111-16
133337
P-72

NASA Contractor Report 189653, Volume III (Revised)

Interplanetary Program To Optimize Simulated Trajectories (IPOST)

Volume III - Programmer's Manual

P. E. Hong, P. D. Kent, D. W. Olson, and C. A. Vallado

Martin Marietta Astronautics
Space Launch Systems Company
Denver, Colorado

Contract NAS1-18230
October 1992

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665-5225

TABLE OF CONTENTS

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.

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 subproblem 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 RELATIONSHIP TO POST

The software architecture of IPOST has been influenced by the architecture of the POST trajectory simulation program. Major features derived from the POST program include the Input Processor, the cycling and phasing logic, general table look up capability, and the dictionary of output variables.

The Input Processor accepts input in a namelist format from an input file and stores the input data by phase records in a data structure, XBKT and XGEN, borrowed directly from the POST program and called "the bucket". In IPOST some input variables can be names of other output variables as in the POST program and the Input Processor modifies these names to index pointers to the output variables. Other modifications and processing of the data is also performed by the Input Processor.

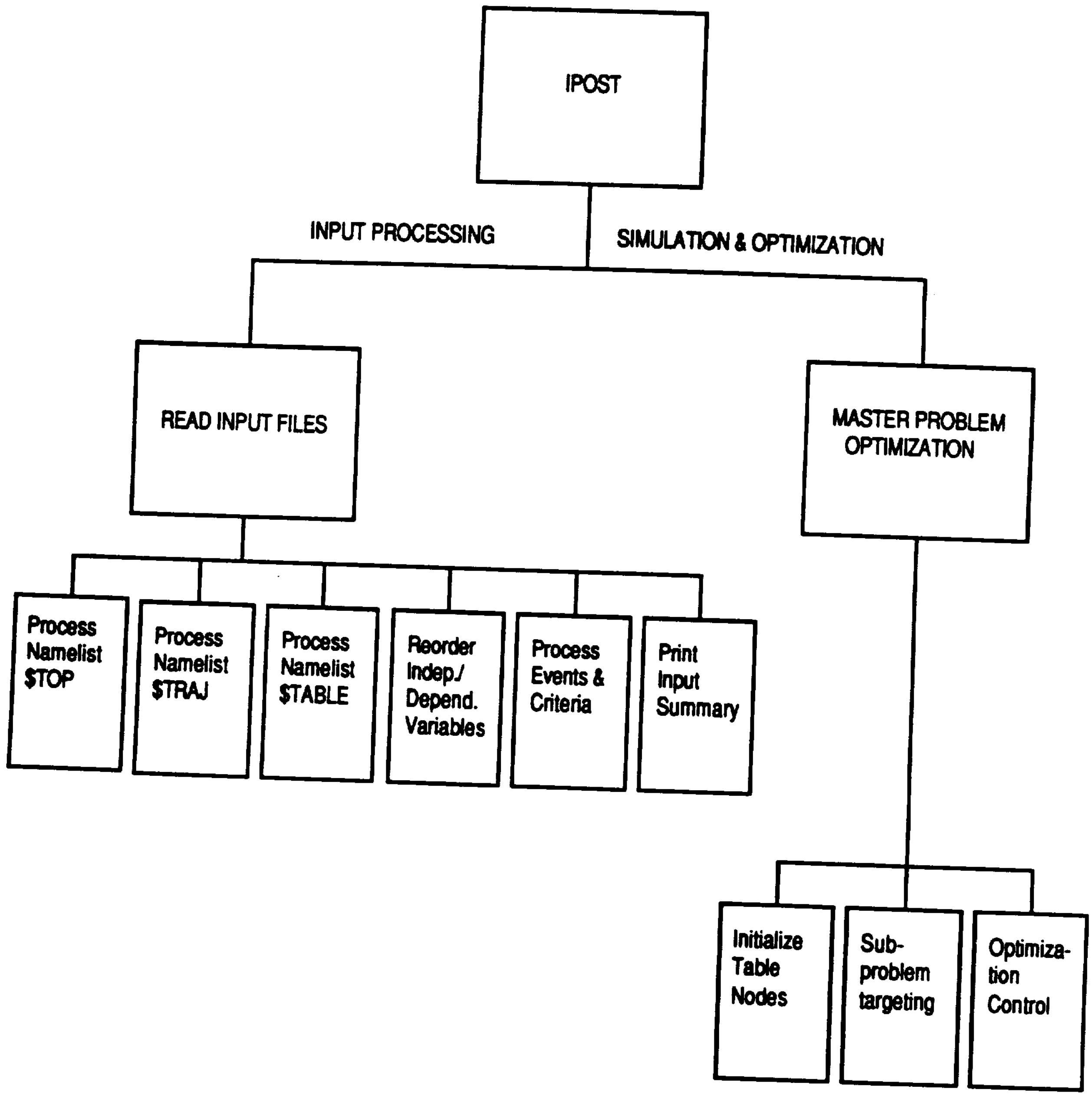
Enhancements envisioned for the IPOST Input Processor include interactive input manipulation and display, to be derived from the GMAP tool (a close cousin to POST).

The cycling, phasing and time-to-go program structure has been borrowed directly from POST. Unused capabilities, such as secondary events have been removed.

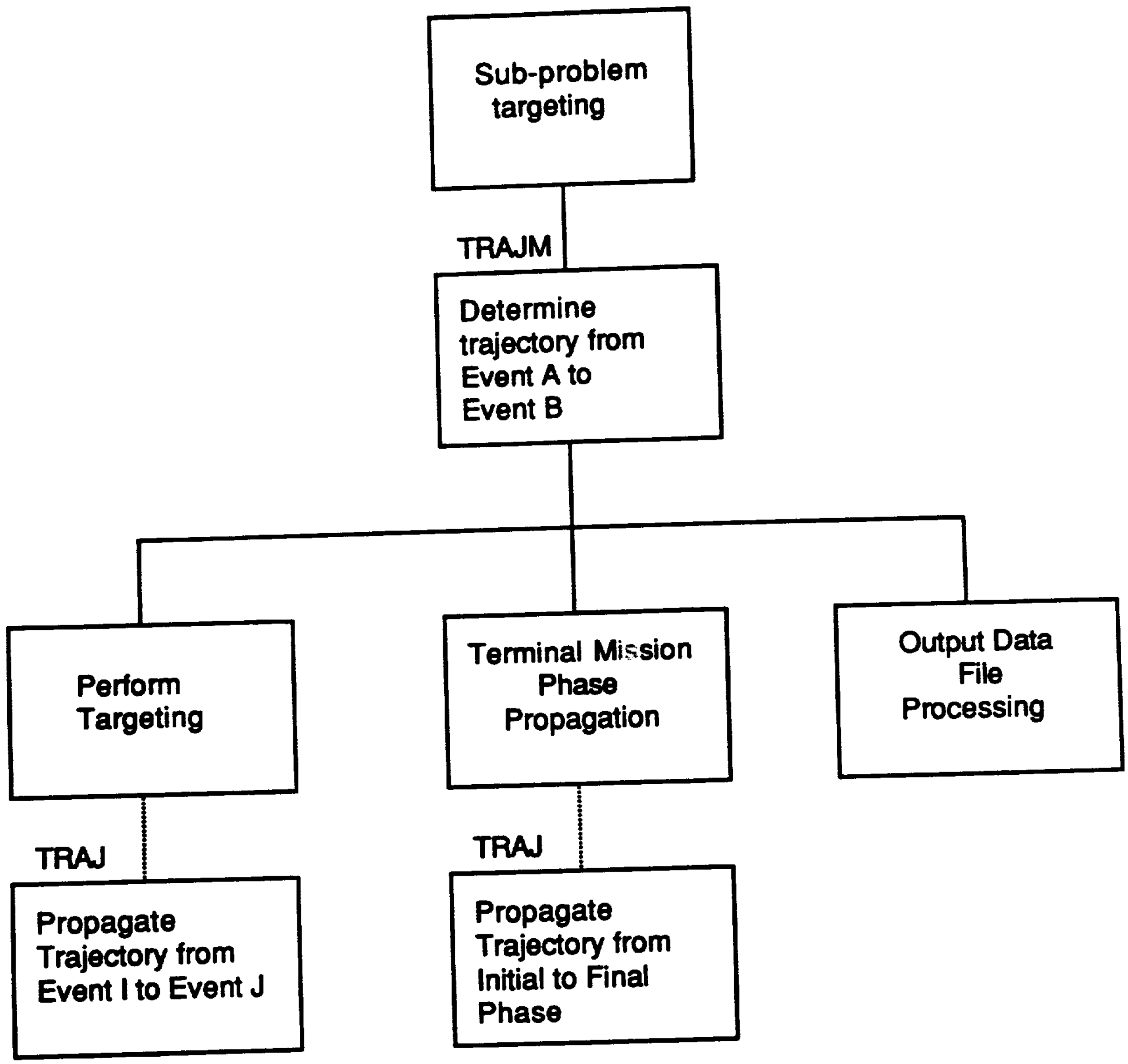
The cycling and phasing have been restructured in accordance with trajectory decomposition logic. Mission phases have been grouped into sub-problems which are targeted to specific values. Targeting may involve iterative computational passes through each group of sub-problem phases. These targets are adjusted each cycle to optimize the mission profile. Previously, all flight phases were computed.

The design and structure for general table look up and interpolation has been borrowed from the POST program. The dictionary of output variables has been borrowed from the POST program to support the design and capabilities described above. Any variable whose name appears in the dictionary may be written to the output device(s), used as the criterion for an event, a target in the decomposition sub-problem, a target of objective function of the main program or as a control in either the sub-problem or the main problem.

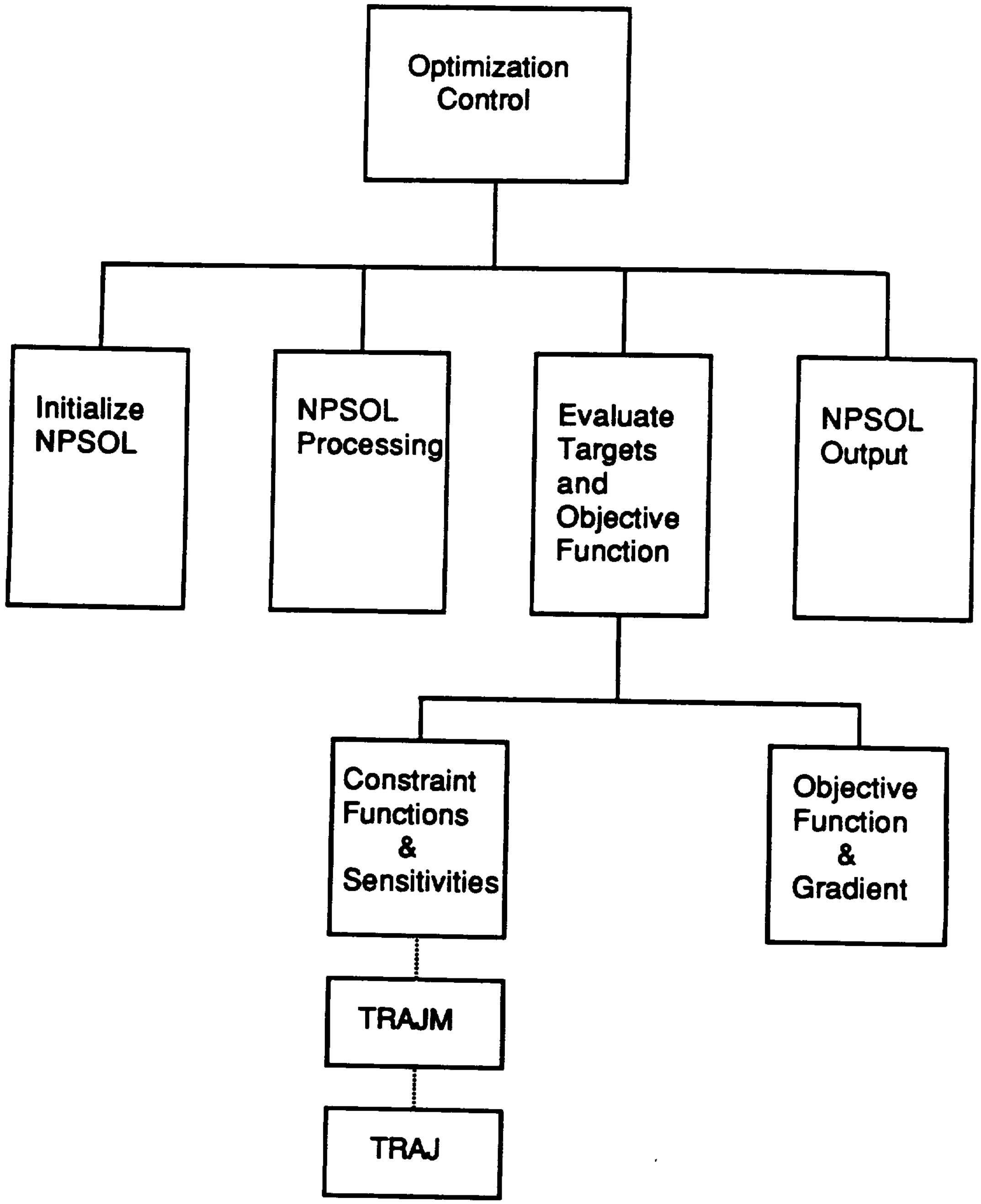
3.0 PROGRAM MACROLOGIC



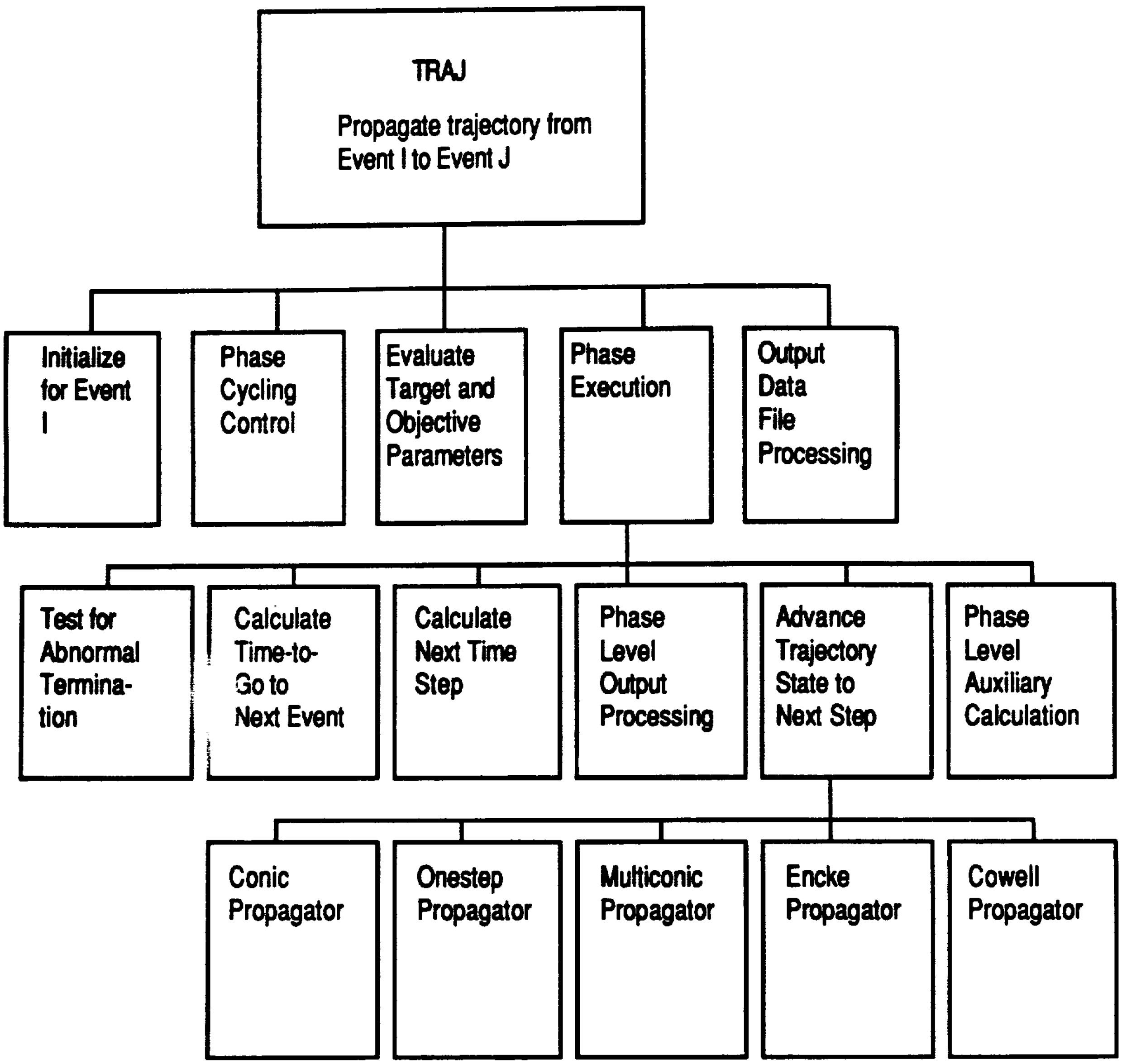
3.0 PROGRAM MACROLOGIC Continued



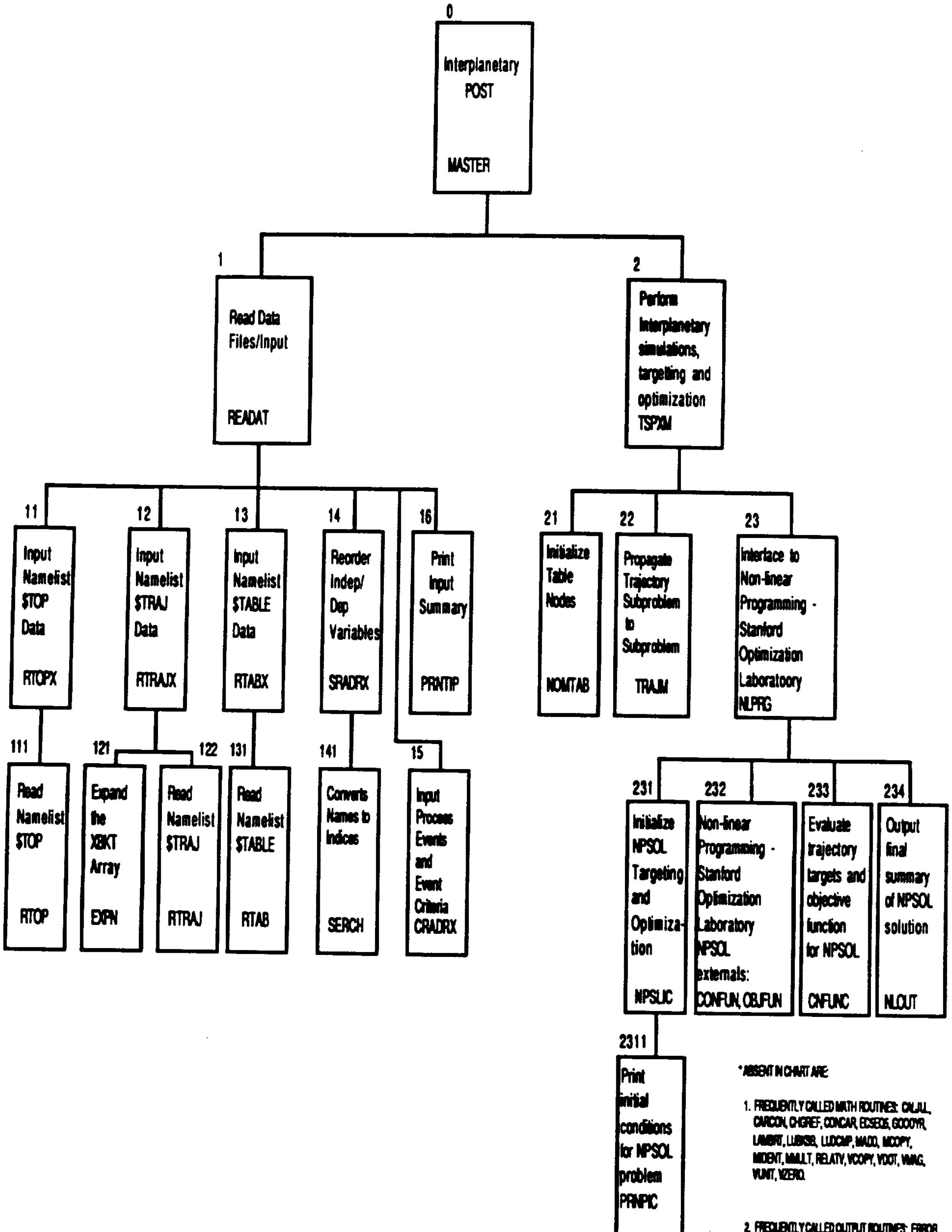
3.0 PROGRAM MACROLOGIC Continued



3.0 PROGRAM MACROLOGIC Continued



4.0 SUBROUTINE HIERARCHY

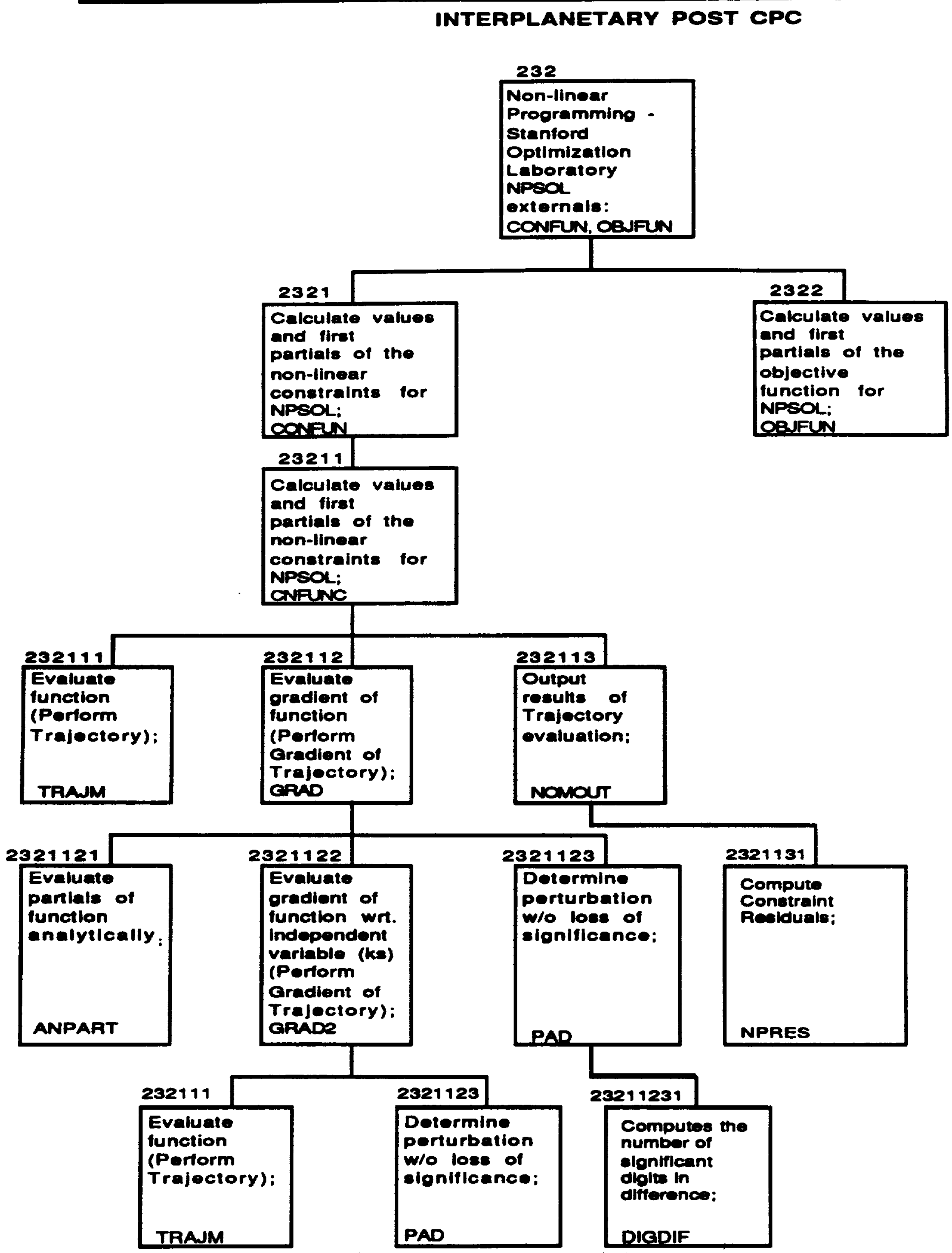


*ABSENT IN CHART ARE:

1. FREQUENTLY CALLED MATH ROUTINES: CALJUL, CARCON, CHGREF, CONCAR, ECSEOS, GOODYR, LAMBRT, LUBKSB, LUDCMP, MADD, MCOPY, MIDENT, MMULT, RELATV, VCOPY, VDOT, VMAG, VUNIT, VZERO

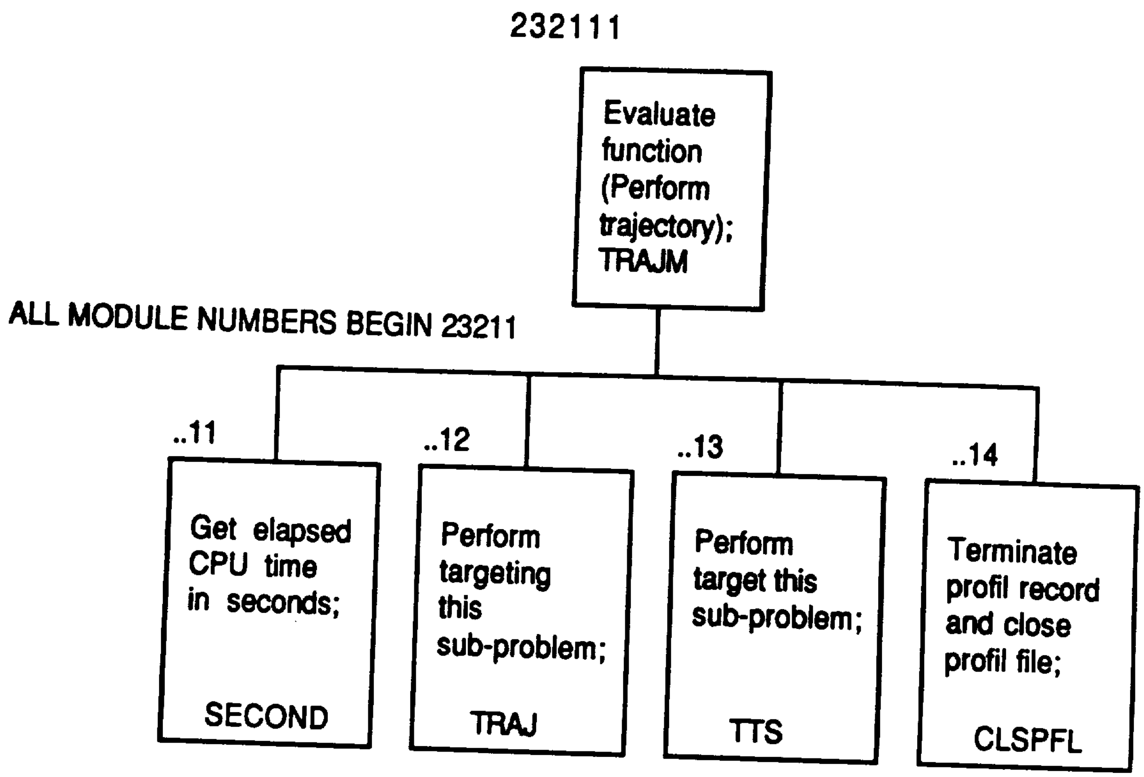
2. FREQUENTLY CALLED OUTPUT ROUTINES: ERROR, ORBOUT, PAGER

4.0 SUBROUTINE HIERARCHY Continued



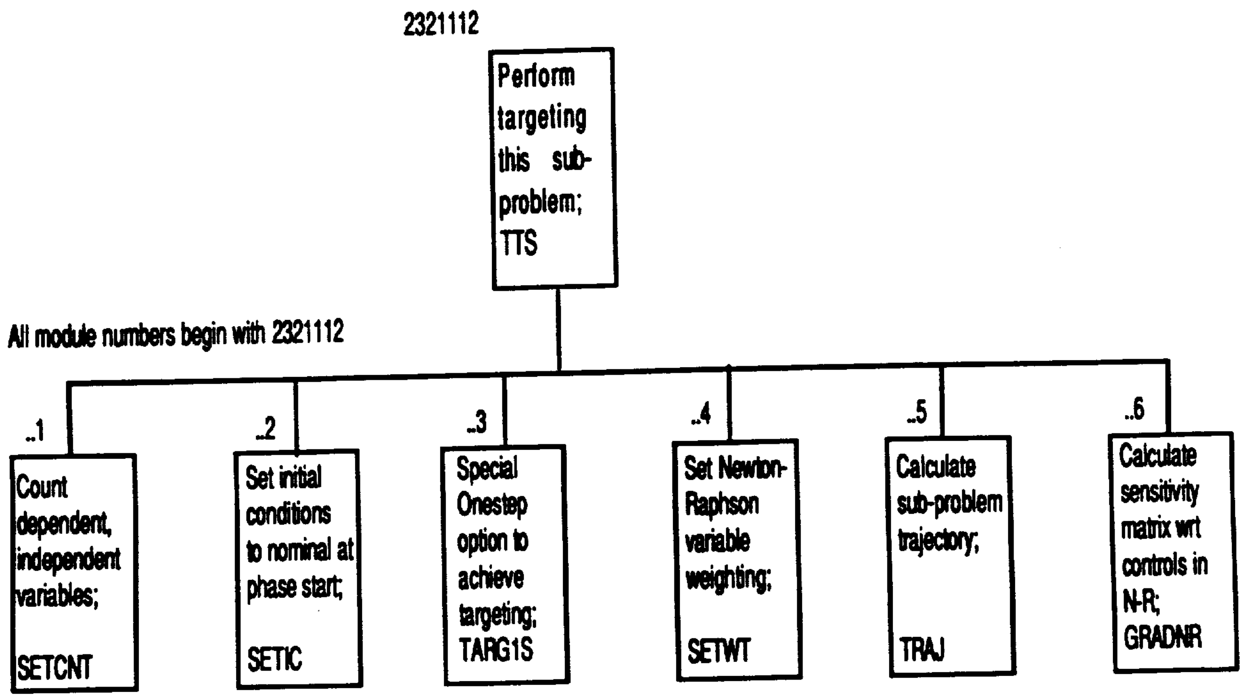
4.0 SUBROUTINE HIERARCHY Continued

INTERPLANETARY POST CPC

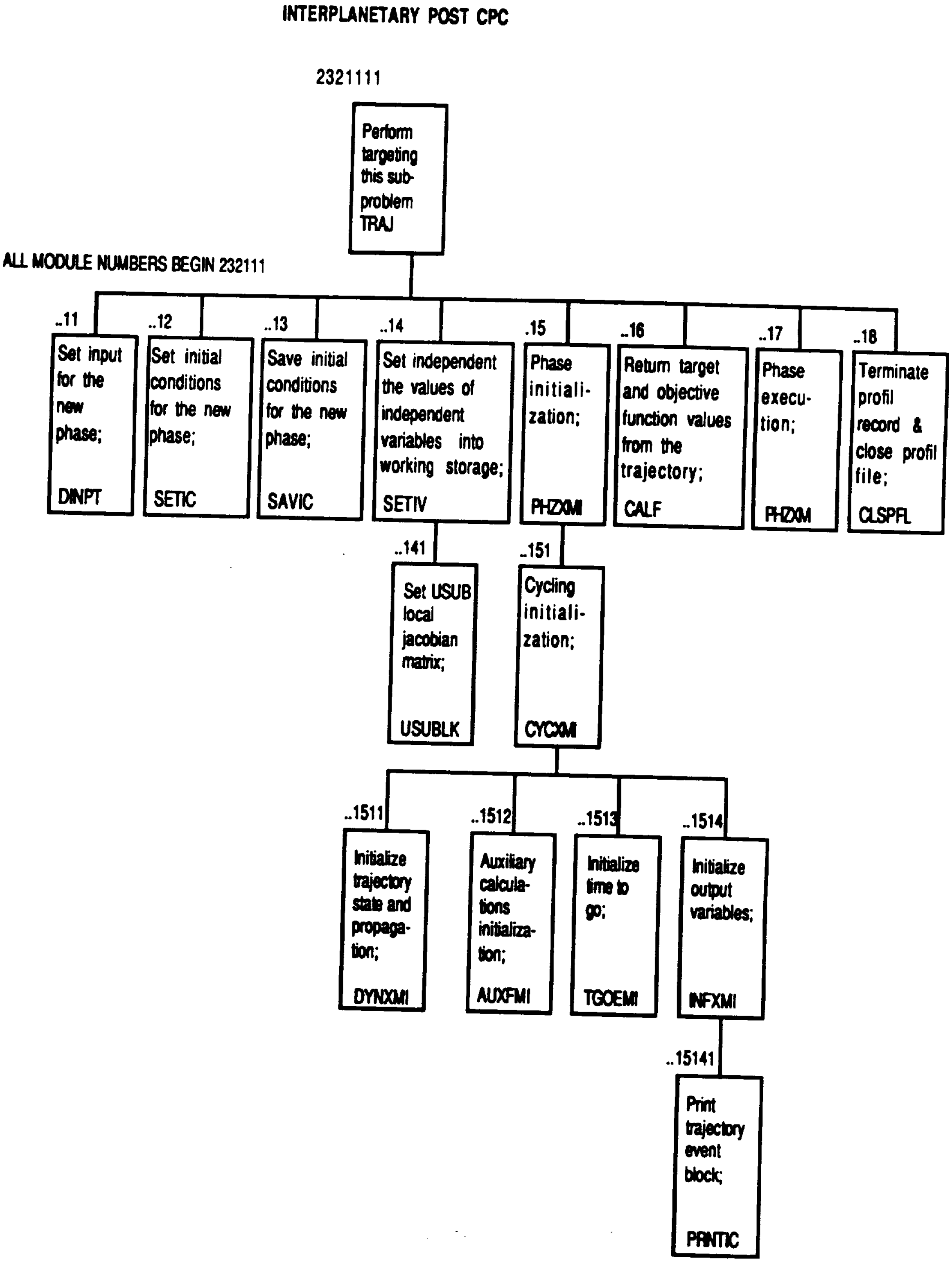


4.0 SUBROUTINE HIERARCHY Continued)

INTERPLANETARY POST CPC

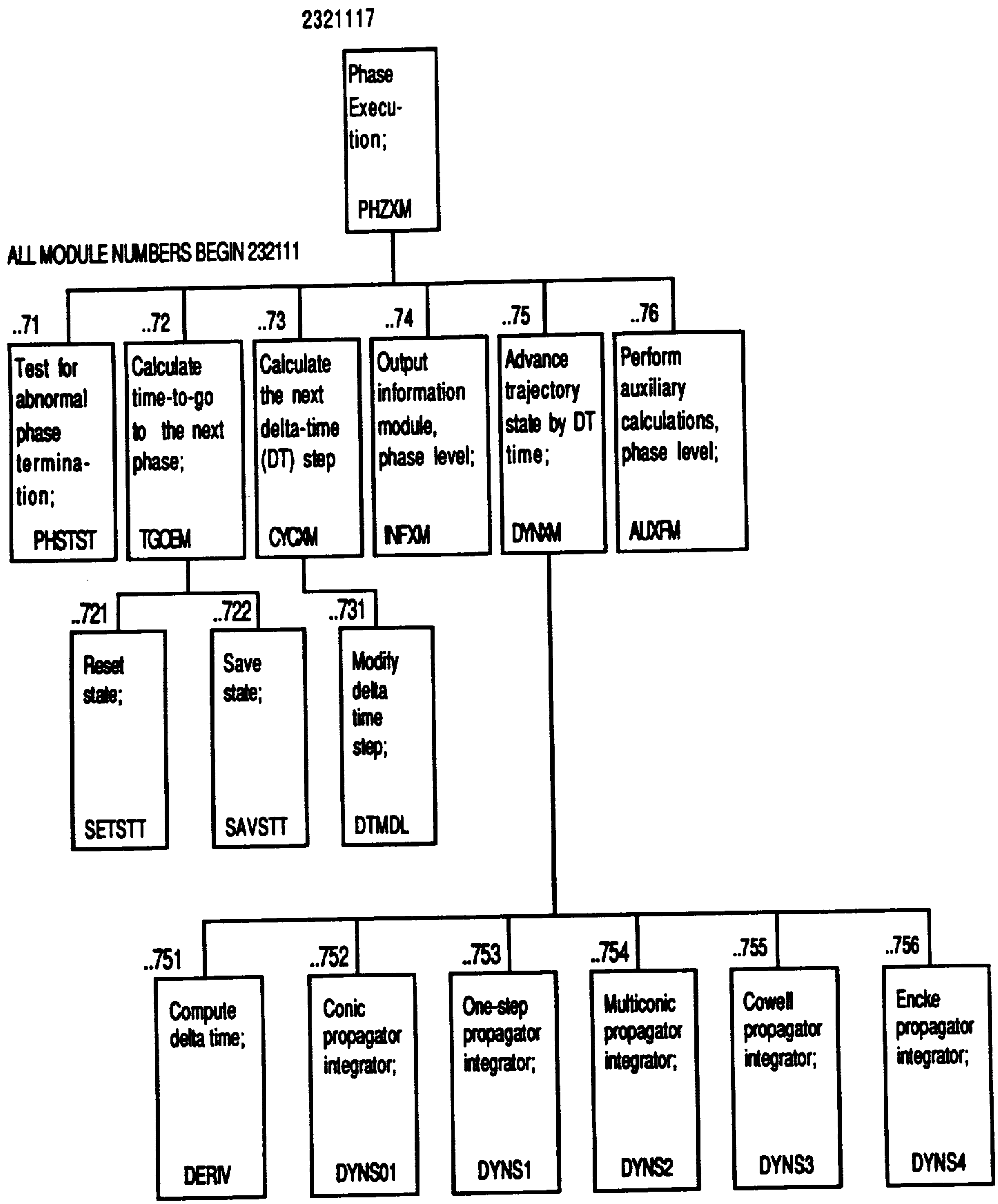


4.0 SUBROUTINE HIERARCHY Continued)



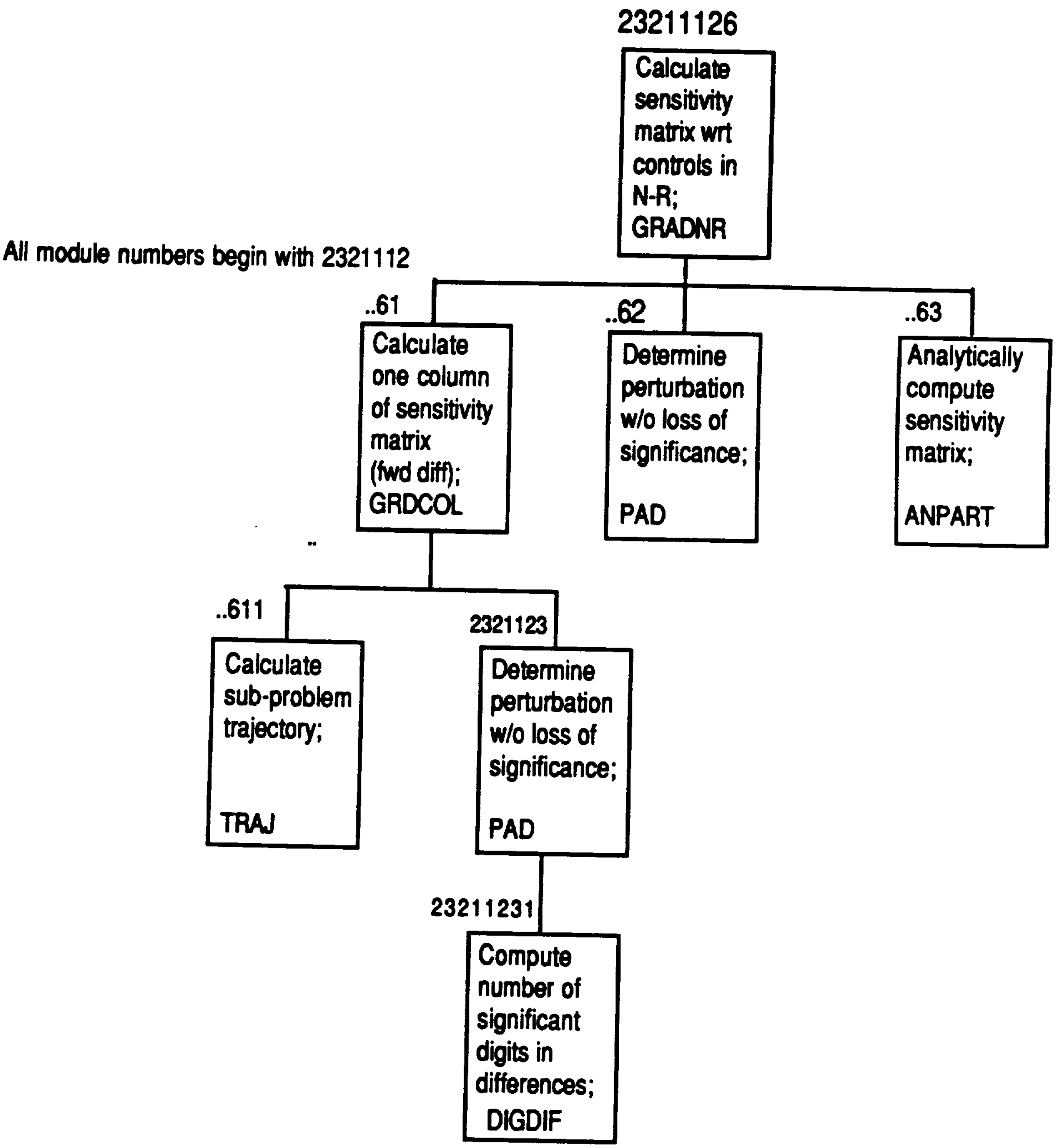
4.0 SUBROUTINE HIERARCHY Continued)

INTERPLANETARY POST CPC



4.0 SUBROUTINE HIERARCHY Continued)

INTERPLANETARY POST CPC



5.0 LIST OF IPOST SUBROUTINES

SUBROUTINE NAME	PURPOSE
ANPART	Calculates the unweighted sensitivity matrix (CJAC) and the unweighted gradient of the objective variable (OBJGRD) using analytical methods supplied by the user.
ANPARTM	Calculates the analytic partials of the master problem dependent variables objective function with respect to the master problem independent variables.
ATMOS	Calculates the pressure, density, temperature, and molecular weight at a given altitude for the primary planet. Currently, only earth data is available.
ATMOS2	Interpolates on the atmospheric tabular data to give the pressure, density, molecular weight, and temperature for a given altitude.
AUXFM	Performs auxiliary calculations at the phase level.
BLKDT1	Block data initialization for targeting and optimization variables.
CALF	Returns the value of the TARGET(I) and the objective function at event DEPPH(I) and OPTPH, respectively.
CDERIV	Computes the derivative of the state with respect to time for use in integrating the equations of motion or the Cowell method.
CLSPFL	Terminates Profile record and closes Profile file.
CNFUNC	Evaluates nonlinear constraints and their derivatives with respect to the variables U(I).
COLLCI	Initializes problem for the collocation algorithm

CONFUN	Computes the values and first derivatives of the nonlinear constraints.
COWELL	Performs the propagation of a trajectory using the Cowell method.
CRAO	Provides an indexing function to CRADRX to promote portability.
CRADRX	Finds the addresses of the CRITR for each phase record, in IBKT, and finds the addresses of INDVR/DEPVR = 5HCRITR.
CYCXM	Performs cycling functions and calculates the delta time step for the trajectory propagation.
CYCXMI	Performs cycling initialization.
DATA	Block data initialization for real trajectory variables.
DATA1	Block data initialization for integer trajectory variables.
DERIV	Computes derivative for the trajectory propagator.
DICT	Block data initialization for names of real trajectory variables.
DICT1	Block data initialization for names of integer trajectory variables.
DIGDIF	Computes the number of significant figures in the difference A less B.
DINPT	Retrieves input data for this phase from GBKT and puts it in the trajectory variables.
DTMDL	Modifies the value of DELT according to the user-selected simulation models.
DTMULT	Calculates the variable step, DT, for the Multiconic propagation method.
DYNSO1	Trajectory propagator/dynamics integration for the Conic integrator.

DYNS1	Trajectory propagator/dynamics integration for the One-step integrator.
DYNS2	Trajectory propagator/dynamics integration for the Multiconic integrator.
DYNS3	Trajectory propagator/dynamics integration for the Cowell integrator.
DYNS4	Trajectory propagator/dynamics integration for the Encke integrator.
DYNXM	Calls user-specified propagation method.
DYNXMI	Calls appropriate impulsive maneuver subroutine if applicable.
EDERIV	Evaluates the derivative of the deviation state matrix at any time.
ENCKDT	Determines the step size for the Encke propagator.
ENCKE1	Performs trajectory propagation on the state of the S/C about the primary body with perturbations using the Encke method.
ERRDVG	Determines whether an error string diverges.
ERROR	Prints an error/warning message on the output device, then terminates the job if it is a fatal error.
EXPN	Input utility to create open space in the "bucket" by shifting existing data up into the array.
FINDT	Finds the normalized time value for Lambert's problem.
FMATRX	Evaluates the derivative of the acceleration applied to the S/C with respect to the position and velocity.
GENTAB	General table interpolation routine.

GRAD	Calculates the gradients to each of the targets and to the optimization index with respect to the controls.
GRAD2	Calculates the gradient of each constraint/objective function with respect to the KSth control.
GRADNR	Calculates the sensitivity matrix with respect to perturbations of the controls.
GRDCOL	Performs the finite difference for subroutine GRADNR by the brute force method.
HERM	Determines the polynomial coefficients for the hermite cubic polynomial representing the state
IMPULS	Computes the impulsive delta velocity parameters for midcourse.
INFXM	Information output subroutine for controlling printing trajectory print blocks.
INFXMI	Performs quantization of the printed page print time and the profile print time.
ISERCH	Converts dictionary names to indices relative to IV.
ISORTD	Sorts an array in decreasing order using the Shell-Mezgar algorithm.
LAGRNG	Fits a polynomial to three points using Lagrange's method.
LAUNCH	Calculates a hyperbolic escape trajectory from a park orbit including post-injection Cartesian state at periapsis.
LOCF	Provides an addressing algorithm for IPOST. LOCF is returned in units of INTEGER*4.
MASSCK	Checks for sufficient propellant mass for sub-events.
MASSDT	Mass integration for active thrust sub-events.

MASSET	General N-stage mass modelling initialization and jettison.
MASTER	Main program of the Interplanetary Post Simulation Program.
MD2050	Transforms a vector from mean equator and equinox 1950 (or mean 2000) to mean of date, or vice versa.
MFROMV	Extracts a matrix from a given vector by columns.
MOTAB	Returns the index to the greatest independent table-point less than or equal to the value of the independent variable.
MOTION	Trajectory state and propagation initialization.
MPHI	Computes the state transition matrix by chain rule from subproblem maneuver M1 to the next subproblem maneuver M2. (M2.GE.M1) and store in partitions.
MPHIO	Computes the composite state transition matrix by the chain rule from one event to another.
MSRR1	Computes the sensitivity matrix SRR.1, delta position (I) with respect to delta position (T-1) assuming intermediate target conditions are held constant for the I^{th} maneuver.
MSVPO	Computes the sensitivity matrix SVPO, maneuver velocity with respect to targets.
MSVR2	Computes the sensitivity matrix SVR2, velocity at I with respect to position at I-1 assuming all other intermediate conditions are constant.
MSVRO	Computes the sensitivity matrix SVRO, velocity at I with respect to position at I, assuming fixed target conditions.

MULTIC	Performs the propagation of a trajectory from time TI by a delta time step of DT days using the STUMPFF-WEISS method.
NCOUNT	Determines the values of variables NSDEPV, NSINDV, and NSUB by counting INDXSD and INDXSI arrays. Also, determines the number of independent and dependent master level variables.
NLOUT	Outputs the summary of NPSOL's final solution.
NLPRG	Executive to implement NPSOL Optimization package into IPOST.
NOMTAB	Sets the table nodes to default values.
NOMOUT	Prints summary of NPSOL constraint/ objective and derivative evaluation.
NPRES	Computes constraint residuals.
NPSLIC	Sets initial conditions for the Stanford University Optimization Laboratory Non-linear Programming Algorithm, NPSOL.
OBJFUN	Computes the value and first derivatives of the nonlinear objective function.
OFFBND	Handles an out-of-bounds table exception.
ONESTP	Performs the propagation of a trajectory from time TI to time TF using the One step method.
ORBINS	Computes transfer maneuvers from an approach hyperbola to a desired elliptical orbit, including post injection state at periapsis.
PACC	Computes perturbing accelerations for trajectory propagators.
PAD	Determines the delta X that produces the most precise finite difference derivative without losing significance.

PAGER	Controls paging for output.
PARITO	Computes the master problem cost value and partial for the Interplanetary Targeting and Optimization Option (ITOO).
PBLOCK	Prints out various blocks of data as required.
PHSTST	Performs test for abnormal phase termination.
PHZCM	Performs the phasing functions for integration over a phase for collocation
PHZCMI	Performs phasing initialization
PHZXM	Performs the phasing functions for integration over a phase.
PHZXMI	Performs phasing initialization.
PLOT	Collocation post processing
PLOTIT	Collocation post-processing
POLEQ50	Calculates the rotation matrix to convert from earth equatorial to planet equatorial system and vice versa. Also, calculates the transpose of this rotation matrix for rotating from planet equatorial to earth equatorial system.
PRNPIC	Prints initial user inputs to NPSOL Targeting and Optimization package.
PRNTIP	Prints the initial conditions for the trajectory and Targeting/Optimization algorithm for the current problem.
PSCAN	Parameter scan master level target variables.
READAT	Input Processor Executive subroutine for the IPOST program.

RECTFY	Determines if rectification is necessary, and if so, a new osculating orbit is found by choosing a starting point that coincides with the true orbital path.
ROTRTN	Calculates the rotation matrix from the inertial equatorial system to the RTN system and vice versa.
ROTRYP	Calculates the rotation matrix to convert a vector in the body system to a vector in either the RTN system, the UVW system, the inertial equatorial system, or the inertial ecliptic system.
ROTUVW	Calculates the rotation matrix from the inertial equatorial system to the UVW system and vice versa.
RTAB	Reads Namelist $TAB.
RTABX	Executive subroutine for reading the table data input.
RTOP	Reads targeting and optimization Namelist input.
RTOPX	Executive subroutine for reading targeting and optimization input and storing it in the data "bucket".
RTRAJ	Reads trajectory Namelist input.
RTRAJX	Executive subroutine for reading trajectory input and storing it in the data "bucket".
RUNGE4	Performs fourth order Runge-Kutta integration on the state.
SAVDAT	Saves default AAIVC to ZZENDC (Block data) values over multi-problem execution.
SAVIC	Saves the current state of the trajectory (event -) for quick function evaluation during targeting/ optimization trajectory perturbations.
SAVSTT	Saves the state.

SCAREA	Calculates the S/C area normal to the velocity vector through the atmosphere.
SEARC	Performs collocation algorithms
SECOND	Gets the elapsed CPU time in seconds.
SERCH	Converts dictionary names to indices.
SETCNT	Counts the number of independent and dependent variables in each sub-problem.
SETIC	Restores the trajectory state previously saved by SAVIC.
SETIV	Sets the Targeting/optimization independent (control) variables to the desired values, based on the calculated control correction.
SETSTT	Resets the state.
SETWT	Sets weighting for Newton-Raphson targeting method for sub-problems.
SNMOUT	Writes out subproblem status.
SOICHK	Verifies if given radius vector in primary body reference frame is still within the primary body's sphere of influence. If it is not, change state vector and primary body to reflect which sphere of influence the radius is within.
SRAO2	Provide an indexing function to CRADRX to promote portability.
SRADP	Computes solar radiation pressure for trajectory propagation.
SRADRX	Processes the namelist $TOP variables. Reorders the independent and dependent variables.
TARG1S	Special One step targeting option which varies pseudostate to achieve desired target conditions.

TARGET	Converts state vector into specified conic parameters and impulsive delta velocity.
TBADRX	Sets addresses for tables; converts names of table arguments to addresses.
TGOEM	Computes time-to-go to the next pending event.
TGOEMI	Time-to-go initialization.
TPRP	Finds the closest approach and time of closest approach of the vehicle to a secondary body for a given time interval and a primary central body. Only the attraction of the primary body is considered.
TRAJ	Propagates the trajectory phase-to-phase over one subproblem.
TRAJC	Performs logic to evaluate the collocation trajectory from phase, iensi, to phase, iensf, phase-to-phase.
TRAJM	Performs logic to propagate trajectory subproblem to subproblem.
TSPXM	Top level simulation module.
TTS	Target this subproblem. Propagates a trajectory to achieve a desired targeting.
USUBLK	Sets the USUB local jacobian matrix for sub-problem control.

6.0 LIST OF UTILITY SUBROUTINES

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
ANBET (A,B)	F	Function ANBET calculates the smallest angle between any two vectors A and B.
ANOMLY (E,IOPT,AM,F)	S	Subroutine ANOMLY converts true anomaly to mean anomaly or vice versa.
CALJUL (ICODE,DAY,IYR, MO, IDAY,IHR,MIN,SEC)	S	Subroutine CALJUL converts Julian date to calendar date or vice versa.
CARCON (GMU,STATE,ORBT)	E	Entry Point CARCON in Subroutine CHGELM calculates orbital elements from a state vector.
CHGREF (T,NOLD,NNEW, STATEO,STATEN)	S	Subroutine CHGREF converts a state vector from one celestial body centered ecliptic reference frame to a new celestial body centered ecliptic reference frame.
CONCAR (GMU,STATE,ORBT)	E	Entry Point CONCAR in Subroutine CHGELM calculates the state vector from the orbital elements.
DANBET (A,B,REF)	F	Function DANBET calculates the directed angle between any two vectors A and B.

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
EQTECT (DJ,XIN,XOUT)	S	Subroutine EQTECT transforms a vector from equator of date to ecliptic of date.
ECTEQT (DC,XIN,XOUT)	E	Entry point ECTEQT in Subroutine EQTECT transforms a vector from ecliptic of date to equator of date.
EQ5EC5 (DJ,XIN,XOUT)	E	Entry Point EQ5EC5 in Subroutine EQTECT transforms from equator of 1950.0 to ecliptic of 1950.0.
EC5EQ5 (DJ,XIN,XOUT)	E	Entry Point EC5EQ5 in Subroutine EQTECT transforms from ecliptic of 1950.0 to equator of 1950.0.
EPH50 (N,T,STATE)	S	Returns planet position and velocity vectors (R,V) in mean ecliptic and equinox of 1950.0.
EPHEMS (NP,T,IEPHEM,STATE)	S	Subroutine EPHEMS finds the state vector of a specified body at a specified time in heliocentric mean ecliptic and equinox of 1950.0.
EPHEMP (T,IBODY1,IBODY2, PSTATE)	S	Calculates position and velocity of an EPHEMERIS body from JPL Chebyshev coefficients.

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
EPHSAT (T,XPRI,N,IPRIB, ISATB,XSAT)	S	Subroutine EPHSAT finds the state vector of a satellite orbiting its primary body at a specified time.
GOODYR (XI,TAU,GMU, IPFLAG,PSI,XF,PHI, PHINV)	S	Subroutine GOODYR solves a two body problem with partial derivatives.
IFRM50 (SIN, SOUT)	S	Subroutine IFRM50 converts the input state vector from the I/O body reference frame to ecliptic mean of date 1950.
JACOBI (JTARG,X,AUX,Y,S)	S	Subroutine JACOBI computes the 3x6 sensitivity matrix of S = dY/dX by finite differencing. JACOBI presumes the subroutine TARGET has been called to compute and store the nominal Y parameter.

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
LAMBRT (R1,R2,TFS,NREV, GMU,V1,V2)	S	Subroutine LAMBRT solves LAMBERT'S problem by determining an orbit given two position vectors and a interval.
LUBKSB (A,N,NP,INDX,B)	S	Subroutine LUBKSB solves the set of N linear equations AX = B. Not as the matrix A but rather as its LU decomposition determined by LUDCMP.
LUDCMP (A,N,NP,INDX,D)	S	Subroutine LUDCMP replaces an NxN matrix A with the lower-upper (LU) decomposition of a row wise permutation of itself.
M50IFR (SIN,SOUT)	S	Subroutine M50IFR converts an input state from ecliptic mean of data 1950 to I/O body reference frame.
MADD (A,SA,B,SB,N,M,C)	S	Subroutine MADD performs matrix addition and scalar multiplication.
MATOUT (A,N,M)	S	Subroutine MATOUT prints an NxM matrix A to output device.
MCOPY (A,N,M,B)	S	Subroutine MCOPY copies matrix A to matrix B.
MIDENT (N,A)	S	Subroutine MIDENT transforms the matrix A into an identity matrix.

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
MINV (A,N,B,ISING)	S	Subroutine MINV calculates the inverse, if it exists, of matrix A.
MMULT (A,B,L,M,N,C)	S	Subroutine MMULT performs matrix multiplication.
RDCHBY (ET,IBODY,CHBYFL, NC,PARAM,ICENT)	S	Reads Ephemeris file created by PREPRO for the current body and time.
RELATV (T,NPRIM,NSEC,RHO)	S	Subroutine RELATV finds the state vector representing the position and velocity of a secondary celestial body with respect to a specified central celestial body.
TARGET (ITARG,X,GMU,Y, AUXO)	S	Subroutine TARGET converts a state vector into specified conic parameters.
VANGO (GAM,XNODE,XINC, VECTOR)	S	Subroutine VANGO computes a unit pointing vector.
VCOPY (A,N,B)	S	Subroutine VCOPY copies vector A to vector B.
VCROSS (A,B,C)	S	Subroutine VCROSS computes the cross product of two vectors.
VDOT (A,B)	F	Subroutine VDOT computes the dot product of two vectors.

NAME	E-ENTRY POINT F-FUNCTION S-SUBROUTINE	VARIABLE
VMAG (A)	F	Subroutine VMAG calculates the magnitude of vector A.
VSCALE (S,A,N,B)	S	Subroutine VSCALE scales a vector A and outputs vector B.
VUNIT (A,B)	S	Subroutine VUNIT calculates unit vector B from vector A.
VZERO (N,A)	S	Subroutine VZERO converts vector A to a zero vector.

7.0 GLOBAL COMMON BLOCKS

COMMON AAIBKT - Data structure containing event definition records, tables, and phase state transition matrices.

COMMON AAIVC - Defines beginning of the dictionary.

COMMON ATMOSC - Contains real type variables defining the atmospheric data for the earth.

COMMON CYCNC - Contains integer type variables used to perform cycling functions.

COMMON CYCVC - Contains real type variables used to perform cycling functions.

COMMON DVIVC - Contains delta velocity variables.

COMMON DYNVC - Contains time references and other variables used to perform dynamics functions.

COMMON EPHEJC - Contains character type variables defining the planets' alphanumeric names.

COMMON ER - Internal Table errors common.

COMMON EPHEMC - Contains the variables for the analytic planetary ephemeris.

COMMON GENIC - Contains miscellaneous top level variables.

COMMON GENRL - Data structure containing real and integer type input from namelist $TRAJ.

COMMON INFVC - Contains printout control variables.

COMMON INFV1C - Contains the title and profile file identification character variables.

COMMON INPVC - Contains miscellaneous top level input control variables.

COMMON IPRT0 - Contains internal variables used to control printout during targeting and optimization.

COMMON ITOOJC - ITOO input variables common.

COMMON MNVRJC - Contains integer and character type variables for impulsive maneuver sub-events.

COMMON MOTBLC	-	Table Nodes common (also MOTBLO).
COMMON PACVC	-	Contains perturbing accelerations for trajectory propagation.
COMMON PADC	-	Contains variables used in controlling perturbation in the targeting and optimization algorithm.
COMMON PADSWC	-	Contains internal sub-problem control variables.
COMMON PAGERC	-	Contains variables used in pagination control.
COMMON PHZNC	-	Contains integer type variables associated with phasing functions.
COMMON PHZVC	-	Contains real type variables associated with phasing functions.
COMMON PLANEC	-	Contains planet related variables.
COMMON PROPDC	-	Contains real variables controlling trajectory propagation and perturbing influences.
COMMON PROPJC	-	Contains integer variables controlling trajectory propagation and perturbing influences.
COMMON REDAT	-	Contains input processing variables.
COMMON SEARC	-	Contains master level targeting and optimization variables, independent and dependent variables.
COMMON SENSIT	-	Contains sensitivity matrix generation parameters for swingby targeting and optimization.
COMMON SERVC	-	Service common containing constants and temporary arrays.
COMMON STATEC	-	Contains the vehicle's position and velocity and the orbital elements.
COMMON STATNC	-	Contains integer and character type variables defining the vehicle's position and velocity.
COMMON SUBPVC	-	Contains sub-problem level targeting variables, independent and dependent variables.
COMMON TGONC	-	Contains integer type time-to-go variables.

COMMON TGOVC - Contains real type time-to-go variables.

COMMON ZZENDC - Defines the end of the dictionary.

