00000000E+00d	19z0	0.0	-0.52473290E-10	0.52473290E-10
105	o	17m0	0.0	0.34730064E+01	0.00000000E+00d	19u0	0.0	-0.42638517E-13	0.42638517E-13
106	o	18x0	0.0	0.40067618E+07	0.00000000E+00d	19v0	0.0	-0.20187614E-13	0.20187614E-13
107	o	18y0	0.0	-0.63941886E+05	0.00000000E+00d	19w0	0.0	-0.26000854E-14	0.26000854E-14
108	o	18z0	0.0	0.11855427E+06	0.00000000E+00d	19m0	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$top
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,
  idbody    = 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,

 $
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 MODELT 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 ΔV is minimized.

```
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
c  master controls are Jupiter TCA, arrival BDT, arrival BDR,
c
  indxi      = 1,2,3,4,
  indvr      = 5hcritr,8hdepsvl02,8hdepsvl03,5hcritr,
  indph      = 3*20,30,
  u          = 706.,.175565d7,.121609d6,1487.,
  indplb     = 650.,.88d6,.6d5,1300.,
c  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)   = 8hdepsvl05,8hdepsvl06,5hcritr,8hdepsvl08,8hdepsvl09,5hcritr,
  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,.001,
  wvu(5)     = .359699d6,.178342d5,3.099,.137566d6,.275594d5,4.486,
c
c  minimize delta-v for total mission
c
  optvar     = 5hdvsum,
  opt        = -1,
  optph      = 90,
  wopt       = 8.,
  etanl      = .5,
c
c subrproblem setup
c
  modelt     = 'nraph','nraph','nraph','nraph',
  spfesn     = 20,30,40,50,
  tolf       = 1.0d0,
  tolu       = 1.0d0,
  npi        = 8,
c
c controls
c
  indxsi     = 1,1,1, 2,2,2,
  indsvr     = 5hvinfx,5hvinfy,5hvinfz, 3hdvx,3hdvy,3hdvz,
  indsph     = 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
c targets
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,
  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
c
  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
c
```

```
  event      = 15,
  critr      = 5htdurp,
  value      = 20.,
  ipbody     = 0,5,
  idbody     = 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 idbody
c
  event      = 25,
  critr      = 5htdurp,
  value      = 0.,
  ipbody     = 0,6,
  idbody     = 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
  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$top
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.,    .1,

  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.,
  wvnlc(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 idbody: earth
c
  u(8)= 0.57790518E+04,
        0.56101708E+04,
       -0.11805884E-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 idbody: earth
c
       -0.58963384E+04,
        0.61478585E+04,
       -0.10105050E-14,
       -0.50762013E+01,
       -0.46307005E+01,
        0.10379708E-17,
        0.19999950E+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 idbody: earth
c
       -0.73366315E+04,
       -0.52111341E+04,
        0.00000000E+00,
        0.35904416E+01,
       -0.53670536E+01,
       -0.57761545E-17,
        0.19999915E+05,

 $
p$traj
  event  = 10,
  iepoch = 'calend',
  date   = 1992, 7, 1,
  tol    = 1.d-8,
  idfram = 'ecliptic',
  ipbody = 3,
  idbody = 3,
  scmass = 20000.,
  spi    = 320.,
  inputx = 'conic',
  x      = 8000., 0., 0., 0., 0., 0.,
  wprop  = 10000.,
  icoord = 3,
  iforce(5) = 1,
  pitch0 = 0.,
  yaw0   = 90.,
  th10   = 1.d0,
  namlst = 'table',

  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 0,
  nsgpwi = 0,
  cointp = 'linear',
 $
p$tab
  table  = 'thrstt',0.,5000.,
  namlst = 'traj',
$
p$traj
  event = 20.,
  critr = 'tdurp',
  value = .007,
  iforce(5) = 0,
  nsegph    = 1,
  nsgph0    = 0,
  nsgpwd = 0,
  nsgpwi = 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$tab
  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$top
c...  Galileo 1989 VEEGA trajectory
  srchm      = 'npsol',
  iprint     = 0,
  ipro       = 0,
  fesn       = 90,
  istm       = 'central',
  npad(1)    = 0,
  mxitop     = 30,
  ftol       = 1.d-6,

  indxi      = 1,2,3,
  indvr      = 'pitch0','yaw0','th10',
  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
c  maximize s/c mass at the end
c
  optvar     = 6hscmass,
  opt        = 1,
  optph      = 90,
  wopt       = 2.d5,
  etanl      = .5,
c
c targets
c
  indxd     = 1,2,3,
  depvr     = 'tfp','rperi',
  depph     = 3*20,
  depvlb    = -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.,
 $
p$traj
c  earth escape
c
  event      = 10,
```

```
  critr      = 6htimrfl,
  value      = 20.,

  iprop      = 'lstep',
  ipbody     = 0,3,

  mantyp     = 'launch',
  ilnch      = 2,
  vinfx      = 2.26374,
  vinfy      = 9.45391,
  vinfz      = 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.,
  dt         = .5d0,
 $
p$traj
  event      = 18,
  critr      = 6htimrfl,
  value      = 608.,
  iforce(5)  = 0,
  iprop      = 'lstep',
 $
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
c  master controls are Jupiter TCA, arrival BDT, arrival BDR,
c
  indxi      = 1,2,3,4,
  indvr      = 5hcritr,8hdepsvl02,8hdepsvl03,5hcritr,
  indph      = 3*20,30,
  u          = 706.,.175565d7,.121609d6,1487.,
  indplb     = 650.,.88d6,.6d5,1300.,
c  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)   = 8hdepsvl05,8hdepsvl06,5hcritr,8hdepsvl08,8hdepsvl09,5hcritr,
  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,.001,
  wvu(5)     = .359699d6,.178342d5,3.099,.137566d6,.275594d5,4.486,
c
c  minimize delta-v for total mission
c
  optvar     = 5hdvsum,
  opt        = -1,
  optph      = 90,
  wopt       = 8.,
  etanl      = .5,
c
c subrproblem setup
c
  modelt     = 'nraph','nraph','nraph','nraph',
  spfesn     = 20,30,40,50,
  tolf       = 1.0d0,
  tolu       = 1.0d0,
  npi        = 8,
c
c controls
c
  indxsi     = 1,1,1, 2,2,2,
  indsvr     = 5hvinfx,5hvinfy,5hvinfz, 3hdvx,3hdvy,3hdvz,
  indsph     = 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
c targets
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,
  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
c
  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
c
  event     = 15,
  critr     = 5htdurp,
  value     = 20.,
  ipbody    = 0,5,
```

```
  idbody    = 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 idbody
c
  event     = 25,
  critr     = 5htdurp,
  value     = 0.,
  ipbody    = 0,6,
  idbody    = 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,
  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',
 $
```

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.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1992

3. REPORT TYPE AND DATES COVERED
Contractor Report

4. TITLE AND SUBTITLE
Interplanetary Program To Optimize Simulated Trajectories (IPOST)
Volume IV - Sample Cases

5. FUNDING NUMBERS
C NAS1-18230
WU 506-49-11-02

6. AUTHOR(S)
P. E. Hong, P. D. Kent, D. W. Olson, and C. A. Vallado

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Martin Marietta Astronautics
Space Launch Systems Company
P. O. Box 17
Denver, CO 80201

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA CR-189653,
Volume IV

11. SUPPLEMENTARY NOTES
Langley Technical Monitor: Richard W. Powell
Final Report

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 16

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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 coat 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.

14. SUBJECT TERMS
Collocation, targeting, trajectory propagation

15. NUMBER OF PAGES
138

16. PRICE CODE
A07

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT