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OPS BENCH NAVIGATION PROGRAM USER'S MANUAL

8 January 1980

Prepared for:

National Aeronautics and Space Administration
Johnson Space Center

Contract NAS9-15722

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TRW

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National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: Mr. E. R. Schiesser, Branch Chief
Mathematical Physics Branch

Subject: OPS Bench Navigation Program User's Manual

Gentlemen:

The subject document is attached. This document satisfies line 12 of the CDRL, T1527, for the Ground Navigation Software Support for Shuttle MCC Contract, NAS9-15722.

Very truly yours,

O. R. Bergman, Manager
Ground Navigation Project Office

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OB:mh
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1. INTRODUCTION

1.1 OPS BENCH PROGRAM DESCRIPTION

The OPS Bench Navigation Program is a single-vehicle weighted least squares orbit determination (OD) program with the added capability of generating and storing ephemerides for three Tracking Data Relay Satellites (TDRS). This program was developed under NASA Contract NAS9-15722 for use in verification of the OPS MCC Ground Navigation Program.

Both ground-based and satellite-relayed observations may be processed by the OPS Bench Program. The ground-based observations may be in-plane and out-of-plane angles, range, or Doppler. The satellite-relayed observations may be range or Doppler.

The ICOASV predictor in the OPS Bench Program is designed to propagate a vehicle state vector in free flight under the influence of significant natural forces in the solar system. The scope of the modeling is limited to perturbative forces consistent with free-flight techniques. On option, the models for atmospheric drag, solar radiation, and venting may be included in the predictor computations. Integration is performed in double precision using a variable order Gauss-Jackson numerical integration scheme. The normal integration mode is the Encke-beta mode, but it is possible to select via user input either the Encke-time mode or the Cowell mode.

The OPS Bench Program employs a differential correction processor to solve the weighted least squares problem and update the vehicle state and error covariance matrix. Parameters which may be included in the differential correction process are components of vent forces, drag multiplier, and relay biases.

Output of the OPS Bench Program in the execution of an OD solution consist of a listing of input data, including a full listing of data batches employed in the OD process, a summary of vehicle trajectory, and a complete summary of the differential correction iterations. Vehicle trajectory, when such a trajectory is required, may be displayed in a number of coordinate frames.

The OPS Bench Program is written in double-precision FORTRAN for the UNIVAC 1108 - EXEC 8 operating system.

1.2 USER'S MANUAL SUMMARY

The OPS Bench Program User's Manual describes in detail all information required by the user to operate successfully the OPS Bench Program.

Section 2 discusses the tape and card inputs to the OPS Bench Program, and complete details of the FORTRAN NAMELIST input format are provided.

Section 3 offers complete descriptions of each of the namelist entities, and a listing of inputs available to the user in each namelist.

Section 4 provides input tape unit assignments and program deck set up for a Bench Program run.

Section 5 contains sample cases which illustrate the output of typical OPS Bench Program runs.

2. PROGRAM INPUT

In this section, the various tape and card inputs to the OPS Bench Program are discussed. For reference, a simplified input/output scheme for the orbit determination process of the Bench Program is shown in Figure 2-1 on the following page.

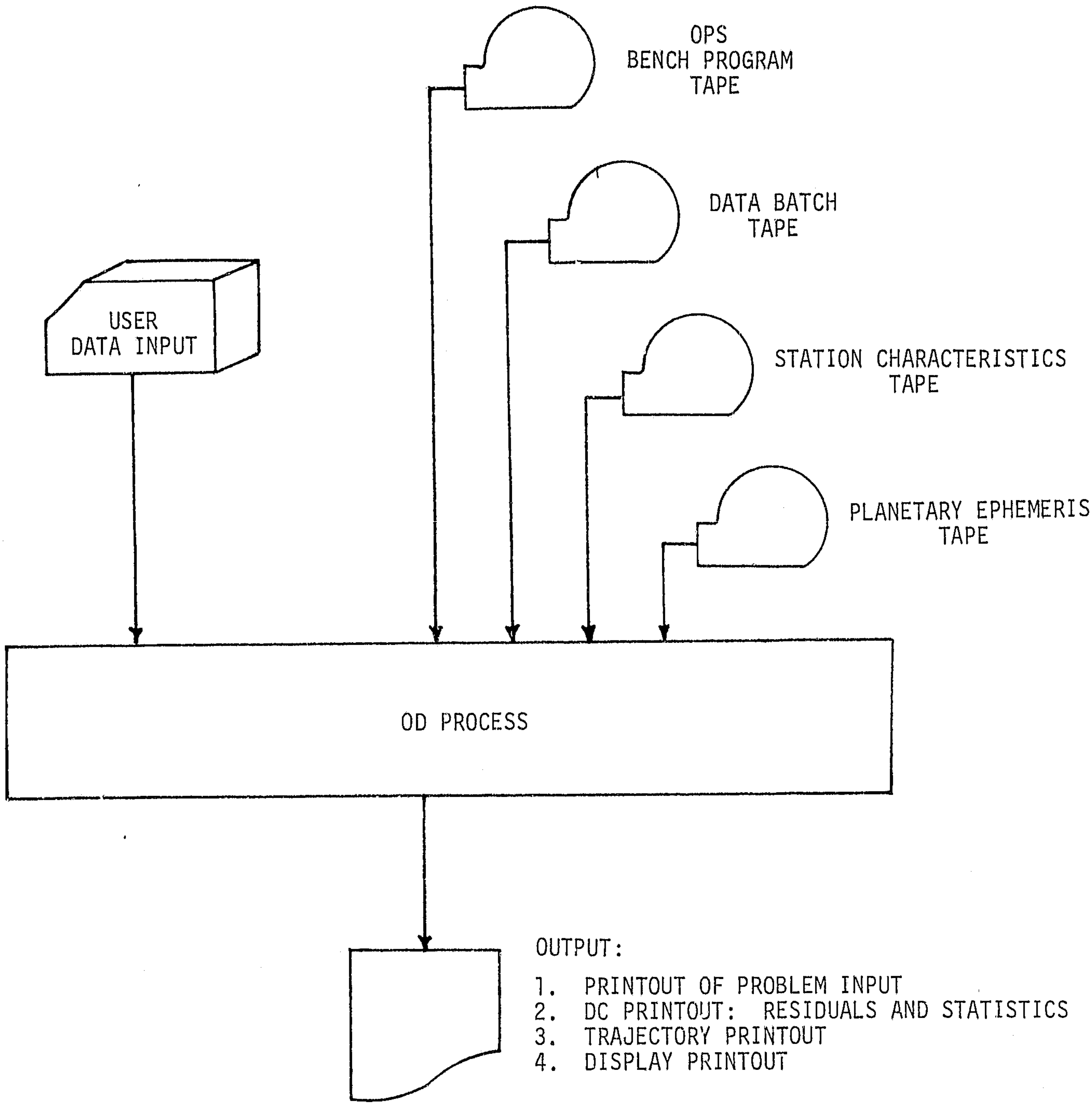

Figure 2.1. OPS Bench Program Input/Output Scheme

2.1 TAPE INPUT

Tape inputs to the OPS Bench Program fall into several categories. These include a program tape, observation data batch tape, station characteristics tape, and planetary ephemeris tape. The basic format of each of these tapes is described in a separate subsection below.

2.1.1 OPS Bench Program Tape

The OPS Bench Program Tape is required for the execution of an OD solution. This is a baseline tape which contains the actual Bench Program software, and several programmer reference files. The files contained in the tape are as follows:

(a) MAINTAIN File. This file consists of canned @ADD elements which perform a number of functions essential to the creation and use of the Baseline tape.

(b) SOURCE File. This file contains the FORTRAN source for the Bench Program and its utility processors. In addition, SOURCE contains the COMGEN Data Base.

(c) RELOC File. This file contains the relocatable elements created by the compilation of the SOURCE file elements.

(d) ABS File. This file contains the absolute executable elements for the Bench Program and its utility processors.

(e) MAPS File. The MAPS file contains the map directives necessary to create the ABS file elements from the relocatable elements in RELOC.

(f) TCASES File. This file provides the programmer with input data for a set of standard test cases developed for the Bench Program.

(g) ALTERS File. This file contains the modifications used to create the current Baseline tape from its predecessor.

2.1.2 Observation Data Batch Tape

The Observation Data Batch Tape is required input for an OD in which ground-tracking or TDRS-relayed data is to be processed.

The Data Batch Tape consists of an arbitrary number of batches of navigation tracking data, each batch accompanied by a batch header array of information.

The data batches occur in chronological order based upon the time of the first valid data observation contained in the batch. Each data batch consists of a time sequence of data frames, each containing the following information:

(a) Data frame time tag

(b) Angle observables (XY30,XY85,Az,El)

(c) Range observable

(d) Doppler observable

(e) Doppler count interval

Each data batch contains a maximum of 100 data frames.

Each data batch is preceded by its own batch header. This header is an array containing the following information:

(a) NR = Receiver ID

NX = Transmitter ID

(b) NT1 = TDRS Forward Link ID

NT2 = TDRS Peturn Link ID

(c) NV = Vehicle ID

DT = Data Tape

(d) NF = Number of Data Frames

(e) V_{NX} = Transmitter Direct Frequency

(f) V_{NR} = Receiver Direct (Reference) Frequency

(g) BF_p = Return TDRS Translation Frequency

(h) W_4 = Doppler Model Frequency Multiplier

(i) W_3 = Doppler Bias Frequency

(j) A_R = Range Ambiguity Interval

(k) BT = Batch Time

2.1.3 Station Characteristics Tape

The Station Characteristics Tape is required input for an OD problem. This tape provides the identifying characteristics of various STDN tracking stations currently employed for ground navigation of the Shuttle Orbiter. The information supplied for each tracking station is the following:

STA(1) = Station ID (JSC acronym)

STA(2) = Geodetic Longitude

STA(3) = Geodetic Latitude (GDLAT)

STA(4) = Geocentric Latitude (GCLAT)

STA(5) = sin (GDLAT)

STA(6) = cos (GDLAT)

STA(7) = sin (GCLAT)

STA(8) = cos (GCLAT)

STA(9) = Altitude above Ellipsoid

STA(10) = Station Radius (R_S)

STA(11) - STA(22) = Refraction Moduli (N_o)

$STA(23) - STA(34)$ = Atmospheric Scale Heights (H_S)

$STA(35)$ = Ellipsoid Radius (R_E)

$STA(36) = R_E[STA(8)] + [STA(9)] \cdot [STA(6)]$

$STA(37) = R_E[STA(7)] + [STA(9)] \cdot [STA(5)]$

$STA(38)$ = 2-way Doppler Coefficient (W_{D2})

$STA(39)$ = 3-way Doppler Coefficient (W_{D3})

$STA(40)$ = Range Coefficient (W_R)

$STA(41)$ = Angle Coefficient (W_A)

2.1.4 Planetary Ephemeris Tape

The Planetary Ephemeris Tape is required for the calculation of vehicle acceleration due to the planetary disturbing bodies selected in the gravitational potential model of the ICOASV predictor. The current tape in use is the PE50D tape generated from the JPL DE19 series ephemeris tapes. It provides the ephemerides of all planets and the Moon, spanning the time December 1961 to December 1994.

The time interval for planetary ephemeris points is 4 days, with the exception of Mercury, which has a 2 day interval. The interval between the Moon's ephemeris points is 12 hours. The planet data consist of heliocentric position and velocity components with their modified second and fourth differences. Data for the Moon consist of geocentric position and velocity components and the associated modified second and fourth differences. Units for all position and velocity components are ER and ER/hr. All data are referenced to the M50 coordinate system and are represented in double precision.

2.2 CARD INPUT

The FORTRAN NAMELIST input scheme is employed by the OPS Bench Program for card input data. The NAMELIST scheme provides a streamlined method by which data can be input according to certain catagories called namelists. In each namelist, inputs are identified by variable names, and data is input in a free-field format.

2.2.1 Bench Program Namelists

Input to the OPS Bench Program by cards is divided into thirteen separate namelists. Each namelist provides a set of data variables which collectively furnish data for a specific function. For example, the namelist MISVEH allows the user to input the data necessary to describe the particular MISsion and VEHicle characteristics for the OD.

The following is a complete list of the namelists in the Bench Program input scheme:

(a) SYSTEM - System Parameters

(b) MISVEH - Mission and Vehicle Characteristics

(c) VADRAG - Variable Drag Model Parameters

(d) PRBCTL - OD Problem Control

(e) SBCTL - Superbatch Control

(f) BTBCTL - Batch-to-Batch Control

(g) TRAJ - Trajectory Control

(h) ATOEDT - Automatic Edit Parameters

(i) SOLFOR - Solve-for Parameters

(j) COVARS - A Priori Covariances

(k) MANEDT - Manual Editing Options

(l) BRESPL - Batch Residual Plotter Control

(m) BIASCT - Observation Data Bias Control

2.2.2 Namelist Format

The general format for the Bench Program namelist input for a single OD case is as follows:

```
Column 2
    ↓
    $ NAME1
        .
        .
        .
        .          (NAME1 Data Cards)
        .
        .
    $ END
    $ NAME2
        .
        .
        .
        .          (NAME2 Data Cards)
        .
        .
    $ END
        .
        .
        .
        .
        .
        .
        .
        .
    $ NAMEj
        .
        .
        .          (NAMEj Data Cards)
        .
        .
    $ END
    $ ENDCAS
```

A namelist that is called for data input is opened with a card $NAME having a $ in Column 2 followed by the formal name for that namelist. Following the namelist card are the input data cards for that namelist. These data cards will follow format specifications detailed in Section 2.2.3 below. The namelist is then closed with the $END card; as illustrated, the $ appears in Column 2, followed by the word END. The cards for each namelist requiring input follow this format. These namelist cards are stacked as shown above into a single namelist input deck which is closed with the $ENDCAS card. The order of appearance of the namelists is unimportant, and is left to the user's discretion. The $ENDCAS card terminates the user input for the particular Bench Program case.

If more than one Bench Program case is to be submitted in a single run, the namelist input decks for each problem appear consecutively in the program run deck, the $ENDCAS cards separating the successive namelist input decks. Note: The Program does not carry over input from one case to the next. The namelist input deck provided for each case must therefore be self-contained.

One final item concerning the Bench Program's namelist format must be clarified. This item concerns the requirement for calling a namelist in the namelist input deck. All data variables available in the Bench Program are assigned default values. These default values may either be zeros or nonzero operating values. The user may elect to accept the default value for any data variable by simply omitting to input any data for that variable. Hence, the list of data variables called for input in a namelist may either be a full or partial list of all the data variables available in that namelist. If the full set of default values for a particular namelist is acceptable to the user, or no input for that namelist is required for the case submitted, the user is not required to call that namelist. For example, the SYSTEM namelist is provided a complete set of default values for system parameters and integrator options which the user may opt for by omitting to call SYSTEM in the namelist input deck. An example of a namelist which may not require input for an OD is the namelist BIASCT: if no data biases are to be applied to the observation data batches to be processed in the current OD, then the user omits calling of BIASCT.

All default values for the data variables available in the Bench Program are listed in the user input descriptions of Section 3.

2.2.3 Input Variable Format

At the end of this subsection, an alphabetic listing of all data variables available in the OPS Bench Program is provided in Table 2.1. Corresponding to each data variable in the table there is given the namelist, or namelists, to which the data variable belongs. The user may then refer to Section 3 for complete description of data variables.

Input values for any data variable may take any of the following forms:

- Integer constants.
- Real Constants. These are written with a decimal point, and, optionally, they are written with an exponent consisting of E, +, or -, or a combination of E and sign.
- Double precision constants. These are written with a decimal point and nine or more digits, and, optionally, they are written with an exponent consisting of D, +, or -, or a combination of D and sign. If the input value contains fewer than nine digits, the D form must be used with or without an exponent (e.g., 1.0D0).
- Logical constants. These are written as T, .TRUE., F, or .FALSE..

- Hollerith constants. These are written as nHhhh...h, where hhh...h is a string of n alphanumeric characters including blanks. Six characters can be stored in one location. If less than six characters remain, they are stored left-justified with the rest of the computer word filled out with blanks.

To assign input to a particular data variable, the namelist to which that variable corresponds must first be called, as detailed in the previous section. Input data cards follow this format line: Variable name can begin on a card anywhere execept Column 1. Since the $ cards begin in Column 2, it is suggested that variable names be placed beginning in Column 3 for ease in identifying separate namelists in the printout of user input data. The variable name is followed by an equal sign, which is followed in turn by the input data. In the case of input to a variable array, input elements are separated by commas. Arrays of input elements may overflow to one or more other cards, with the provision that no blanks should be embedded in an input constant. Blanks may be freely used elsewhere.

The forms that the input data may take are the following:

(a) VARIABLE NAME = constant. In this case, the variable called is a simple variable. Examples of this type of input are

NTDRS = 2; and

LEDIT = .TRUE.

The first example is that of the namelist MISVEH input which specifies the number of TDRS vehicles involved in the OD problem. The second example is that of the namelist BTBCTL input which specifies that the automatic edit option in the batch-to-batch processing mode is desired.

(b) SUBSCRIPTED VARIABLE = constant. In this case the variable called is a single element of a variable array. An example of this type of input is

POTENT(11) = -2.15D-6

This example is one in which the coefficient J_3 of the Earth geopotential model, located in the eleventh position in the 600-element array POTENT, is given the value -2.15D-6 by the user, rather than allowing use of the default value -2.56D-6. POTENT is a SYSTEM namelist input, so the usual namelist call is required for this input.

(c) SUBSCRIPTED VARIABLE = set of constants. In this case, an ordered string of elements in a variable array is called for user input. The variable array name is followed immediately on the data card by the subscript of the array element at which the input is to begin. Following the equal sign, the constants appear in the order in which input is desired, and the number of constants input must not exceed the space available in the array following the starting element. Input may be individual constants, or a repeated constant. The latter will be of the form R*constant where R is an unsigned integer. Examples of this type of input are

POTENT(10) = 1079.2D-6, -2.15D-6, -1.6D-6; and

POTENT(296) = 21*0.D0

In the first example, the coefficients of the Earth geopotential model J_2, J_3, J_4 have been assigned values by the user. J_2 occupies the array element POTENT(10). In the second example, the Moon geopotential coefficients J_1 through $C_{3,3}$ have been assigned zeros. In actuality, only the coefficients J_2, J_3, $C_{2,2}$, $C_{3,1}$, and $C_{3,3}$ (i.e., POTENT(297), POTENT(298), POTENT(313), POTENT(314), and POTENT(316)) have nonzero default values, but the method of giving them zero values shown in the example is easier for the user than handling each coefficient as a separate subscripted variable.

In the case of a doubly subscripted variable array, an ordered string of elements is called for user input by columns. An example of this type of usage is the following:

VTFORC(1,1) = 20.0, -2.6, 0.8

The VTFORC array in the SOLFOR namelist is used to input the a priori force levels for a maximum of three solve-for vents. Each a priori vent is resolved into its component forces, in units of lbs, along each of the vehicle body coordinate axes. For the J-th such vent, the X_{BY}-, Y_{BY}-, and Z_{BY}- component forces are loaded into the J-th column of VTFORC (into the (1,J), (2,J), and (3,J) entries, respectively). In the example above, the user has input the first a priori vent by components into the first column of VTFORC. Input of a second a priori vent could be accomplished in either of two ways, at the user's convenience:

(1) VTFORC(1,1) = 20.0, -2.6, 0.8
VTFORC(1,2) = 2.0, 0.0, 1.8
or
(2) VTFORC(1,1) = 20.0, -2.6, 0.8, 2.0, 0.0, 1.8

(d) ARRAY NAME = set of constants. In this case, the variable called is an entire array. The set of input values may be individual constants, or a repeated constant. The set of input values specified will be loaded by columns into the array beginning at the first position: NAME(1) for a singly subscripted array, or NAME(1,1) for a doubly subscripted array. The number of input values must not exceed the storage available in the array.

An example of this type of array input is in input of a vehicle state vector in M50 coordinates $(x,y,z,\dot{x},\dot{y},\dot{z})$ via the INVEC variable array in the MISVEH namelist. For convenience, this might be input on two cards:

```
INVEC = .828614678,  .311808358,   .532416856,
      -.596813269, 4.097290949, -1.459561936
```

Table 2.1. OPS Bench Program Input Variables

VARIABLE	NAMELIST
B	
BCONV	SBCTL
BIAS	SOLFOR
BIASIN	BIASCT
BIASV	BIASCT
BTAB	MISVEH
C	
CDA	VADRAG
CDETUT	MISVEH
CDF	VADRAG
CDN	VADRAG
CDRAG	MISVEH
CDS	VADRAG
CPN	VADRAG
CSA	MISVEH
D	
DA	SBCTL
DAYS	MISVEH
DCONV	SBCTL
DELTAT	TRAJ
DELTA1	ATOEDT
DELTA2	ATOEDT
DKFACT	SOLFOR
DK1	ATOEDT
DK2	ATOEDT
E	
EDLIM	ATOEDT
EPSQR	SYSTEM
ETAB	MISVEH
F	
FKGAMA	COVARS
G	
GET	MISVEH
H	
HMS	MISVEH
I	
IBATT	MISVEH
ICOV	COVARS
ID	ATOEDT
IDCM	PRBCTL
IDIS	COVARS
IEXBAT	MANEDT
IG	ATOEDT
IMODE	SYSTEM
INVEC	MISVEH
IPRINT	SYSTEM
IRKST	SYSTEM
ISLVBI	SBCTL
ISLVDR	SBCTL
ITRF	MISVEH
IUNITS	BRESPL
IVARFX	SYSTEM
J	
JDRAG	PRBCTL
JSOLAR	PRBCTL
JVENT	PRBCTL
K	
KEYS	MISVEH
KPR	PRBCTL
KREF	PRBCTL
L	
LANCHL	SBCTL
LAPCOV	BTBCTL, SBCTL
LEDIT	BTBCTL
LEXCCA	MANEDT
LEXCCE	MANEDT
LEXCCR	MANEDT
LEXCHD	MANEDT
LEXCHR	MANEDT
LEXCLC	MANEDT
LEXCLR	MANEDT
LEXCLS	MANEDT
LEXCRD	MANEDT
LEXCRR	MANEDT

Table 2.1. OPS Bench Program Input Variables (Concluded)

VARIABLE	NAMELIST	VARIABLE	NAMELIST
LEXCSX	MANEDT	RMAX	ATOEDT
LEXCSY	MANEDT	RMIN	ATOEDT
LEXCSR	MANEDT	RMNEL	BTBCTL, SBCTL
LEXCS2	MANEDT	RPLOT	BRESPL
LEXCS3	MANEDT	**S**	
LFORCE	BTBCTL, SBCTL	SCVBH	COVARS
LTPROP	SBCTL	SCVB23	COVARS
M		SCVNT	COVARS
MAXDV	BTBCTL, SBCTL	SDRAG	COVARS
MAXIT	BTBCTL, SBCTL	SRCH1	ATOEDT
MEDIT	MANEDT	SRCH2	ATOEDT
MINCA	BTBCTL, SBCTL	SSCOV	COVARS
MINEL	BTBCTL, SBCTL	**T**	
MIN1	ATOEDT	TDRS	MISVEH
MIN2	ATOEDT	TEDELT	SYSTEM
MONTH	MISVEH	TSTART	TRAJ
MXELOP	ATOEDT	TSTOP	TRAJ
N		**V**	
NFBAT	BTBCTL, SBCTL	VCONV	BTBCTL, SBCTL
NLBAT	BTBCTL, SBCTL	VEDELT	SYSTEM
NORD	SYSTEM	VENTIN	MISVEH
NPBI	COVARS	VTCONV	BTBCTL, SBCTL
NTDRS	MISVEH	VTFORC	SOLFOR
NVNTSL	BTBCTL, SBCTL	VTSTRT	SOLFOR
P		VTSTOP	SOLFOR
POTENT	SYSTEM	**W**	
PRODES	PRBCTL	WT	MISVEH
R		WTAB	MISVEH
RCONV	BTBCTL, SBCTL	**Y**	
		YEAR	MISVEH

3. USER INPUT DESCRIPTION

This section provides a delineation of user inputs for the OPS Bench Program. Each namelist is detailed in a separate subsection: the namelist itself is described, and the input variables available in that namelist are catalogued. Included at the end of each namelist subsection is an alphabetic listing of the namelist variables with full description of each variable (name, dimension, type, capsule description, and default value).

Provided in Figure 3.1 on the following page for the user's convenience is a "walk-through" flow diagram of the namelist input scheme. Each namelist is labeled either as optional or mandatory. If a namelist is mandatory, the OD requires input in that namelist. If a namelist is optional, the user may provide inputs or else accept the default values assigned to the variables in that namelist. This diagram will enable the user to ensure that sufficient data has been provided for the OD.

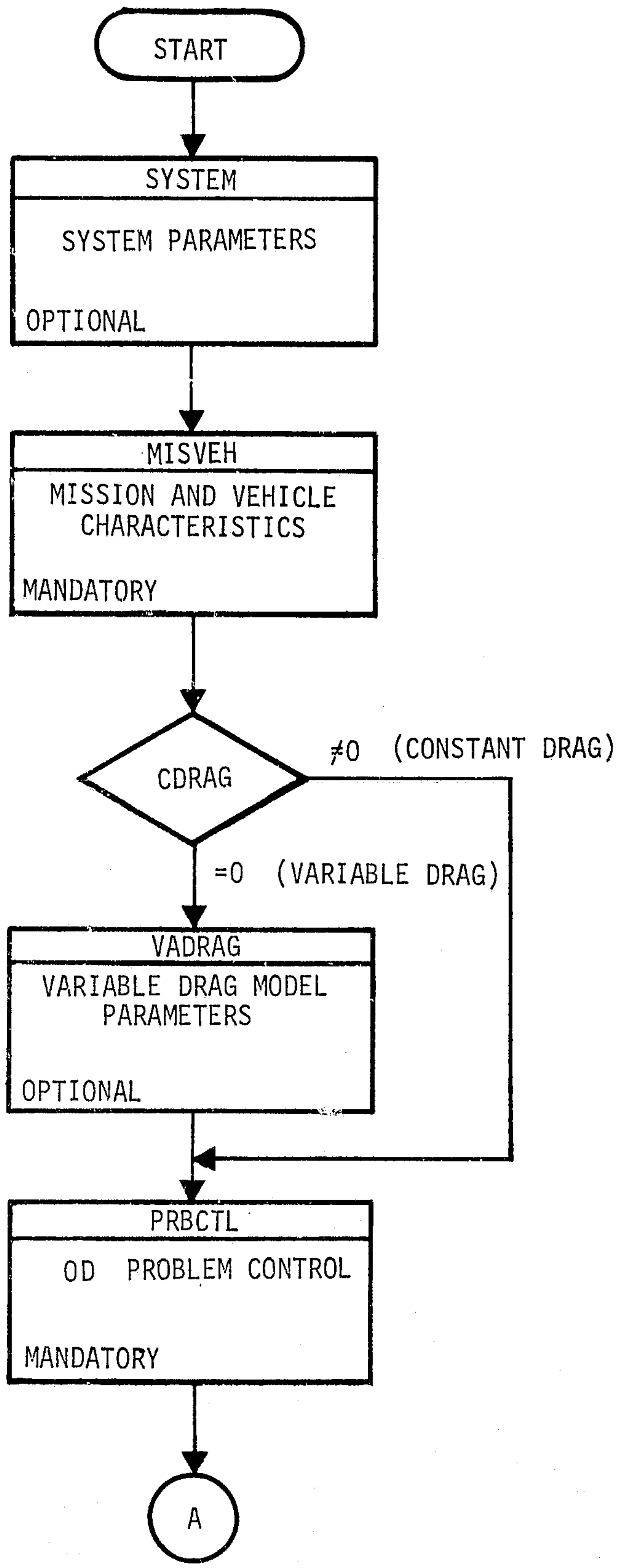

Figure 3.1. OPS Bench Program Input Flow Diagram

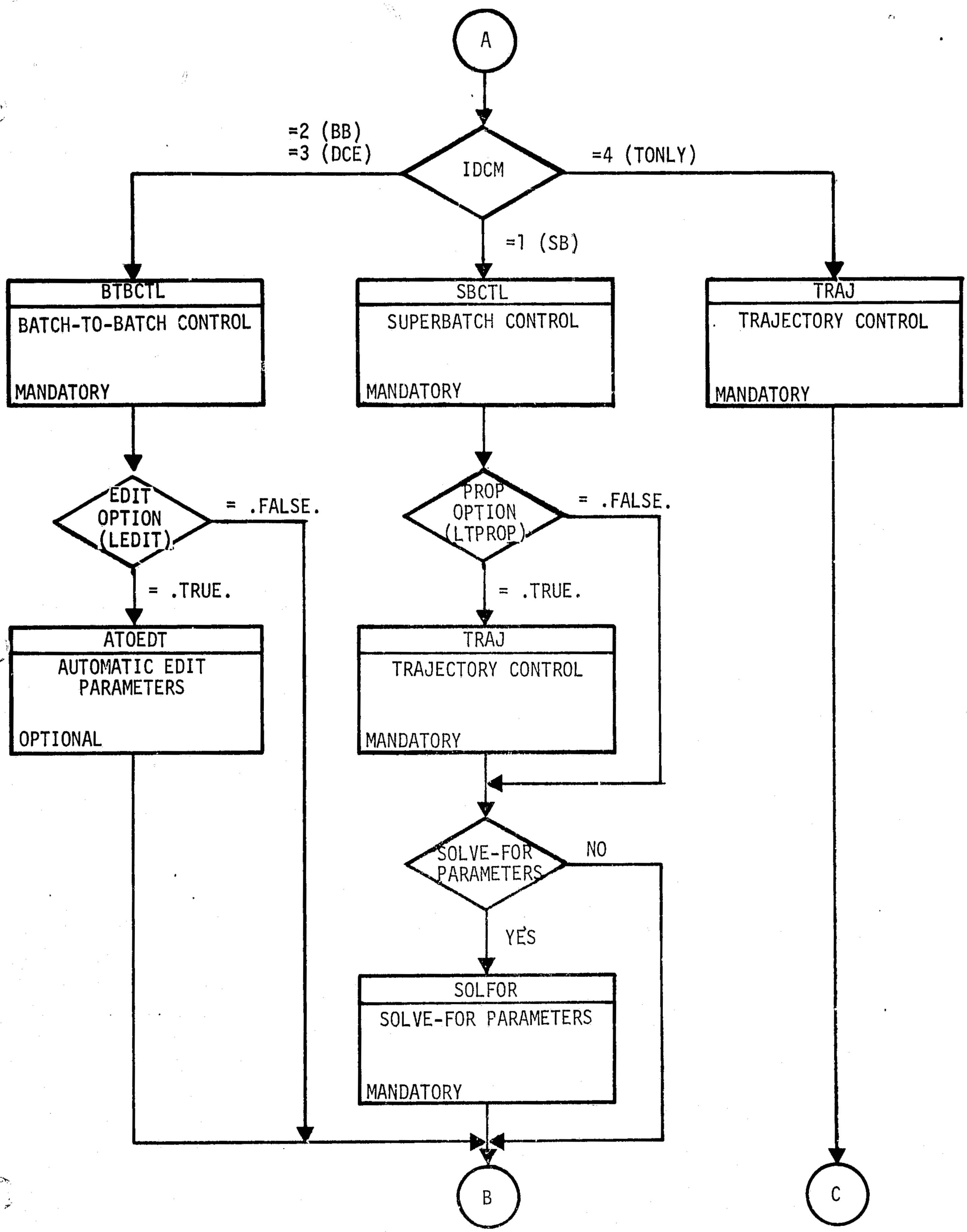

Figure 3.1. OPS Bench Program Input Flow Diagram (Continued)

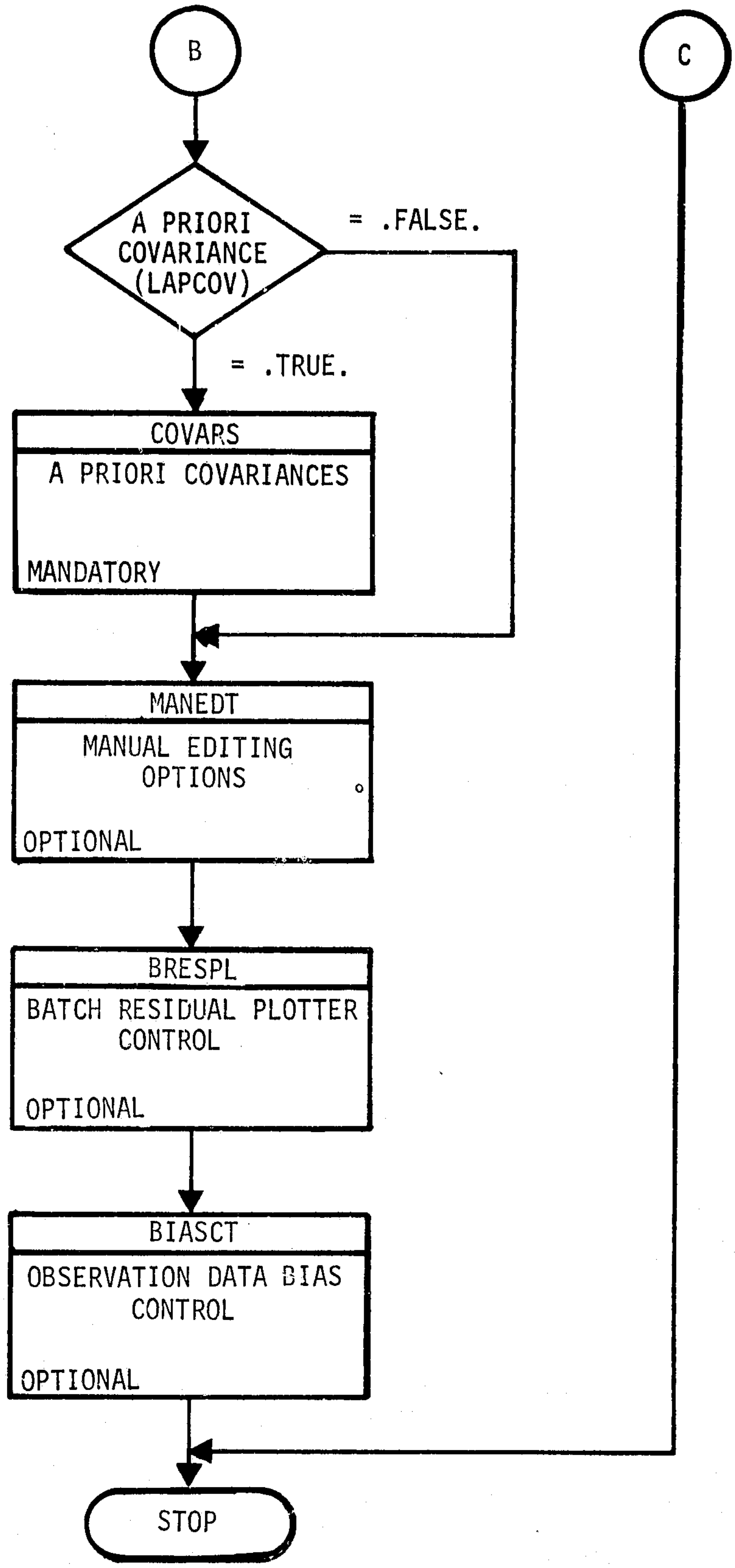

Figure 3.1. OPS Bench Program Input Flow Diagram (Concluded)

3.1 SYSTEM NAMELIST

Through the SYSTEM namelist of inputs, the user exercises control of parameters governing the performance of the ICOASV free-flight predictor. SYSTEM inputs include major integrator options, vehicle ephemeris time parameters, and coefficients for the disturbing body gravitational potential models.

3.1.1 Integrator Options

Numerical integration is performed in double precision using a Gauss-Jackson backward difference algorithm with a Runge-Kutta starter. Integrator options available to the user are the following:

(a) Integrator mode (IMODE)

(b) Rectification tolerance (EPSQR: Encke modes only)

(c) Integration step control (IVARFX)

(d) Order of Gauss-Jackson backward difference (NORD)

(e) Number of Runge-Kutta steps per Gauss-Jackson (IRKST)

(f) Integrator printout control (IPRINT)

(g) Shuttle ephemeris storage time step (VEDELT)

(h) TDRS ephemeris storage time step (TEDELT)

3.1.2 Gravitational Potential Model Parameters

ICOASV performs computation of vehicle acceleration due to the gravitational attraction of selected disturbing bodies in the solar system. (See Section 3.1.3, Note 1). The coefficients of the gravitational potential models for each of the selected bodies are input via the POTENT array.

For the OPS Bench Program, Earth is selected as the primary body, and the Sun and Moon are selected as secondary disturbing bodies. Other planets and natural satellites are available for inclusion as disturbing bodies, but require program modification. (See Section 3.1.3, Note 2).

POTENT is a 600-element array. Coefficients for the potential models of certain planets and the Moon can be input as follows:

(a) Coefficients for Venus model (POTENT(1-8))

(b) Coefficients for Earth model (POTENT(9-263))

(c) Coefficients for Mars model (POTENT(264-271))

(d) Coefficients for Jupiter model (POTENT(272-279))

(e) Coefficients for Saturn model (POTENT(280-287))

(f) Coefficients for Neptune model (POTENT(288-295))

(g) Coefficients for Moon model (POTENT(296-550))

(h) POTENT(550-600) (not used)

3.1.3 Notes to User

Note 1: Four sources of acceleration on a vehicle in free flight can be modeled in the Bench Program: gravitation, atmospheric drag, solar radiation, and venting. Parameters for drag and vent models can be found in the namelist VADRAG and MISVEH. The switching flags for the drag, solar radiation, and vent models are set via the problem control namelist PRBCTL.

Note 2: The inclusion flags for planets and certain natural satellites are located in the IPLNET and ISATEL arrays in the BLKDAT subroutine.

Table 3.1. SYSTEM Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
EPSQR	1	DP	Rectification tolerance for Encke integration modes		1.0D-4
IMODE	1	I	Integration mode flag =0, Encke-beta mode =1, Encke-time mode =2, Cowell mode		0
IPRINT	1	I	Integrator printout flag =-1, print initial and final vehicle state =0, no state vector print >0, print every N-th point computed along the trajectory (where N = IPRINT) including initial and final vehicle state		-1
IRKST	1	I	Number of Runge-Kutta steps per Gauss-Jackson step		1
IVARFX	1	I	Indicator flag for variable or fixed integrator step size =0, fixed step size =1, variable step size		0
NORD	1	I	Highest order backward difference in the Gauss-Jackson algorithm (NORD $\leq$ 15)		8
POTENT	600	DP	Coefficients for the non-spherical gravitation potential models of the planets and natural satellites		

Table 3.1. SYSTEM Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(I) (I=1,2,...,8)			Coefficients for Venus Model		
POTENT(1-2)			J_1 through J_2		2*0.D0
POTENT(3)			$C_{1,1}$		0.D0
POTENT(4-5)			$C_{2,1}$ through $C_{2,2}$		2*0.D0
POTENT(6)			$S_{1,1}$		0.D0
POTENT(7-8)			$S_{2,1}$ through $S_{2,2}$		2*0.D0
POTENT(I) (I=9,10,...,263)			Coefficients for Earth Model		
POTENT(9)			J_1		0.D0
POTENT(10)			J_2		1082.7D-6
POTENT(11)			J_3		-2.56D-6
POTENT(12)			J_4		-1.58D-6
POTENT(13-23)			J_5 through J_{15}		11*0.D0
POTENT(24)			$C_{1,1}$		0.D0
POTENT(25)			$C_{2,1}$		0.D0
POTENT(26)			$C_{2,2}$		1.57D-6
POTENT(27-29)			$C_{3,1}$ through $C_{3,3}$		3*0.D0
POTENT(30-33)			$C_{4,1}$ through $C_{4,4}$		4*0.D0
POTENT(34-38)			$C_{5,1}$ through $C_{5,5}$		5*0.D0
POTENT(39-44)			$C_{6,1}$ through $C_{6,6}$		6*0.D0
POTENT(45-51)			$C_{7,1}$ through $C_{7,7}$		7*0.D0
POTENT(52-59)			$C_{8,1}$ through $C_{8,8}$		8*0.D0
POTENT(60-68)			$C_{9,1}$ through $C_{9,9}$		9*0.D0

Table 3.1. SYSTEM Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(69-78)			$C_{10,1}$ through $C_{10,10}$		10*0.D0
POTENT(79-89)			$C_{11,1}$ through $C_{11,11}$		11*0.D0
POTENT(90-100)			$C_{12,1}$ through $C_{12,12}$		12*0.D0
POTENT(102-114)			$C_{13,1}$ through $C_{13,13}$		13*0.D0
POTENT(115-128)			$C_{14,1}$ through $C_{14,14}$		14*0.D0
POTENT(129-143)			$C_{15,1}$ through $C_{15,15}$		15*0.D0
POTENT(144)			$S_{1,1}$		0.D0
POTENT(145)			$S_{2,1}$		0.D0
POTENT(146)			$S_{2,2}$		-.897D-6
POTENT(147-149)			$S_{3,1}$ through $S_{3,3}$		3*0.D0
POTENT(150-153)			$S_{4,1}$ through $S_{4,4}$		4*0.D0
POTENT(154-158)			$S_{5,1}$ through $S_{5,5}$		5*0.D0
POTENT(159-164)			$S_{6,1}$ through $S_{6,6}$		6*0.D0
POTENT(165-171)			$S_{7,1}$ through $S_{7,7}$		7*0.D0
POTENT(172-179)			$S_{8,1}$ through $S_{8,8}$		8*0.D0
POTENT(180-188)			$S_{9,1}$ through $S_{9,9}$		9*0.D0
POTENT(189-198)			$S_{10,1}$ through $S_{10,10}$		10*0.D0
POTENT(199-209)			$S_{11,1}$ through $S_{11,11}$		11*0.D0
POTENT(210-221)			$S_{12,1}$ through $S_{12,12}$		12*0.D0
POTENT(222-234)			$S_{13,1}$ through $S_{13,13}$		13*0.D0
POTENT(235-248)			$S_{14,1}$ through $S_{14,14}$		14*0.D0
POTENT(249-263)			$S_{15,1}$ through $S_{15,15}$		15*0.D0

Table 3.1. SYSTEM Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(I) (I=264,265,...,271)			Coefficients for Mars Model		
POTENT(264)			J_1		0.D0
POTENT(265)			J_2		.197D-2
POTENT(266)			$C_{1,1}$		0.D0
POTENT(267-268)			$C_{2,1}$ through $C_{2,2}$		2*0.D0
POTENT(269)			$S_{1,1}$		0.D0
POTENT(270-271)			$S_{2,1}$ through $S_{2,2}$		2*0.D0
POTENT(I) (I=272,273,...,279)			Coefficient for Jupiter Model		
POTENT(272)			J_1		0.D0
POTENT(273)			J_2		-.296D-1
POTENT(274)			$C_{1,1}$		0.D0
POTENT(275-276)			$C_{2,1}$ through $C_{2,2}$		2*0.D0
POTENT(277)			$S_{1,1}$		0.D0
POTENT(278-279)			$S_{2,1}$ through $S_{2,2}$		2*0.D0
POTENT(I) (I=280,281,...,287)			Coefficients for Saturn Model		
POTENT(280)			J_1		0.D0
POTENT(281)			J_2		.27D-1
POTENT(282)			$C_{1,1}$		0.D0
POTENT(283-284)			$C_{2,1}$ through $C_{2,2}$		2*0.D0
POTENT(285)			$S_{1,1}$		0.D0

Table 3.1. SYSTEM Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(286-287)			$S_{2,1}$ through $S_{2,2}$		2*0.DO
POTENT(I) (I=288,289,...,295)			Coefficients for Neptune Model		
POTENT(288)			J_1		0.DO
POTENT(289)			J_2		.35D-2
POTENT(290)			$C_{1,1}$		0.DO
POTENT(291-292)			$C_{2,1}$ through $C_{2,2}$		2*0.DO
POTENT(293			$S_{1,1}$		0.DO
POTENT(294-295)			$S_{2,1}$ through $S_{2,2}$		2*0.DO
POTENT(296,297,...,550)			Coefficients for Moon Model		
POTENT(296)			J_1		0.DO
POTENT(297)			J_2		2.07108D-4
POTENT(298)			J_3		-2.1D-5
POTENT(299-310)			J_4 through J_{15}		12*0.DO
POTENT(311)			$C_{1,1}$		0.DO
POTENT(312)			$C_{2,1}$		0.DO
POTENT(313)			$C_{2,2}$		2.0716D-5
POTENT(314)			$C_{3,1}$		3.4D-5
POTENT(315)			$C_{3,2}$		0.DO
POTENT(316)			$C_{3,3}$		2.583D-6
POTENT(317-320)			$C_{4,1}$ through $C_{4,4}$		4*0.DO
POTENT(321-325)			$C_{5,1}$ through $C_{5,5}$		5*0.DO

Table 3.1. SYSTEM Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(326-331)			$C_{6,1}$ through $C_{6,6}$		6*0.D0
POTENT(332-338)			$C_{7,1}$ through $C_{7,7}$		7*0.D0
POTENT(339-346)			$C_{8,1}$ through $C_{8,8}$		8*0.D0
POTENT(347-355)			$C_{9,1}$ through $C_{9,9}$		9*0.D0
POTENT(356-365)			$C_{10,1}$ through $C_{10,10}$		10*0.D0
POTENT(366-376)			$C_{11,1}$ through $C_{11,11}$		11*0.D0
POTENT(377-388)			$C_{12,1}$ through $C_{12,12}$		12*0.D0
POTENT(389-401)			$C_{13,1}$ through $C_{13,13}$		13*0.D0
POTENT(402-415)			$C_{14,1}$ through $C_{14,14}$		14*0.D0
POTENT(416-430)			$C_{15,1}$ through $C_{15,15}$		15*0.D0
POTENT(431)			$S_{1,1}$		0.D0
POTENT(432-433)			$S_{2,1}$ through $S_{2,2}$		2*0.D0
POTENT(434-436			$S_{3,1}$ through $S_{3,3}$		3*0.D0
POTENT(437-440)			$S_{4,1}$ through $S_{4,4}$		4*0.D0
POTENT(441-445)			$S_{5,1}$ through $S_{5,5}$		5*0.D0
POTENT(446-451)			$S_{6,1}$ through $S_{6,6}$		6*0.D0
POTENT(452-458)			$S_{7,1}$ through $S_{7,7}$		7*0.D0
POTENT(459-466)			$S_{8,1}$ through $S_{8,8}$		8*0.D0
POTENT(467-475)			$S_{9,1}$ through $S_{9,9}$		9*0.D0
POTENT(476-485)			$S_{10,1}$ through $S_{10,10}$		10*0.D0
POTENT(486-496)			$S_{11,1}$ through $S_{11,11}$		11*0.D0
POTENT(497-508)			$S_{12,1}$ through $S_{12,12}$		12*0.D0

Table 3.1. SYSTEM Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
POTENT(509-521)			$S_{13,1}$ through $S_{13,13}$		13*0.D0
POTENT(522-535)			$S_{14,1}$ through $S_{14,14}$		14*0.D0
POTENT(536-550)			$S_{15,1}$ through $S_{15,15}$		15*0.D0
TEDELT	1	DP	TDRS ephemeris storage time delta	hrs	.045D0
VEDELT	1	DP	Shuttle ephemeris storage time delta	hrs	.015D0

3.2 MISVEH NAMELIST

The namelist MISVEH allows the user to input all data pertaining to vehicle state and mission characteristics.

3.2.1 Shuttle Vehicle State

The input state of the Shuttle vehicle is input through the MISVEH namelist, and the user has the option to choose the reference frame for the vehicle input state. Inputs are the following:

(a) Input state (INVEC)

(b) Time tag of input state (HMS)

(c) Description keys of input state (KEYS)

(d) Indicator for transformation of input state to M50 coordinates (ITRF)

3.2.2 TDRS Vehicle State

For OD problems which include relayed tracking data, the user may input the number of TDRS vehicles involved and their associated input state vectors. Unlike the Shuttle vehicle state, TDRS state vectors must be input in M50 coordinates only. Inputs are the following:

(a) Number of TDRS vehicles involved (NTDRS)

(b) Input TDRS state vectors (TDREST, TDRWST, TDRSPR)

3.2.3 Mission History Tables

The MISVEH namelist provides the chronological history tables for vehicle attitude, weight and door configuration, and nominal vent data. Inputs are the following:

(a) Vehicle attitude history

(i) Indicator to get attitude data (IBATT)

(ii) Attitude history table (BTAB)

(iii) Attitude rate table (ETAB)

(b) Vehicle weight and configuration history (WTAB)

(c) Vehicle nominal vent table (VENTIN)

3.2.4 Vehicle Drag Parameters

The user can set the constants for vehicle mass and cross-sectional area used in the vehicle drag computations. In addition, user may specify constant area drag by input of a nonzero drag coefficient C_D.

Inputs are the following:

(a) Vehicle mass (WT)

(b) Reference cross-sectional vehicle area (CSA)

(c) Drag Coefficient C_D (CDRAG)

3.2.5 Mission Time Parameters

Inputs of various time parameters associated with the vehicle mission that are provided in the MISVEH namelist are:

(a) Epoch time (MONTH, DAYS, YEAR)

(b) Vehicle launch date (GET)

(c) E.T. - U.T. offset calculation constants (CDETUT)

Table 3.2. MISVEH Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
BTAB	(12,20)	DP	Attitude History Table		
BTAB(1,J) (J=1,2,...,20)			Entry times (in chronological order)	hrs from epoch	20*0.D0
BTAB(2,J) (J=1,2,...,20)			Vehicle attitude mode =1, inertial hold (IH) =2, inertial barbecue (BBQ) =3, local vertical-local horizontal(LVLH) =4, solar inertial (SI)		20*0
BTAB(I,J) (I=3,4,...,11; J=1,2,...,20)			Attitude matrix (loaded by columns) BTAB(2,J) = 1 ⇒ BODY to M50 BTAB(2,J) = 2 ⇒ BODY to M50 BTAB(2,J) = 3 ⇒ BODY to LVLH BTAB(2,J) = 4 ⇒ BODY to SI		180*0.D0
BTAB(12,J) (J=1,2,...,20)			Pointer into ETAB for rotation information =N, go to ETAB(I,N) (I=1,2,3,4) for rotation axis vector and rotation rate		20*0
CDETUT	2	DP	Coefficients in the ET-UT offset calculations		
CDETUT(1)				sec	21.251711D0
CDETUT(2)				sec/day	.002592D0
CDRAG	1	DP	Drag coefficient C_D =0, variable drag model on ≠0, value is C_D for constant drag		0.D0
CSA	1	DP	Reference vehicle cross-sectional area		

Table 3.2. MISVEH Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
DAYS	1	R	Day of epoch	calendar day	0
ETAB	(4,5)	DP	Attitude Rate Table		
ETAB(I,J) (I=1,2,3;J=1,2,...,5)			Axis of rotation in BODY coordinates	ER	3*0.D0
ETAB(4,J) (J=1,2,...,5)			Angular rate of rotation	rad/sec	0.D0
GET	3	DP	Vehicle launch date		
GET(1)			hours from epoch	hr	0.D0
GET(2)			minutes from epoch	min	0.D0
GET(3)			seconds from epoch	sec	0.D0
HMS	3	DP	Time tag of vehicle input state vector		
HMS(1)			hours from epoch	hr	0.D0
HMS(2)			minutes from epoch	min	0.D0
HMS(3)			seconds from epoch	sec	0.D0
IBATT	1	I	Attitude data flag =0, no data =1, get attitude data		0
INVEC	6	DP	Shuttle input state vector	ER, ER/hr	6*0.D0

Table 3.2. MISVEH Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
ITRF	1	I	Indicator flag for transformation of input to M50 coordinates =0, no =1, yes	ER, ER/hr	0
KEYS	8	I	Input state description keys		
KEYS(1)			Input state coordinates =1, $x,y,z,\dot{x},\dot{y},\dot{z}$ (CARTESIAN) =2, $\nu,\lambda,\psi,\phi,\lambda,r$ (POLAR) (r is replaceable by h: See KEYS(7)) =3, a,e,i,Ω,ω,ν (ORBITAL ELTS.)		1
KEYS(2)			Input reference frame =1, M50 =2, M50 =3, Selenographic (See KEYS(8)) =4, Skylab (not used) =5, MNBY		1
KEYS(3)			Units for distance parameters =1, ER =2, feet =3, yards =4, kilometers =5, nautical miles =6, statute miles		1
KEYS(4)			Units for distance part of velocity parameters =1, ER =2, feet =3, yards =4, kilometers =5, nautical miles =6, statute miles		1

Table 3.2. MISVEH Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
KEYS(5)			Units for time part of velocity parameters =1, hours =2, minutes =3, seconds		1
KEYS(6)			Units for angle parameters =1, radians =2, degrees		1
KEYS(7)			Polar coordinate flag (set only in case KEYS(1) = 2) =-1, h is assumed =1, r is assumed		1
KEYS(8)			Selenographic reference frame flag (set only in case KEYS(2) = 3) =0, non-rotating frame =1, rotating frame		
MONTH	1	R	Month of epoch	calendar month	0
NTDRS	1	I	Number of TDRS vehicles (NTDRS $\leq$ 3)		0
TDREST	7	DP	TDRS-EAST state vector and time tag		7*0.D0
TDREST(1)			Time tag of TDRS-EAST state vector	hrs from epoch	
TDREST(I) (I = 2,3,...,7)			TDRS-EAST state vector (position and velocity)	ER, ER/hr	
TDRSPR	7	DP	TDRS-SPARE state vector and time tag		7*0.D0

Table 3.2. MISVEH Namelist (Continued)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
TDRSPR(1)			Time tag of TDRS-SPARE state vector	hrs from epoch	
TDRSPR(I) (I = 2,3,...,7)			TDRS-SPARE state vector (position and velocity)	ER, ER/hr	
TDRWST	7	DP	TDRS-WEST state vector and time tag		7*0.D0
TDRWST(1)			Time tag of TDRS-WEST state vector	hrs from epoch	
TDRWST(I) (I2,3,...,7)			TDRS-WEST state vector (position and velocity)	ER, ER/hr	
VENTIN	(3,20)	DP	Input nominal vent table		
VENTIN(1,J) (J = 1,2,...,10)			Vent start time (in chronological order)	hrs from epoch	10*0.D0
VENTIN(2,J) (J = 1,2,...,10)			Vent stop time	hrs from epoch	10*0.D0
VENTIN(3,J) (J = 1,2,...,10)			Pointer into the right half of the VENTIN array for vent thrust information =N, go to VENTIN(I,N+10) (I=1,2,3) for vent thrust values along each of the vehicle body axes.		10*0.D0
VENTIN(1,J) (J = 11,12,...,20)			Thrust along X_{BY}-axis of indicated vent	lbs	10*0.D0
VENTIN(2,J) (J = 11,12,...,20)			Thrust along Y_{BY}-axis of indicated vent	lbs	10*0.D0
VENTIN(3,J) (J = 11,12,...,20)			Thrust along Z_{BY}-axis of indicated vent	lbs	10*0.D0

Table 3.2. MISVEH Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
WT	1	DP	Vehicle mass	lbs-m	0.D0
WTAB	(3,5)	DP	Weight and Configuration History Table		
WTAB(1,J) (J=1,2,...,5)			Entry times (in chronological order)	hrs from epoch	5*0.D0
WTAB(2,J) (J=1,2,...,5)			Vehicle weight	lbs-m	5*0.D0
WTAB(3,J) (J=1,2,...,5)			Vehicle configuration =1, doors shut =2, doors open		5*0.D0
YEAR	1	R	Year of epoch	calendar year	0.D0

3.3 VADRAG NAMELIST

Whenever CDRAG = 0 in the MISVEH namelist inputs, the variable area drag model is called to compute the vehicle on-orbit drag coefficient C_D. The VADRAG namelist contains the drag model parameters used to compute C_D.

3.3.1 Drag Model Parameters

Each parameter in the drag model is assigned two values: the first value is used when drag is computed for the vehicle doors-open configuration, and the second value is used for vehicle doors-closed configuration. Inputs to the drag model are:

(a) Frontal area constant (CDF)

(b) Side area constant (CDS)

(c) Normal (viewed from above) area increase constant (CDN)

(d) Exponential shaping factor (CPN)

(e) Model constant (CDA)

Table 3.3. VADRAG Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
CDA	2	DP	Variable drag model constant		
CDA(1)			Doors open		.77015D0
CDA(2)			Doors closed		.64592D0
CDF	2	DP	Frontal area drag constant		
CDF(1)			Doors open		.85532D0
CDF(2)			Doors closed		.7859D0
CDN	2	DP	Normal (viewed from above) area increase constant		
CDN(1)			Doors open		2.74618D0
CDN(2)			Doors closed		2.41256D0
CDS	2	DP	Side area constant		
CDS(1)			Doors open		1.84306D0
CDS(2)			Doors closed		1.92837D0
CPN	2	DP	Exponential shaping constant		
CPN(1)			Doors open		1.31376D0
CPN(2)			Doors closed		1.31586D0

3.4 PRBCTL NAMELIST

The PRBCTL namelist allows the user to select the desired job mode for the Bench Program, and to choose from the output options available for residual print and display. In addition the user may select via PRBCTL the optional acceleration models available in the Bench Program.

3.4.1 Problem Description

The user has the option of providing a brief description of the current OD case, which description will appear in the printout summarizing the case input. This description may use up to 72 alphanumeric characters, including blanks. Input is accomplished via the PRODES array, which contains twelve elements, each six characters in length.

3.4.2 DC Job Mode

The DC job mode is input via the PRBCTL variable IDCM. User may select

(a) Superbatch (SB) mode (IDCM = 1)

(b) Batch-to-batch (BB) mode (IDCM = 2)

(c) DC-Edit (DCE) mode (IDCM = 3)

(d) Trajectory only (TONLY) mode (IDCM = 4)

Additional controlling input for the OD process is provided in the namelists SBCTL (for SB mode), BTBCTL (for BB and DCE modes), and TRAJ (for TONLY mode).