8.0 DATA BLOCK VALUES

```
      block data blkdt1
      implicit real*8 (a-h,o-z)
c*** blkdat
c        set initial program values
c*** the data statements in this routine are standardized
c
c
c     standard fortran declarations
c          common
c          dimension
c          equivalence
c          type (can be anywhere above)
c          data (can be anywhere)
c          namelist
c
c
      include 'aaibkt.inc'
      include 'genic.inc'
      include 'infjc.inc'
      include 'inpvc.inc'
      include 'itoojc.inc'
      include 'padc.inc'
      include 'pagerc.inc'
      include 'parmsc.inc'
      include 'pr0fc.inc'
      include 'searc.inc'
      include 'servc.inc'
      include 'subpvc.inc'

      parameter (mxinv5=5*mxinv)
      parameter (mxinv2=3*mxinv*mxinv+41*mxinv)
c
c -----------------------------------------------------------------
c       include 'aaibkt.inc'
c -----------------------------------------------------------------
c       common      /aaibkt/
      data
     1 ibkt(1)/ 0       /
c
c -----------------------------------------------------------------
c       include 'genic'
c -----------------------------------------------------------------
c       common      /genic         /
      data
     1 iprt     / 63    /
c
c -----------------------------------------------------------------
```

```
c      include 'infjc'
c -------------------------------------------------------
c      common    /infjc /
       data
  1     iprofl        / 0     /
      data
  1  npvar / 33 /
c
c      common    /infjcc        /
       data outnam
  o   /'time  '
  1   ,'x     ','y     ','z     ','vx    ','vy    ','vz    '
  2   ,'sma   ','eccen ','inc   ','anlong','argp  ','meaan '
  3   ,'truan ','rperi ','vperi ','tfp   ','rapoap','period'
  4   ,'radius','speed ','btheti','vinfxi','vinfyi','vinfzi'
  5   ,'bdti  ','bdri  ','hypta ','c3i   ','rai   ','deci  '
  6   ,'btheto','vinfxo','vinfyo','vinfzo','bdto  ','bdro  '
  7   ,'hypta ','c3o   ','rao   ','deco  ','fpa   ','altit '
  8   ,'longp ','lat   ','long  ','b     ', 53*'      '
  n   /
c
c -------------------------------------------------------
c      include 'inpvc'
c -------------------------------------------------------
c      common    /inpvc        /
       data
  1     ioflag        / 3     /
c
c      common    /inpcc        /
       data
  1     iprops        /maxevt*'none'/
       data
  1     mnvrs         /maxevt*'none'/
c
c -------------------------------------------------------
c      include 'itoojc'
c -------------------------------------------------------
c      common    /itoojc       /
       data
  1     itoowt        / 'sumass'  /
c
c -------------------------------------------------------
c      include 'padc'
c -------------------------------------------------------
c      common    /padc /
       data
  1     npad          / 9.d0, 4.d0, 14.44943979d0          /
  2    ,pdlmax        / 2.0d0        /
  3    ,sigdel / 0.0d0        /
```

```
     4    ,sdif  / 0.0d0          /
c
c ------------------------------------------------------------
c       include  'pagerc'
c ------------------------------------------------------------
c       common     /pagerc       /
        data
     1   icase          / 0     /
     2  ,nlines         / 60    /
     3  ,header         / ' '   /
     4  ,npage          / 1     /
c       common     /pager2       /
        data
     1   ptime          / ' '   /
c
c ------------------------------------------------------------
c       include  'pr0fc.inc'
c ------------------------------------------------------------
c
      data idxdat  / prsize * 0.0 /
      data hdrdat  / prsize*'         '/
      data frsttl  / 0/
      data nxtrec  / 3/
      data cirn    / 1/
      data cdrn    / 2/
      data chrn    / 2/
      data ciep    / 34/
      data cdep    / 0/
      data chep    / -1/
      data tdpos   / 0/
c
c ------------------------------------------------------------
c       include  'searc.inc'
c ------------------------------------------------------------
c       common     /seric        /
        data
     1   ideb  /0       /
     2  ,ifdeg          /25 * 0/
     3  ,indxi          /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20
     4  ,21,22,23,24,25/
     6  ,indxd          /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20
     7  ,21,22,23,24,25/
     8  ,ipro  /0       /
     9  ,ismdep         /0      /
     o  ,ismind         / lmxinv*0   /
     1  ,mxitop /10, 5*-1/
     2  ,ndepv          /0      /
     3  ,nindv          /0      /
     4  ,nclin          /0      /
```

```
     5     ,nsminc     /0     /
           data
     1      nsmind     /0     /
     2     ,opt   /0      /
     3     ,pert  /mxinv * .0001d0    /
     4     ,smincr     /1.d0  /
     5     ,srchm      /'none'      /
     6     ,isens      /0     /
      7 ,etanl  /.9d0  /
      8 ,prntpd        /.false./
      9 ,sclflg  /.false./
      o   ,wgtflg /.true.       /
      1 ,ftol     /1.d-14       /
      2 ,indplb /mxinv*-10.d10      /
      3 ,indpub        /mxinv*+10.d10     /
      data
      1    depvlb /mxinv*-10.d10    /
      2    ,depvub       /mxinv*+10.d10     /
      3    ,deptl        /mxinv*1.0d0       /
      4    ,iter   /0      /
      5    ,nstep        /0     /
      6    ,inform       /0     /
      7    ,nrowa        /10    /
      8    ,nrowj        /7000  /
      9    ,nrowr        /7000  /
      o    ,nctotl       /0     /
      1    ,msglvl       /10    /
      2    ,nstate       /0     /
           data
      1     istate       /mxinv*0, mxinv*0        /
      2    ,clamda       /mxinv*0.d0, mxinv*0.d0/
      3    ,orthog /.true.      /
      4    ,leniw        /mxinv5      /
      5    ,lenw         /mxinv2      /
      6    ,icnfun       /0     /
      7    ,nbase        /2     /
      8    ,ndigit       /56    /
      9    ,epsmch       /2.78d-17    /
      o    ,flmin        /2.94d-39    /
      1    ,flmax        /1.70d+38    /
      2    ,nin   /5      /
      3    ,nout /6       /
      4    ,rteps        /1.d-7 /
      5    ,epsaf        /1.d-14      /
       6  ,weight /mxinv*0./
c
c          common        /sercc       /
           data
      1     istm / 'forward'  /
```

```
     2  npinpt / 'npinput'   /
c
c       common    /serfc        /
        data
    1    fesn  / 999.0d0     /

c       common    /tofioc       /
        data depvl /mxinv * 0.0d0/,optvl/0.0d0/,u/mxinv*0.0d0/
c
c       common    /tofeic       /
       data
    1    depph        /mxinv * 900.0d0   /
    2   ,depvr        /mxinv * 0.0d0     /
    3   ,indph        /mxinv * 0   /
    4   ,indvr        /mxinv * 0   /
    5   ,optph        /900.0d0     /
    6   ,optvar /0.0d0       /
    7   ,sindph /mxinv*0.d0      /
    8   ,namsvr      /mxinv*0,mxinv*0/
    9  ,namopt / 0/
    o   ,wvu  / mxinv*0.d0       /
    1   ,wvlc /10*1.0d0      /
    2   ,wvnlc       /mxinv*0.0d0        /
    3   ,wopt /1.0d0         /
c
c -----------------------------------------------------
c       include  'servc'
c -----------------------------------------------------
c       common    /servc        /
        data
    1    temp          /50*0.d0      /
    2   ,stemp         /25*0.0d0     /
    3   ,pio2  /1.57079632679489d0          /
    4   ,pi    /3.14159265358898d0          /
    5   ,rpd   /0.0174532925199433d0        /
    6   ,dpr   /57.295779513082d0           /
    7   ,twopi         /6.28318530717796d0          /
    8   ,spdy / 86400.d0    /
    9   ,sphr / 3600.d0     /
    o   ,fp1   /1.0d0        /
    1   ,fpem6        / 1.0d-6       /
    2   ,fpem8        / 1.0d-8       /
    3   ,fpem10       / 1.0d-10      /
    4   ,fpem12 / 1.0d-12   /
    5   ,idebug       /0      /
    6  ,iephem /0    /
       data
    1   unitm        /1.d0  ,0.d0  ,0.d0
```

```
 2          ,0.d0  ,1.d0  ,0.d0
 3          ,0.d0  ,0.d0  ,1.d0
 4          /
     data
 1 zerom    /0.d0  ,0.d0  ,0.d0
 2          ,0.d0  ,0.d0  ,0.d0
 3          ,0.d0  ,0.d0  ,0.d0
 4          /
     data
 1   en0is        / 1.0d-8       /
 2   ,xinf  / 1.0d+38
c
c -------------------------------------------------------
c      include       'subpvc'
c -------------------------------------------------------
c      common      /subvpc        /
     data
 1    atarwt       / 2.d0, 7.d0, 3.d0, 1.d0, 1.d1, 8.d0,
 2               5.d0, 0.7d0, 2*0.d0         /
 3  ,indslb /mxnsvr*-1.d38/
 4  ,indsub /mxnsvr*1.d38/
 5  ,indxsd / mxnsvr*0  /
 6   ,indxsi / mxnsvr*0          /
 7  ,isub   / mxnsub*0 /
 8  ,mxitar        / 1     /
 9  ,npi     / 7       /
 o  ,nsdepv        / 0     /
 1  ,nsindv        / 0     /
 2   ,nsub         / 0     /
 3   ,pertsb       / mxnsvr*0.0001d0          /
 4   ,targmt       / mxnsub*1.0d0    /
 5   ,rfsoi / mxnsub*0.5d0      /
 6  ,optsvr / mxnsub*0.d0  /
 7  ,optsph / mxnsub*900    /
 8  ,tolf  / 1.d0/
 9  ,tolu  / 1.d0/
c      common      /subpcc        /
       data
 1    modelt       / mxnsub*'nraph '          /
     end
```

```
 block data data
   implicit real*8 (a-h,o-z)
c*************************************************************
c
c    data - defines computational commons
c    (aaiv - zzend) computational values
c
c    the data statements in this routine are standardized
c
c*************************************************************
c
      include 'aaivc.inc'
      include 'atmosc.inc'
      include 'cycvc.inc'
      include 'dvivc.inc'
      include 'ephemc.inc'
      include 'infvc.inc'
      include 'motblc.inc'
      include 'pacvc.inc'
      include 'phzvc.inc'
      include 'planec.inc'
      include 'propdc.inc'
      include 'sensit.inc'
      include 'statec.inc'
      include 'tgovc.inc'
c
c*************************************************************
c
c *** computational data
c
c*************************************************************
c
c -------------------------------------------------
c       include  'aaivc.inc'
c -------------------------------------------------
c       common      /aaivc        /
        data
  1     iv(0)  /0      /
c
c *** common atmosc
c
   data alt/0.d0,11.019d0,20.063d0,32.162d0,47.350d0,52.43d0,61.59d0,
  +      80.d0,90.d0,100.d0,110.d0,120.d0,150.d0,160.d0,170.d0,
  +      190.d0,230.d0,300.d0,400.d0,500.d0,600.d0,700.d0,
  +      28*0.d0/
   data atms/1.225d0,1.01325d5,28.964d0,3.139d-7,2.87d2,7.12d0,
  +       0.d0,1.4d0,0.d0,0.d0/
   data tpt/288.1d0,216.65d0,216.25d0,228.65d0,270.65d0,270.65d0,
  +      252.65d0,180.65d0,180.65d0,210.65d0,260.65d0,360.65d0,
```

```
     +        960.65d0,1110.65d0,1210.65d0,1350.65d0,1550.65d0,
     +        1830.65d0,2160.65d0,2420.65d0,2590.65d0,2700.65d0,
     +        28*0.d0/
      data pres/1.d0,2.284d-1,5.462d-2,8.567d-3,1.095d-3,5.823d-4,
     +        1.797d-4,1.024d-5,1.622d-6,2.98d-7,7.22d-8,2.488d-8,
     +        5.0d-9,3.64d-9,2.756d-9,1.66d-9,6.869d-10,1.86d-10,
     +        3.977d-11,1.08d-11,3.4d-12,1.176d-12,28*0.d0/
      data wgt/9*28.964d0,28.88d0,28.56d0,28.07d0,26.92d0,26.66d0,
     +        26.5d0,25.85d0,24.69d0,22.66d0,19.94d0,17.94d0,16.84d0,
     +        16.17d0,28*0.d0/
c
c *** cycvc common
c
      data date / 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0/
      data dt / 1.0d+6/
      data dtime / 0.d0 /
      data dtimr / 1.d0, 19 * 0.d0 /
      data dt0 / 0.d0 /
      data juldat / 0.d0/
      data tdurp / 0.d0/
      data time / 0.d0/
      data timrb / 20 * 0.d0/
      data timrf / 20 * 0.d0/
      data tref / 0.d0/
      data trefp / 0.d0/
c
c *** dvivc common
c
      data dvx / 3*0.d0/
      data dvmag / 0.d0/
      data dvsum / 0.d0/
c
c *** ephemc common
c
      data gmu  / 1.327124419330078d+11
     m          ,2.203208080433758d+4
     v          ,3.248587705064894d+5
     e          ,3.986004850429589d+5
     m          ,4.282828685339965d+4
     j          ,1.266858077864550d+8
     s          ,3.792449009286876d+7
     u          ,5.802058945865924d+6
     n          ,6.850305659666957d+6
     p          ,4.423748064433594d+4
     m          ,4.9027927809d+3,12*0.d0
     z /
c
c   radius of the sphere of influence
c
```

```
      data rsoi / 1.000000000000d+11
     m        ,3.189878022841d+05
     v        ,1.458336566233d+06
     e        ,2.167226195872d+06
     a        ,1.563493250956d+06
     j        ,7.664078431145d+07
     s        ,9.399359395396d+07
     u        ,1.010084500916d+08
     n        ,1.677463630809d+08
     p        ,5.000000000000d+08
     m        ,6.6d+04,12*0.d0/
c
c   time radius of sphere of influence
c
      data tsoi / 1.00d+11
     m        ,2.00d+01
     v        ,2.00d+01
     e        ,2.00d+01
     a        ,2.00d+01
     j        ,7.00d+02
     s        ,7.00d+02
     u        ,7.00d+02
     n        ,7.00d+02
     p        ,2.00d+02
     m        ,0.5d0,12*0.d0/
c
c      semi-major axis time polynomial coefficients
c      of solar-system bodies
       data
     z  ((c(i,j,1),i=1,4),j=0,22)
     s        /4*0.d0
     m        ,5.790977169d+07   ,3*0.d0
     v        ,1.0820988790d+08  ,3*0.d0
     e        ,1.495998116d+08   ,3*0.d0
     a        ,2.279418963d+08   ,3*0.d0
     j     ,7.783076165d+08      ,3*0.d0
     s        ,1.429411131d+09   ,3*0.d0
     u        ,2.875072804d+09   ,-5.568
     $        ,2*0.d0
     n        ,4.504503336d+09   ,-24.89
     $        ,2*0.d0
     p        ,5.890213800d+09   ,3*0.d0
     m        ,3.843984402d+05   ,3*0.d0
     $        ,48*0.d0
     z        /
c      eccentricity time polynomial coefficients
c     of solar-system bodies
       data
     z  ((c(i,j,2),i=1,4),j=0,5)
```

```
     s          /4*0.d0
     m       ,.20563175          ,2.0406d-5
     $          ,-2.84d-8          ,-1.7d-10
     v          ,6.77188d-3          ,-4.7766d-5
     $          ,9.75d-8          ,4.4d-10
     e          ,.01670862          ,-4.2037d-5
     $          ,-1.236d-7          ,4.d-11
     a          ,.09340062          ,9.0483d-5
     $          ,-8.06d-8          ,-3.5d-10
     j          ,.04849485          ,1.63244d-4
     $          ,-4.719d-7          ,-1.97d-9
     z          /
        data
     z   ((c(i,j,2),i=1,4),j=6,22)
     s          /.05550862          ,-3.46818d-4
     $          ,-6.456d-7          ,3.38d-9
     u          ,.04629590          ,-2.7337d-5
     $          ,7.9d-8          ,2.5d-10
     n          ,8.98809d-3          ,6.408d-6
     $          ,-8.d-10          ,-5.d-11
     p          ,2.488033d-01                    ,3*0.d0
     m          ,5.4900489d-02                    ,3*0.d0
     z          ,48*0.d0
     z          /
c       inclination time polynomial coefficients
c       of solar-system bodies
        data
     z   ((c(i,j,3),i=1,4),j=0,5)
     s          /4*0.d0
     m          ,.122260070                ,-1.0387d-4
     $          ,1.414d-8                ,7.156d-10
     v          ,.05924803                ,-1.4954d-5
     $          ,-5.662d-7                ,1.75d-10
     d          ,0.d0                          ,-4.207828d-3
     $          ,7.0983d-7                ,-2.316d-8
     a          ,.0322838                ,-1.42208d-4
     $          ,-3.936d-7                ,-4.71d-10
     j          ,.02274635                ,-3.4683d-5
     $          ,5.791d-7                ,1.6d-9
     z          /
        data
     z   ((c(i,j,3),i=1,4),j=6,22)
     s          /.04343912                ,4.45321d-5
     $          ,-9.557d-7                ,3.14d-10
     u          ,.0134948                ,-2.94496d-5
     $          ,6.0912d-8                ,2.8d-10
     n          ,.03089149                ,3.9392d-6
     $          ,4.014d-9                ,0.d0
     p          ,2.996707636393978d-01                ,3*0.d0
```

```
     m          ,8.9804108d-02                        ,3*0.d0
     z          ,48*0.d0
     z          /
c       longitude of ascending node polynomial coefficients
c       of solar-system bodies
        data
     z   ((c(i,j,4),i=1,4),j=0,5)
     s          /4*0.d0
     m          ,.84353321          ,-2.189026d-3
     $          ,-1.5416d-6         ,-3.421d-9
     v          ,1.3383171          ,-4.852155d-3
     $          ,-2.4881d-6         ,-3.456d-9
     d          ,3.0521127          ,-4.207828d-3
     $          ,7.0983d-7          ,-2.316d-8
     a          ,.86495189          ,-5.44845d-3
     $          ,-1.11689d-5        ,-3.7402d-8
     j          ,1.753435277        ,3.083697d-3
     $          ,1.57755d-5         ,-1.277d-7
     z          /
        data
     z   ((c(i,j,4),i=1,4),j=6,22)
     s          /1.98383764         ,-4.47965d-3
     $          ,-3.2018d-6         ,6.23d-9
     u          ,1.291647441        ,1.29409d-3
     $          ,7.07556d-6         ,1.82d-9
     n          ,2.300065696        ,-1.07601d-4
     $          ,-3.82d-8           ,-1.36d-9
     p          ,1.914337511979504d+00    ,3*0.d0
     m          ,4.523601515d+00    ,-9.2422d-04
     $          ,3.6267d-05         ,3.4d-08
     z          ,48*0.d0
     z          /
c       argument of perigee polynomial coefficients
c       of solar-system bodies
        data
     z   ((c(i,j,5),i=1,4),j=0,5)
     s          /4*0.d0
     m          ,.50833109          ,4.961748d-3
     $          ,1.307d-6           ,4.102d-9
     v          ,.957902789         ,4.93706d-3
     $          ,-2.16379d-5        ,-8.961d-8
     d          ,-1.255517014       ,9.83749d-3
     $          ,1.91271d-6         ,3.1503d-8
     a          ,5.087672137        ,.0128958
     $          ,8.1458d-6          ,4.2638d-8
     j          ,-1.503306748       ,6.784042d-4
     $          ,-3.165154d-6       ,4.2621d-8
     z          /
        data
```

```
     z    ((c(i,j,5),i=1,4),j=6,22)
     s          /-.3596903           ,.0143678
     $          ,1.2419d-5           ,7.898d-8
     u          ,1.7278622           ,2.64845d-4
     $          ,-8.728d-6           ,5.39d-9
     n          ,-1.46014884         ,6.1652d-4
     $          ,1.2688d-6           ,9.6d-10
     p          ,1.995581715995208d+00   ,3*0.d0
     m          ,1.311550025d+00    ,2.868587d-03
     $          ,-2.16472d-04                  ,-2.43d-07
     z          ,48*0.d0
     z          /
c         mean anomaly polynomial coefficients
c         of solar-system bodies
          data
     z    ((c(i,j,6),i=1,4),j=0,5)
     s          /4*0.d0
     m          ,3.0[illegible]07445           ,2608.7875
     $          ,4.5691d-3           ,-6.46d-10
     v          ,.879926836          ,1021.32847
     $          ,2.415483d-5         ,9.303d-8
     d          ,-.043125323         ,628.3019552
     $          ,-2.72167d-6         ,-8.34d-9
     a          ,.3381233516         ,334.0534958
     $          ,3.06864d-6          ,-5.288d-9
     j          ,.3494179706         ,52.9653341
     $          ,-1.4094d-5          ,8.018d-8
     z          /
          data
     z    ((c(i,j,6),i=1,4),j=6,22)
     s          /-.7501305745        ,21.32002138
     $          ,-5.55102d-6         ,-8.554d-8
     u          ,2.461784222         ,7.476600918
     $          ,1.568d-6            ,-7.103d-9
     n          ,4.471969422         ,3.812794648
     $          ,-1.22d-6            ,3.7d-10
     p          ,5.265441408840871d+00   ,6.962635701795701d-05
     $          ,2*0.d0
     m          ,4.719966573d+00    ,2.29971481d-01
     $          ,-1.9774d-05         ,3.3d-08
     z          ,48*0.d0
     z          /
c
c         pole vector right ascension polynomial coefficients
c         of solar-system bodies
          data
     z    ((polev(i,j,1),i=1,4),j=0,22)
     s          /286.0193d0   ,3*0.d0
     m          ,280.86554d0                  ,-.03289d0
```

```
     $          ,.00001d0          ,0.d0
     v          ,98.02255d0        ,3*0.d0
     e          ,-1.3435d-6        ,-.6402780091d0
     $          ,-8.39481d-5       ,-5.0003d-6
     a          ,316.8538d0        ,-.0996d0
     $          ,2*0.d0
     j          ,268.0447d0        ,3*0.d0
     s          ,38.41314d0        ,3*0.d0
     u          ,76.761d0          ,3*0.d0
     n          ,295.5712d0        ,3*0.d0
     p          ,313.89136d0               ,3*0.d0
     z          ,52*0.d0
     z          /
c       pole vector declination polynomial coefficients
c       of solar-system bodies
        data
     z   ((polev(i,j,2),i=1,4),j=0,22)
     s          /63.7718d0         ,3*0.d0
     m          ,61.39767d0        ,-.00471d0
     $          ,.00001d0          ,0.d0
     v          ,-68.98877d0       ,3*0.d0
     e          ,89.999998317d0            ,-.5567500297d0
     $          ,1.185607d-4       ,1.16119d-5
     a          ,53.0066d0         ,-.0566d0
     $          ,2*0.d0
     j          ,64.5528d0         ,3*0.d0
     s          ,83.31049d0        ,3*0.d0
     u          ,14.920d0          ,3*0.d0
     n          ,41.46635d0        ,3*0.d0
     p          ,66.36420d0        ,3*0.d0
     z          ,52*90.d0
     z          /
c
c     pole vector "i'm not sure ... but it's needed!"
c
      data ((polev(i,j,3),i=1,4),j=0,22)
     s /60.38908d0,-.10213d0,.00003d0,0.d0,
     m  37.95923d0,-.09577d0,-.00008d0,0.d0,
     v  180.28229d0,.11043d0,.00062d0,0.d0,
     e  89.9999986565d0,-.6402781d0,-3.042075d-4,-5.0837d-6,
     a  43.34526d0,-.09181d0,.0001d0,0.d0,
     j  317.92374d0,.08006d0,-.00019d0,0.d0,
     s  46.0629d0,.01624d0,-.00010d0,0.d0,
     u  6.05795d0,.00182d0,-.00004d0,0.d0,
     n  17.21185d0,.00078d0,-.00002d0,0.d0,
     p  69.13587d0,0.d0,0.d0,0.d0,
     $  52*0.d0/
c
c *** infvc common
```

```
c
      data esnprt / 0.d0 /
      data pinc, pinctm / 1.0d+6, 0.d0/
      data prnc, prnctm /-1.d0, 0.d0 /
c
c ---------------------------------------------------
c       include  'motblc.inc'
c ---------------------------------------------------
c       common     /motblc      /
c       motblc is initialized in subroutine nomtab
        data
     $   thrstt(1)     /0.     /
c
c *** pacvc common
c
      data pacav / 3*0.d0/
c
c ---------------------------------------------------
c       include  'phzvc.inc'
c ---------------------------------------------------
c       common     /phzvc       /
        data
     $   maxtim     /1000.       /
c
c *** common planec
c
      data altatm / 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0,
     $          0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0,
     $          0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0, 0.d0 /
      data gj2 /0.d0,.0001d0,0.d0,.00108263d0,.0019628d0,.014733d0,
     $     .01664d0,.023d0,0.d0,0.d0,.00021d0,12*0.d0/
      data re /696000.d0,2439.d0,6052.d0,6378.14d0,3397.2d0,71398.d0,
     $     60000.d0,25400.d0,24300.d0,1500.d0,1738.09d0,12*0.d0/
c
      data thedot /2.86533d-6,1.240012d-6,2.992369d-7,7.292116d-5,
     $        7.088218d-5,1.758532d-4,1.63785d-4,1.012372d-4,
     $        9.469017d-5,1.138585d-5,13*0.d0/
c
c
c - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
c    common propdc
c
      data bthrst / 1.d0,2*0.d0 /
      data cd    / 0.d0 /
      data cl    / 0.d0 /
      data fbody  / 2*0.d0/
      data fraci  / 0.d0 /
      data frac   / 0.d0 /
      data go    /9.80665d-3/
```

```
      data pdump  / 0.d0  /
      data pitch0 / 0.d0 /
      data pitch1 / 0.d0 /
      data pitch2 / 0.d0 /
      data prpdat / 20*0.d0 /
      data pscale / 1.d0 /
      data rect   / .01d0 /
      data roll0  / 0.d0 /
      data roll1  / 0.d0 /
      data roll2  / 0.d0 /
      data scdrag / 3*0.d0/
      data scmass / 1.d6 /
      data scsfa  / 3*0.d0/
      data sfc    / 1.024d17/
      data spi    / 1.d6/
      data step   / 0.d0 /
      data thrust / 1.d6  /
      data thl0   / 1.d0 /
      data thl1   / 0.d0 /
      data thl2   / 0.d0 /
      data wjett  / 0.d0 /
      data wjettm / 0.d0 /
      data wprop  / 1.d6 /
      data yaw0   / 0.d0 /
      data yaw1   / 0.d0 /
      data yaw2   / 0.d0 /
c
c *** sensit common
c
      data pertsj / 2*1.d-6 /
c
c *** statec common
c
      data x / 6*0.d0/
      data x1 / 6*0.d0/
c
c
c *** tgovc common
c
      data fuxn  /6hfuxn1 ,6hfuxn2 ,6hfuxn3 ,6hfuxn4 ,6hfuxn5 ,
     $           6hfuxn6 ,6hfuxn7 ,6hfuxn8 ,6hfuxn9 ,6hfuxn10/
c
      data tgo   /6htgo    /
      data timemn/6htimemn /
      data timx  /6htimx   /
c
      end
```

```
      block data data1
      implicit integer (a-z)
c*************************************************
c
c     data1 - defines computational commons
c     (aaiv - zzend) computational values
c
c     the data statements in this routine are standardized
c
c*************************************************
c
      include 'collonc.inc'
      include 'cycnc.inc'
      include 'ephejc.inc'
      include 'infv1c.inc'
      include 'mnvrjc.inc'
      include 'phznc.inc'
      include 'propjc.inc'
      include 'statnc.inc'
      include 'tgonc.inc'
      include 'zzendc.inc'

c       common  /collonc/
      data nsegph /1/
      data nsgph0 /0/
      data nsgpwd /-1/
      data nsgpwi /-1/

c       common  /collocc/
      data cointp / 'linear'/

c       common     /cycnc         /
        data
    1    jevt   /0      /
c *** cyccc common
c
     data iepoch / 'julian'/
     data iprop / '1step'/
c
c *** ephecc common
c
      data kernel /'/home/clarkent/pephem/leapseconds.ker',
     $            '/home/clarkent/pephem/p_constants.ker'/
      data pefile /'condensed'/
      data planet /'sun     ',
     m            'mercury ',
     v            'venus   ',
     e            'earth   ',
     m            'mars    ',
```

```
     j          'jupiter ',
     s          'saturn  ',
     u          'uranus  ',
     n          'neptune ',
     p          'pluto   ',
     m          'moon    ',
     @          '        ','        ','        ',
     @          '        ','        ','        ',
     @          '        ','        ','        ',
     @          '        ','        ','        '/
      data ref   /'b1950'/
      data spk    /'/home/clarkent/pephem/de130.bsp',9*'none'/
c
c *** infv1c common
c
      data title / ' '/
      data fid   / 'ipost file i.d. 0000'/
      data sfid  / ':'/
c
c *** mnvrjc common
c
      data ilnch /0/
c
c *** mnvrcc common
c
      data mantyp /'none'/
c
c *** phznc common
c
      data inff / 0/
      data ipif / 1/
c
c *** propjc common
c
      data idt    / 1 /
      data icoord / 1 /
      data itabsz /22 /
      data npert  / 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0/
      data iforce / 0,0,0,0,0 /
      data iatmos / 1 /
      data jett   / 0 /
c
c *** propcc common
c
      data massfi / 'none' /
c
c *** statnc common
c
      data idbody / 0/
```

```
      data ipbody / 0,3/
      data ibody /0000,0001,0002,0003,0004,0005,0006,0007,0008,0009,
     +        0103,12*0/
      data jplbdy/10,1,2,399,499,599,699,799,899,999,301,12*0/
      data jpbody/-1/
c
c    statcc common
c
      data idfram / 'ecliptic', 'mean2000'/
      data inputx / 'none'/
c
c
c ---------------------------------------------------------------------
c       include  'tgonc.inc'
c ---------------------------------------------------------------------
c       common     /tgonc        /
        data
     1   nxevt       /0     /
c
c ---------------------------------------------------------------------
c       include  'zzendc.inc'
c ---------------------------------------------------------------------
c       common     /zzendc       /
        data
     1   end   /0.    /
c
      end
```

```
      block data dict
       implicit real*8 (a-h,o-z)
c**********************************************************************
c
c     dict - defines computational commons
c     (aaiv - zzend) dictionary values data
c
c     the data statements in this routine are standarized.
c
c**********************************************************************
c
       include 'aaivd.inc'
       include 'atmosd.inc'
       include 'cycvd.inc'
       include 'dvivd.inc'
       include 'ephemd.inc'
       include 'infvd.inc'
       include 'motbld.inc'
       include 'pacvd.inc'
       include 'phzvd.inc'
       include 'planed.inc'
       include 'propdd.inc'
       include 'sensid.inc'
       include 'stated.inc'
       include 'tgovd.inc'
c
c**********************************************************************
c
c *** commons not included in dictionary
c
c**********************************************************************
c
c     none.
c
c**********************************************************************
c
c *** computational data dictionary
c
c**********************************************************************
c
c *** aaivd common
c
      data vi   /6hvi0  ,6hvi1  ,6hvi2  /
c
c *** atmosd common
c
      data alt  /6halt1 ,6halt2 ,6halt3 ,6halt4 ,6halt5 ,
     +           6halt6 ,6halt7 ,6halt8 ,6halt9 ,6halt10,
     +           6halt11,6halt12,6halt13,6halt14,6halt15,
```

```
     +        6halt16 ,6halt17 ,6halt18 ,6halt19 ,6halt20 ,
     +        6halt21 ,6halt22 ,6halt23 ,6halt24 ,6halt25 ,
     +        6halt26 ,6halt27 ,6halt28 ,6halt29 ,6halt30 ,
     +        6halt31 ,6halt32 ,6halt33 ,6halt34 ,6halt35 ,
     +        6halt36 ,6halt37 ,6halt38 ,6halt39 ,6halt40 ,
     +        6halt41 ,6halt42 ,6halt43 ,6halt44 ,6halt45 ,
     +        6halt46 ,6halt47 ,6halt48 ,6halt49 ,6halt50 /
      data pres  /6hpres1 ,6hpres2 ,6hpres3 ,6hpres4 ,6hpres5 ,
     +        6hpres6 ,6hpres7 ,6hpres8 ,6hpres9 ,6hpres10,
     +        6hpres11,6hpres12,6hpres13,6hpres14,6hpres15,
     +        6hpres16,6hpres17,6hpres18,6hpres19,6hpres20,
     +        6hpres21,6hpres22,6hpres23,6hpres24,6hpres25,
     +        6hpres26,6hpres27,6hpres28,6hpres29,6hpres30,
     +        6hpres31,6hpres32,6hpres33,6hpres34,6hpres35,
     +        6hpres36,6hpres37,6hpres38,6hpres39,6hpres40,
     +        6hpres41,6hpres42,6hpres43,6hpres44,6hpres45,
     +        6hpres46,6hpres47,6hpres48,6hpres49,6hpres50 /
      data tpt  /6htpt1  ,6htpt2  ,6htpt3  ,6htpt4  ,6htpt5  ,
     +        6htpt6  ,6htpt7  ,6htpt8  ,6htpt9  ,6htpt10 ,
     +        6htpt11 ,6htpt12 ,6htpt13 ,6htpt14 ,6htpt15 ,
     +        6htpt16 ,6htpt17 ,6htpt18 ,6htpt19 ,6htpt20 ,
     +        6htpt21 ,6htpt22 ,6htpt23 ,6htpt24 ,6htpt25 ,
     +        6htpt26 ,6htpt27 ,6htpt28 ,6htpt29 ,6htpt30 ,
     +        6htpt31 ,6htpt32 ,6htpt33 ,6htpt34 ,6htpt35 ,
     +        6htpt36 ,6htpt37 ,6htpt38 ,6htpt39 ,6htpt40 ,
     +        6htpt41 ,6htpt42 ,6htpt43 ,6htpt44 ,6htpt45 ,
     +        6htpt46 ,6htpt47 ,6htpt48 ,6htpt49 ,6htpt50 /
      data wgt  /6hwgt1  ,6hwgt2  ,6hwgt3  ,6hwgt4  ,6hwgt5  ,
     +        6hwgt6  ,6hwgt7  ,6hwgt8  ,6hwgt9  ,6hwgt10 ,
     +        6hwgt11 ,6hwgt12 ,6hwgt13 ,6hwgt14 ,6hwgt15 ,
     +        6hwgt16 ,6hwgt17 ,6hwgt18 ,6hwgt19 ,6hwgt20 ,
     +        6hwgt21 ,6hwgt22 ,6hwgt23 ,6hwgt24 ,6hwgt25 ,
     +        6hwgt26 ,6hwgt27 ,6hwgt28 ,6hwgt29 ,6hwgt30 ,
     +        6hwgt31 ,6hwgt32 ,6hwgt33 ,6hwgt34 ,6hwgt35 ,
     +        6hwgt36 ,6hwgt37 ,6hwgt38 ,6hwgt39 ,6hwgt40 ,
     +        6hwgt41 ,6hwgt42 ,6hwgt43 ,6hwgt44 ,6hwgt45 ,
     +        6hwgt46 ,6hwgt47 ,6hwgt48 ,6hwgt49 ,6hwgt50 /
      data atms  /6hatms1 ,6hatms2 ,6hatms3 ,6hatms4 ,6hatms5 ,
     +        6hatms6 ,6hatms7 ,6hatms8 ,6hatms9 ,6hatms10/
c
c *** cycvd common
c
      data date
     1 /6hyear  ,6hmonth ,6hday   ,6hhour  ,6hminute,6hsecond/
      data dt  /6hdt   /
      data dtime /6hdtime /
      data dtimr /6hdtimr1,6hdtimr2,6hdtimr3,6hdtimr4,6hdtimr5,
     +        6hdtimr6,6hdtimr7,6hdtimr8,6hdtimr9,6hdtim10,
     +        6hdtim11,6hdtim12,6hdtim13,6hdtim14,6hdtim15,
```

```
+        6hdtim16,6hdtim17,6hdtim18,6hdtim19,6hdtim20/
      data dt0  /6hdt0  /
      data juldat/6hjuldat/
      data tdurp /6htdurp /
      data time  /6htime  /
      data timrb /6htimrb1,6htimrb2,6htimrb3,6htimrb4,6htimrb5,
+        6htimrb6,6htimrb7,6htimrb8,6htimrb9,6htimb10,
+        6htimb11,6htimb12,6htimb13,6htimb14,6htimb15,
+        6htimb16,6htimb17,6htimb18,6htimb19,6htimb20/
      data timrf /6htimrf1,6htimrf2,6htimrf3,6htimrf4,6htimrf5,
+        6htimrf6,6htimrf7,6htimrf8,6htimrf9,6htimf10,
+        6htimf11,6htimf12,6htimf13,6htimf14,6htimf15,
+        6htimf16,6htimf17,6htimf18,6htimf19,6htimf20/
      data tref  /6htref  /
      data trefp /6htrefp /
c
c *** dvivd common
c
      data dvx   /6hdvx   ,6hdvy   ,6hdvz   /
      data dvmag /6hdvmag /
      data dvsum /6hdvsum /
c
c *** ephemd common
c
      data gmu   /6hgmu0  ,6hgmu1  ,6hgmu2  ,6hgmu3  ,6hgmu4  ,
+        6hgmu5  ,6hgmu6  ,6hgmu7  ,6hgmu8  ,6hgmu9  ,
+        6hgmu10 ,6hgmu11 ,6hgmu12 ,6hgmu13 ,6hgmu14 ,
+        6hgmu15 ,6hgmu16 ,6hgmu17 ,6hgmu18 ,6hgmu19 ,
+        6hgmu20 ,6hgmu21 ,6hgmu22 /
c
      data rsoi  /6hrsoi0 ,6hrsoi1 ,6hrsoi2 ,6hrsoi3 ,6hrsoi4 ,
+        6hrsoi5 ,6hrsoi6 ,6hrsoi7 ,6hrsoi8 ,6hrsoi9 ,
+        6hrsoi10,6hrsoi11,6hrsoi12,6hrsoi13,6hrsoi14,
+        6hrsoi15,6hrsoi16,6hrsoi17,6hrsoi18,6hrsoi19,
+        6hrsoi20,6hrsoi21,6hrsoi22/
c
      data tsoi  /6htsoi0 ,6htsoi1 ,6htsoi2 ,6htsoi3 ,6htsoi4 ,
+        6htsoi5 ,6htsoi6 ,6htsoi7 ,6htsoi8 ,6htsoi9 ,
+        6htsoi10,6htsoi11,6htsoi12,6htsoi13,6htsoi14,
+        6htsoi15,6htsoi16,6htsoi17,6htsoi18,6htsoi19,
+        6htsoi20,6htsoi21,6htsoi22/
c
      data (elem(i),i=1,50)
+        /6helem1 ,6helem2 ,6helem3 ,6helem4 ,6helem5 ,
+        6helem6 ,6helem7 ,6helem8 ,6helem9 ,6helem10,
+        6helem11,6helem12,6helem13,6helem14,6helem15,
+        6helem16,6helem17,6helem18,6helem19,6helem20,
+        6helem21,6helem22,6helem23,6helem24,6helem25,
+        6helem26,6helem27,6helem28,6helem29,6helem30,
```

```
+         6helem31,6helem32,6helem33,6helem34,6helem35,
+         6helem36,6helem37,6helem38,6helem39,6helem40,
+         6helem41,6helem42,6helem43,6helem44,6helem45,
+         6helem46,6helem47,6helem48,6helem49,6helem50/
 data (elem(i),i=51,100)
+        /6helem51,6helem52,6helem53,6helem54,6helem55,
+         6helem56,6helem57,6helem58,6helem59,6helem60,
+         6helem61,6helem62,6helem63,6helem64,6helem65,
+         6helem66,6helem67,6helem68,6helem69,6helem70,
+         6helem71,6helem72,6helem73,6helem74,6helem75,
+         6helem76,6helem77,6helem78,6helem79,6helem80,
+         6helem81,6helem82,6helem83,6helem84,6helem85,
+         6helem86,6helem87,6helem88,6helem89,6helem90,
+         6helem91,6helem92,6helem93,6helem94,6helem95,
+         6helem96,6helem97,6helem98,6helem99,6hele100/
 data (elem(i),i=101,150)
+        /6hele101,6hele102,6hele103,6hele104,6hele105,
+         6hele106,6hele107,6hele108,6hele109,6hele110,
+         6hele111,6hele112,6hele113,6hele114,6hele115,
+         6hele116,6hele117,6hele118,6hele119,6hele120,
+         6hele121,6hele122,6hele123,6hele124,6hele125,
+         6hele126,6hele127,6hele128,6hele129,6hele130,
+         6hele131,6hele132,6hele133,6hele134,6hele135,
+         6hele136,6hele137,6hele138,6hele139,6hele140,
+         6hele141,6hele142,6hele143,6hele144,6hele145,
+         6hele146,6hele147,6hele148,6hele149,6hele150/
 data (elem(i),i=151,200)
+        /6hele151,6hele152,6hele153,6hele154,6hele155,
+         6hele156,6hele157,6hele158,6hele159,6hele160,
+         6hele161,6hele162,6hele163,6hele164,6hele165,
+         6hele166,6hele167,6hele168,6hele169,6hele170,
+         6hele171,6hele172,6hele173,6hele174,6hele175,
+         6hele176,6hele177,6hele178,6hele179,6hele180,
+         6hele181,6hele182,6hele183,6hele184,6hele185,
+         6hele186,6hele187,6hele188,6hele189,6hele190,
+         6hele191,6hele192,6hele193,6hele194,6hele195,
+         6hele196,6hele197,6hele198,6hele199,6hele200/
 data (elem(i),i=201,250)
+        /6hele201,6hele202,6hele203,6hele204,6hele205,
+         6hele206,6hele207,6hele208,6hele209,6hele210,
+         6hele211,6hele212,6hele213,6hele214,6hele215,
+         6hele216,6hele217,6hele218,6hele219,6hele220,
+         6hele221,6hele222,6hele223,6hele224,6hele225,
+         6hele226,6hele227,6hele228,6hele229,6hele230,
+         6hele231,6hele232,6hele233,6hele234,6hele235,
+         6hele236,6hele237,6hele238,6hele239,6hele240,
+         6hele241,6hele242,6hele243,6hele244,6hele245,
+         6hele246,6hele247,6hele248,6hele249,6hele250/
 data (elem(i),i=251,300)
```

```
+       /6hele251,6hele252,6hele253,6hele254,6hele255,
+        6hele256,6hele257,6hele258,6hele259,6hele260,
+        6hele261,6hele262,6hele263,6hele264,6hele265,
+        6hele266,6hele267,6hele268,6hele269,6hele270,
+        6hele271,6hele272,6hele273,6hele274,6hele275,
+        6hele276,6hele277,6hele278,6hele279,6hele280,
+        6hele281,6hele282,6hele283,6hele284,6hele285,
+        6hele286,6hele287,6hele288,6hele289,6hele290,
+        6hele291,6hele292,6hele293,6hele294,6hele295,
+        6hele296,6hele297,6hele298,6hele299,6hele300/
 data (elem(i),i=301,350)
+       /6hele301,6hele302,6hele303,6hele304,6hele305,
+        6hele306,6hele307,6hele308,6hele309,6hele310,
+        6hele311,6hele312,6hele313,6hele314,6hele315,
+        6hele316,6hele317,6hele318,6hele319,6hele320,
+        6hele321,6hele322,6hele323,6hele324,6hele325,
+        6hele326,6hele327,6hele328,6hele329,6hele330,
+        6hele331,6hele332,6hele333,6hele334,6hele335,
+        6hele336,6hele337,6hele338,6hele339,6hele340,
+        6hele341,6hele342,6hele343,6hele344,6hele345,
+        6hele346,6hele347,6hele348,6hele349,6hele350/
 data (elem(i),i=351,400)
+       /6hele351,6hele352,6hele353,6hele354,6hele355,
+        6hele356,6hele357,6hele358,6hele359,6hele360,
+        6hele361,6hele362,6hele363,6hele364,6hele365,
+        6hele366,6hele367,6hele368,6hele369,6hele370,
+        6hele371,6hele372,6hele373,6hele374,6hele375,
+        6hele376,6hele377,6hele378,6hele379,6hele380,
+        6hele381,6hele382,6hele383,6hele384,6hele385,
+        6hele386,6hele387,6hele388,6hele389,6hele390,
+        6hele391,6hele392,6hele393,6hele394,6hele395,
+        6hele396,6hele397,6hele398,6hele399,6hele400/
 data (elem(i),i=401,450)
+       /6hele401,6hele402,6hele403,6hele404,6hele405,
+        6hele406,6hele407,6hele408,6hele409,6hele410,
+        6hele411,6hele412,6hele413,6hele414,6hele415,
+        6hele416,6hele417,6hele418,6hele419,6hele420,
+        6hele421,6hele422,6hele423,6hele424,6hele425,
+        6hele426,6hele427,6hele428,6hele429,6hele430,
+        6hele431,6hele432,6hele433,6hele434,6hele435,
+        6hele436,6hele437,6hele438,6hele439,6hele440,
+        6hele441,6hele442,6hele443,6hele444,6hele445,
+        6hele446,6hele447,6hele448,6hele449,6hele450/
 data (elem(i),i=451,500)
+       /6hele451,6hele452,6hele453,6hele454,6hele455,
+        6hele456,6hele457,6hele458,6hele459,6hele460,
+        6hele461,6hele462,6hele463,6hele464,6hele465,
+        6hele466,6hele467,6hele468,6hele469,6hele470,
+        6hele471,6hele472,6hele473,6hele474,6hele475,
```

```
     +        6hele476,6hele477,6hele478,6hele479,6hele480,
     +        6hele481,6hele482,6hele483,6hele484,6hele485,
     +        6hele486,6hele487,6hele488,6hele489,6hele490,
     +        6hele491,6hele492,6hele493,6hele494,6hele495,
     +        6hele496,6hele497,6hele498,6hele499,6hele500/
      data (elem(i),i=501,550)
     +       /6hele501,6hele502,6hele503,6hele504,6hele505,
     +        6hele506,6hele507,6hele508,6hele509,6hele510,
     +        6hele511,6hele512,6hele513,6hele514,6hele515,
     +        6hele516,6hele517,6hele518,6hele519,6hele520,
     +        6hele521,6hele522,6hele523,6hele524,6hele525,
     +        6hele526,6hele527,6hele528,6hele529,6hele530,
     +        6hele531,6hele532,6hele533,6hele534,6hele535,
     +        6hele536,6hele537,6hele538,6hele539,6hele540,
     +        6hele541,6hele542,6hele543,6hele544,6hele545,
     +        6hele546,6hele547,6hele548,6hele549,6hele550/
      data (elem(i),i=551,552)
     +       /6hele551,6hele552/
c
      data (pole(i),i=1,50)
     +       /6hpole1 ,6hpole2 ,6hpole3 ,6hpole4 ,6hpole5 ,
     +        6hpole6 ,6hpole7 ,6hpole8 ,6hpole9 ,6hpole10,
     +        6hpole11,6hpole12,6hpole13,6hpole14,6hpole15,
     +        6hpole16,6hpole17,6hpole18,6hpole19,6hpole20,
     +        6hpole21,6hpole22,6hpole23,6hpole24,6hpole25,
     +        6hpole26,6hpole27,6hpole28,6hpole29,6hpole30,
     +        6hpole31,6hpole32,6hpole33,6hpole34,6hpole35,
     +        6hpole36,6hpole37,6hpole38,6hpole39,6hpole40,
     +        6hpole41,6hpole42,6hpole43,6hpole44,6hpole45,
     +        6hpole46,6hpoie47,6hpole48,6hpole49,6hpole50/
      data (pole(i),i=51,100)
     +       /6hpole51,6hpole52,6hpole53,6hpole54,6hpole55,
     +        6hpole56,6hpole57,6hpole58,6hpole59,6hpole60,
     +        6hpole61,6hpole62,6hpole63,6hpole64,6hpole65,
     +        6hpole66,6hpole67,6hpole68,6hpole69,6hpole70,
     +        6hpole71,6hpole72,6hpole73,6hpole74,6hpole75,
     +        6hpole76,6hpole77,6hpole78,6hpole79,6hpole80,
     +        6hpole81,6hpole82,6hpole83,6hpole84,6hpole85,
     +        6hpole86,6hpole87,6hpole88,6hpole89,6hpole90,
     +        6hpole91,6hpole92,6hpole93,6hpole94,6hpole95,
     +        6hpole96,6hpole97,6hpole98,6hpole99,6hpol100/
      data (pole(i),i=101,150)
     +       /6hpol101,6hpol102,6hpol103,6hpol104,6hpol105,
     +        6hpol106,6hpol107,6hpol108,6hpol109,6hpol110,
     +        6hpol111,6hpol112,6hpol113,6hpol114,6hpol115,
     +        6hpol116,6hpol117,6hpol118,6hpol119,6hpol120,
     +        6hpol121,6hpol122,6hpol123,6hpol124,6hpol125,
     +        6hpol126,6hpol127,6hpol128,6hpol129,6hpol130,
     +        6hpol131,6hpol132,6hpol133,6hpol134,6hpol135,
```

```
     +        6hpol136,6hpol137,6hpol138,6hpol139,6hpol140,
     +        6hpol141,6hpol142,6hpol143,6hpol144,6hpol145,
     +        6hpol146,6hpol147,6hpol148,6hpol149,6hpol150/
      data (pole(i),i=151,200)
     +       /6hpol151,6hpol152,6hpol153,6hpol154,6hpol155,
     +        6hpol156,6hpol157,6hpol158,6hpol159,6hpol160,
     +        6hpol161,6hpol162,6hpol163,6hpol164,6hpol165,
     +        6hpol166,6hpol167,6hpol168,6hpol169,6hpol170,
     +        6hpol171,6hpol172,6hpol173,6hpol174,6hpol175,
     +        6hpol176,6hpol177,6hpol178,6hpol179,6hpol180,
     +        6hpol181,6hpol182,6hpol183,6hpol184,6hpol185,
     +        6hpol186,6hpol187,6hpol188,6hpol189,6hpol190,
     +        6hpol191,6hpol192,6hpol193,6hpol194,6hpol195,
     +        6hpol196,6hpol197,6hpol198,6hpol199,6hpol200/
      data (pole(i),i=201,250)
     +       /6hpol201,6hpol202,6hpol203,6hpol204,6hpol205,
     +        6hpol206,6hpol207,6hpol208,6hpol209,6hpol210,
     +        6hpol211,6hpol212,6hpol213,6hpol214,6hpol215,
     +        6hpol216,6hpol217,6hpol218,6hpol219,6hpol220,
     +        6hpol221,6hpol222,6hpol223,6hpol224,6hpol225,
     +        6hpol226,6hpol227,6hpol228,6hpol229,6hpol230,
     +        6hpol231,6hpol232,6hpol233,6hpol234,6hpol235,
     +        6hpol236,6hpol237,6hpol238,6hpol239,6hpol240,
     +        6hpol241,6hpol242,6hpol243,6hpol244,6hpol245,
     +        6hpol246,6hpol247,6hpol248,6hpol249,6hpol250/
      data (pole(i),i=251,276)
     +       /6hpol251,6hpol252,6hpol253,6hpol254,6hpol255,
     +        6hpol256,6hpol257,6hpol258,6hpol259,6hpol260,
     +        6hpol261,6hpol262,6hpol263,6hpol264,6hpol265,
     +        6hpol266,6hpol267,6hpol268,6hpol269,6hpol270,
     +        6hpol271,6hpol272,6hpol273,6hpol274,6hpol275,
     +        6hpol276/
c
c *** infvd common
c
      data esnprt / 6hesnprt/
      data pinc, pinctm / 6hpinc  ,6hpinctm/
      data prnc, prnctm / 6hprnc  ,6hprnctm/
c
c *** motbld common
c
      data thrstt / 6hthrstt/
      data cdt    / 6hcdt   /
      data clt    / 6hclt   /
      data fmasit / 6hfmasit/
      data fmasst / 6hfmasst/
      data smasst / 6hsmasst/
c
c -----------------------------------------------
```

```
c      include 'pacvd.inc'
c -------------------------------------------------------
c      common pacvd
       data
   1    pacav        /6hpacavx,6hpacavy,6hpacavz/
c
c *** phzvd common
c
      data maxtim/6hmaxtim/
      data tcpmax/6htcpmax/
c
c *** planed common
c
     data altatm/6haltat0,6haltat1,6haltat2,6haltat3,6haltat4,
    +         6haltat5,6haltat6,6haltat7,6haltat8,6haltat9,
    +         6halta10,6halta11,6halta12,6halta13,6halta14,
    +         6halta15,6halta16,6halta17,6halta18,6halta19,
    +         6halta20,6halta21,6halta22/
     data gj2  /6hgj20 ,6hgj21 ,6hgj22 ,6hgj23 ,6hgj24 ,
    +         6hgj25 ,6hgj26 ,6hgj27 ,6hgj28 ,6hgj29 ,
    +         6hgj210 ,6hgj211 ,6hgj212 ,6hgj213 ,6hgj214 ,
    +         6hgj215 ,6hgj216 ,6hgj217 ,6hgj218 ,6hgj219 ,
    +         6hgj220 ,6hgj221 ,6hgj222 /
     data re   /6hre0  ,6hre1  ,6hre2  ,6hre3  ,6hre4  ,
    +         6hre5  ,6hre6  ,6hre7  ,6hre8  ,6hre9  ,
    +         6hre10 ,6hre11 ,6hre12 ,6hre13 ,6hre14 ,
    +         6hre15 ,6hre16 ,6hre17 ,6hre18 ,6hre19 ,
    +         6hre20 ,6hre21 ,6hre22 /
     data thedot/6hthdt0 ,6hthdt1 ,6hthdt2 ,6hthdt3 ,6hthdt4 ,
    +         6hthdt5 ,6hthdt6 ,6hthdt7 ,6hthdt8 ,6hthdt9 ,
    +         6hthdt10,6hthdt11,6hthdt12,6hthdt13,6hthdt14,
    +         6hthdt15,6hthdt16,6hthdt17,6hthdt18,6hthdt19,
    +         6hthdt20,6hthdt21,6hthdt22/
c
c *** propdd common
c
      data bthrst /6hbthrs1,6hbthrs2,6hbthrs3/
      data cd    /6hcd   /
      data cl    /6hcl   /
      data fbody /6hfbody1,6hfbody2/
      data fraci /6hfraci /
      data frac  /6hfrac  /
      data go    /6hgo    /
      data pdump /6hpdump /
      data pitch0 /6hpitch0/
      data pitch1 /6hpitch1/
      data pitch2 /6hpitch2/
      data pt    /6hpitch /
      data prpdat /6hprpd1 ,6hprpd2 ,6hprpd3 ,6hprpd4 ,6hprpd5 ,
```

```
     +        6hprpd6 ,6hprpd7 ,6hprpd8 ,6hprpd9 ,6hprpd10,
     +        6hprpd11,6hprpd12,6hprpd13,6hprpd14,6hprpd15,
     +        6hprpd16,6hprpd17,6hprpd18,6hprpd19,6hprpd20/
      data pscale /6hpscale/
      data rect  /6hrect  /
      data rl    /6hroll  /
      data roll0  /6hroll0 /
      data roll1  /6hroll1 /
      data roll2  /6hroll2 /
      data rosc  /6hrosc  /
      data scdrag /6hscdrg1,6hscdrg2,6hscdrg3/
      data scmass /6hscmass/
      data scsfa  /6hscsfa1,6hscsfa2,6hscsfa3/
      data sfc   /6hsfc   /
      data spi   /6hspi   /
      data step  /6hstep  /
      data thrust /6hthrust/
      data thl0  /6hthl0  /
      data thl1  /6hthl1  /
      data thl2  /6hthl2  /
      data tprev  /6htprev /
      data wjett  /6hwjett /
      data wjettm /6hwjettm/
      data wprop  /6hwprop /
      data xosc   /6hxosc1 ,6hxosc2 ,6hxosc3 ,6hxosc4 ,6hxosc5 ,
     +        6hxosc6 /
      data xtrue  /6hxtru1 ,6hxtru2 ,6hxtru3 ,6hxtru4 ,6hxtru5 ,
     +        6hxtru6 ,6hxtru7 ,6hxtru8 ,6hxtru9 ,6hxtru10,
     +        6hxtru11,6hxtru12,6hxtru13,6hxtru14,6hxtru15,
     +        6hxtru16,6hxtru17,6hxtru18,6hxtru19,6hxtru20,
     +        6hxtru21,6hxtru22,6hxtru23,6hxtru24,6hxtru25,
     +        6hxtru26,6hxtru27,6hxtru28,6hxtru29,6hxtru30,
     +        6hxtru31,6hxtru32,6hxtru33,6hxtru34,6hxtru35,
     +        6hxtru36,6hxtru37,6hxtru38,6hxtru39,6hxtru40,
     +        6hxtru41,6hxtru42/
      data yaw0  /6hyaw0  /
      data yaw1  /6hyaw1  /
      data yaw2  /6hyaw2  /
      data yw    /6hyaw   /
c
c *** sensid common
c
      data delta /6hdlt11 ,6hdlt12 ,6hdlt13 ,6hdlt14 ,6hdlt15 ,
     +        6hdlt16 ,6hdlt17 ,6hdlt18 ,6hdlt19 ,6hdlt110,
     +        6hdlt21 ,6hdlt22 ,6hdlt23 ,6hdlt24 ,6hdlt25 ,
     +        6hdlt26 ,6hdlt27 ,6hdlt28 ,6hdlt29 ,6hdlt210,
     +        6hdlt31 ,6hdlt32 ,6hdlt33 ,6hdlt34 ,6hdlt35 ,
     +        6hdlt36 ,6hdlt37 ,6hdlt38 ,6hdlt39 ,6hdlt310/
c
```

```
      data epst /6hepst /
c
      data exvel /6hexvl1 ,6hexvl2 ,6hexvl3 ,6hexvl4 ,6hexvl5 ,
     +        6hexvl6 ,6hexvl7 ,6hexvl8 ,6hexvl9 ,6hexvl10/
c
      data wmass
     1 /6hwmass1,6hwmass2,6hwmass3,6hwmass4,6hwmass5
     2 ,6hwmass6,6hwmass7,6hwmass8,6hwmass9,6hwmas10
     z /
c
c *** stated common
c
      data orbp /
     1   6hsma   , 6heccen , 6hinc   , 6hanlong, 6hargp  ,
     2   6hmeaan , 6htruan , 6hrperi , 6hvperi , 6htfp   ,
     3   6hrapoap, 6hperiod, 6hradius, 6hspeed , 6hbtheti,
     4   6hvinfxi, 6hvinfyi, 6hvinfzi, 6hbdti  , 6hbdri  ,
     5   6hhypta , 6hc3i   , 6hrai   , 6hdeci  , 6hbtheto,
     6   6hvinfxo, 6hvinfyo, 6hvinfzo, 6hbdto  , 6hbdro  ,
     7   6hhypta , 6hc3o   , 6hrao   , 6hdeco  , 6hfpa   ,
     6   6haltit , 6hlongp , 6hlat   , 6hlong  , 6hb     /
c
      data soi  /6hsoi  /
      data ti   /6hti   /
      data tf   /6htf   /
c
      data x    /5hx    ,5hy    ,5hz    ,5hvx   ,5hvy   ,5hvz   /
      data xeq  /5hxeq  ,5hyeq  ,5hzeq  ,5hvxeq ,5hvyeq ,5hvzeq /
      data xo   /5hxo   ,5hyo   ,5hzo   ,5hvxo  ,5hvyo  ,5hvzo  /
      data x1   /5hx1   ,5hy1   ,5hz1   ,5hvx1  ,5hvy1  ,5hvz1  /
      data x2   /5hx2   ,5hy2   ,5hz2   ,5hvx2  ,5hvy2  ,5hvz2  /
      data x2eq /5hx2eq ,5hy2eq ,5hz2eq ,5hvx2eq,5hvy2eq,5hvz2eq/
c
c *** tgovd common
c
      data fuxn /6hfuxn1 ,6hfuxn2 ,6hfuxn3 ,6hfuxn4 ,6hfuxn5 ,
     +        6hfuxn6 ,6hfuxn7 ,6hfuxn8 ,6hfuxn9 ,6hfuxn10/
c
      data tgo  /6htgo  /
      data timemn/6htimemn /
      data timx /6htimx  /
c
      end
```

```
      block data dict1
      implicit integer (a-z)
c*********************************************
c
c     dict1 - defines computational commons
c     (aaiv - zzend) dictionary values
c
c     the data statements in this routine are standardized
c
c*********************************************
c
      include 'collond.inc'
      include 'cycnd.inc'
      include 'ephejd.inc'
      include 'infv1d.inc'
      include 'mnvrjd.inc'
      include 'phznd.inc'
      include 'propjd.inc'
      include 'statnd.inc'
      include 'tgond.inc'
      include 'zzendd.inc'
c
c -----------------------------------------------------
c       include  'collond.inc'
c -----------------------------------------------------
c       common     /collond       /
      data nsegph /0/
      data cointp / 'linear'/
c
c -----------------------------------------------------
c       include  'cycnd.inc'
c -----------------------------------------------------
c       common     /cycnd         /
      data
     1  jevt   /0       /
c       common     /cyccd         /
      data
     1  iepoch       /'julian  '    /
c
c -----------------------------------------------------
c       include  'ephecd.inc'
c -----------------------------------------------------
c       common     /ephecd        /
        data
     1  planet(0)    /'sun     '    /
c
c -----------------------------------------------------
c       include  'infv1d.inc'
c -----------------------------------------------------
```

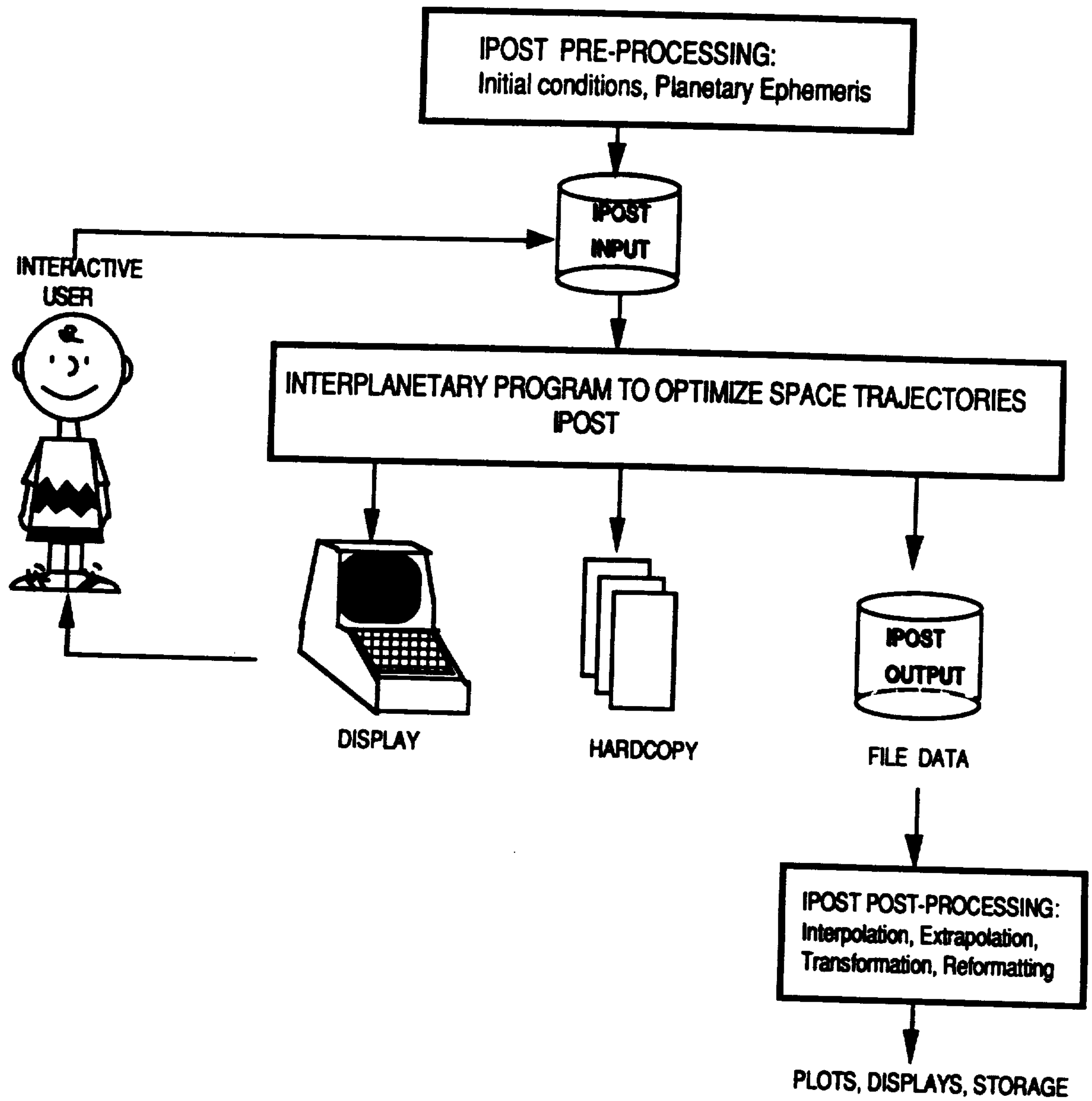
```
c       common    /infv1d        /
        data
   1     title  /' '     /
c
c ------------------------------------------------------------
c       include  'mnvrjd.inc'
c ------------------------------------------------------------
c       common    /mnrvjd        /
        data
   1     ilnch          /0      /
c       common    /mnvrcd        /
        data
   1     mantyp        /'none'        /
c
c ------------------------------------------------------------
c       include  'phznd.inc'
c ------------------------------------------------------------
c       common    /phznd         /
     data
   1     inff   /0       /
c
c ------------------------------------------------------------
c       include  'propjd.inc'
c ------------------------------------------------------------
c       common    /propjd        /
        data
   1     idt      /1       /
      data massfi / 'none' /
c
c ------------------------------------------------------------
c       include  'statnd.inc'
c ------------------------------------------------------------
c       common    /statnd        /
     data
   1     idbody         /0      /
c       common    /statcd        /
   1     inputx         /'none'        /
c
c ------------------------------------------------------------
c       include  'tgond.inc'
c ------------------------------------------------------------
c       common    /tgond         /
        data
   1     nxevt          /0      /
c
c ------------------------------------------------------------
c       include  'zzendd.inc'
c ------------------------------------------------------------
c       common    /zzendd        /
```

```
   1   end  /0.    /
c
    end
```

```
      program master
      implicit real*8 (a-h,o-z)
c
c*** master - main program of the interplanetary post simulation
c         master - main program control
c
c    external files and unit numbers
c      2  dictionary names
c      3  pscan.sav
c     18  profil
c     20  computational iv-to-end
c     31  npinput                    opened in nlprg
c     32  npost3d.rst
c     33  npost3d.out
c     38  ipost.smo, for pscan
c
      include 'ephejc.inc'
c
cc      include 'infvc.inc'
c
      include 'inpvc.inc'
c
      include 'pagerc.inc'

      include 'parmsc.inc'

      include 'pr0fc.inc'

      character*256 arg

      data arg / ',' /
c
c   routine added to handle Sun date and time
      preset = 1
      call fdate  pdate)
cc      call time (ptime)

c    get profile name from command line

      icnt = iargc()

      if (icnt.ne.0) then

        call getarg ( 1, arg )
        prnam = arg

      else

        prnam = 'profil'
```

```
      endif
c... nomtab: set table length into common, set up table nodes
      call nomtab
c
c.....open a scratch file to save the computational iv-to-end
c
      call savdat
c
c.....open the npsol summary output file for optimization
c
       open ( unit=32, status='unknown', file='ipost.rst' ,
     $       form='formatted', access='sequential')
c
c.....open the npsol summary output file for optimization
c
       open ( unit=33, status='unknown', file='ipost.out' ,
     $       form='formatted', access='sequential')
 10   continue
      rewind 31

      call readat
      if ( inpef.ge.0 ) then
         call tspxm
      endif
      if ( inpef.eq.0 ) go to 10
c
      if (iephem.eq.1) close ( unit=7 )
      close ( unit=18, status='keep' )
      close ( unit=32, status='keep' )
      close ( unit=33, status='keep' )
c
      stop
      end
```

9.0 INPUT/OUTPUT INTERFACES



10.0 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

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 III - Programmer's Manual

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 III (Revised)

11. SUPPLEMENTARY NOTES Supersedes NASA CR-189653, Volume III, July 1992.
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
71

16. PRICE CODE
A04

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		