3.4.3 DC Output Options

User option for DC output available in the PRBCTL namelist are the following:

(a) Residual print option (KPR4)

(b) DC display reference system (KREF)

Note that the residual print flag KPR4 serves as an indicator flag for the Batch Residual Plotter. See the BRESPL namelist for plotter control input.

3.4.4 Acceleration Model Flags

Inclusion of the drag model, solar radiation model, or vent model in the computations of vehicle acceleration can be accomplished via the model indicator flags provided in PRBCTL:

(a) Drag model indicator flag (JDRAG)

(b) Solar radiation model indicator flag (JSOLAR)

(c) Vent model indicator flag (JVENT)

These models will not be considered unless the user specifies their inclusion.

Table 3.4. PRBCTL Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
IDCM	1	I	Job mode flag =1, superbatch (SB) =2, batch-to-batch (BB) =3, DC edit (DCE) =4, trajectory only (TONLY)		-1
JDRAG	1	I	Drag model indicator flag =0, model off =1, model on		0
JSOLAR	1	I	Solar radiation model indicator flag =0, model off =1, model on		0
JVENT	1	I	Vent model indicator flag =0, model off =1, model on		0
KPR4	1	I	Residual print option flag =0, print option off =1, print last iteration only =2, print first and last iteration only =3, print all iterations		3
KREF	1	I	Display reference system flag =1, M50 =2, True of date =3, MNBY		1
PRODES	12	H	Case description		12*6Hb̸

3.5 SBCTL NAMELIST

The SBCTL namelist inputs provide the user control of the OD process in the superbatch operating mode. Input is required in SBCTL only in the case IDCM = 1 (SB mode) in PRBCTL.

3.5.1 Batch Processing Control

Control of data batches to processed is provided through SBCTL by allowing the user to specify the data batch span to be considered in the current superbatch OD case. The user identifies the first batch and last batch to be processed by their batch numbers on the Data Batch tape:

(a) Batch number of first batch to be processed (NFBAT)

(b) Batch number of last batch to be processed (NLBAT)

The user is provided further control over the batch processing through the manual edit and batch exclusion options in the MANEDT namelist. Note: Data type exclusion capabilities are available in the SB mode. Parameters governing data type exclusion can also be found in MANEDT.

3.5.2 Superbatch Logic Options

Available to the user are four major options in the main superbatch logic of the Bench Program:

(a) Option to anchor vehicle state at last observation time. If this option is desired, the user sets the logical element LANCHL = .TRUE..

(b) A priori covariance option. If a priori covariance is to be supplied in the current OD case, the user sets the logical element LAPCOV = .TRUE.. Covariances are input via the COVARS namelist.

(c) Force option. If one additional iteration is desired following normal termination of the DC process, the user sets the logical element LFORCE = .TRUE..

(d) Option to propagate updated vehicle state after DC. If this option is desired, the user sets the logical element LTPROP = .TRUE.. Parameters required for this trajectory propagation are input via the TRAJ namelist.

3.5.3 Solve-for Parameters

In the superbatch mode, a maximum of nine solve-for parameters may be included in the OD solution. The user may indicate the number and type of solve-for parameters with the following input variables:

(a) Solve-for relay bias flags (ISLVBI)

(b) Solve-for drag flag (ISLVDR)

(c) Solve-for vents flag (NVNTSL)

A priori values for the solve-for parameters are input via the SOLFOR namelist.

3.5.4 DC Parameters

User may input through the SBCTL namelist all parameters associated with the iterated DC process. Inputs are the following:

(a) Maximum DC iteration (MAXIT)

(b) Maximum divergent DC iterations (MAXDV)

(c) Minimum elevation criteria (MINEL, RMNEL, MINCA)

(d) Convergence criteria (RCONV, VCONV; BCONV, DCONV, VTCONV)

3.5.5 Input State Modification

The user may specify through the variable DA a modification to the semi-major axis of the vehicle input state vector. The value given to DA will be used to calculate new a priori position and velocity for the current OD case.

Table 3.5. SBCTL Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
BCONV	1	DP	Relay bias convergence criterion	MHz	TBD
DA	1	DP	Delta to be added to the semi-major axis of input state		0.D0
DCONV	1	DP	Drag convergence criterion		1.0D-2
ISLVBI	9	H	Solve-for relay bias flags Flag values may be chosen in any order from the following list: 'ESTEST', TDRS EAST 2- or 3-way relay configuration 'WSTWST', TDRS WEST 2- or 3-way relay configuration 'SPRSPR', TDRS SPARE 2- or 3-way relay configuration 'ESTWST', TDRS EAST-WEST hybrid relay configuration 'ESTSPR', TDRS East-SPARE hybrid relay configuration 'WSTEST', TDRS WEST-EAST hybrid relay configuration 'WSTSPR', TDRS WEST-SPARE hybrid relay configuration 'SPREST', TDRS SPARE-EAST hybrid relay configuration 'SPRWST', TDRS SPARE-WEST hybrid relay configuration		9*6HØ
ISLVDR	1	I	Solve-for drag flag =0, no solve-for drag =1, solve for drag		0
LANCHL	1	L	Logical element =.TRUE., anchor vehicle state at last observation time		.FALSE.
LAPCOV	1	L	Logical element =.TRUE., a priori covariance supplied		.FALSE.
LFORCE	1	L	Logical element =.TRUE., force option on		.FALSE.

Table 3.5. SBCTL Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
LTPROP	1	L	Logical element =.TRUE., trajectory propagation after DC is desired		.FALSE.
MAXDV	1	I	Maximum divergent iterations in DC		1
MAXIT	1	I	Maximum iterations in DC		1
MINCA	1	DP	Minimum altitude of closest approach for TDRS/ Shuttle RF link	ER	2.7437444445
MINEL	1	DP	Minimum direct elevation	rad	.87266463D-1
NFBAT	1	I	Number of first batch to process		-1
NLBAT	1	I	Number of last batch to process		-1
NVNTSL	1	I	Number of solve-for vents =0, no solve-for vents >0, solve for N vents (where NVNTSL = N)		0
RCONV	1	DP	Position convergence criterion	ER	1.0D-8
RMNEL	1	DP	Minimum relay elevation angle	rad	.87266463D-1
VCONV	1	DP	Velocity convergence criterion	ER/hr	1.0D-5
VTCONV	1	DP	Solve-for vent convergence criterion	lbs	1.0D-4

3.6 BTBCTL NAMELIST

The BTBCTL namelist inputs provide the user control of the OD process in the batch-to-batch operating modes. Input is required in BTBCTL only in the case IDCM = 2 (BB mode) or IDCM = 3 (DCE mode) in PRBCTL.

3.6.1 Batch Processing Control

Control of data batches to be processed is provided by allowing the user to specify the data batch span to be considered in the current batch-to-batch OD case. User identifies the first batch and last batch to be processed by their batch numbers on the Data Batch Tape:

(a) Batch number of first batch to be processed (NFBAT)

(b) Batch number of last batch to be processed (NLBAT)

The user is provided further control over the batch processing through the manual edit and batch exclusion options in the MANEDT namelist.

3.6.2 Batch-to-Batch Logic Options

Available to the user are three major options in the main batch-to-batch logic of the Bench Program:

(a) A priori covariance option. If a priori covariance is to be supplied in the current OD case, the user sets the logical element LAPCOV = .TRUE.. Covariances are input via the namelist COVARS.

(b) Automatic edit option. If the Batch Edit option is desired in the BB mode (IDCM = 2), the user sets the logical element LEDIT = .TRUE.. Parameters for the automatic editor are available in the ATOEDT namelist. Note: If the DCE mode has been selected (IDCM = 3), it is mandatory that the user set LEDIT = .TRUE..

(c) Force option. The force option, enabled by the logical element LFORCE, is available in the batch-to-batch operating modes. If a data batch is to be processed in one of these modes, and an additional DC iteration is to be forced following normal termination of the DC process in that mode, the user sets LFORCE = .TRUE.. If the force option is called in either the BB mode with edit option, or in the DCE mode, no editing is performed subsequent to the forced iteration.

Note: Care should be taken with the use of this option in the batch-to-batch modes. The force option will apply to all data batches processed in the batch-to-batch modes. Therefore, if only a particular data batch is to be forced, that batch should be processed as a single batch case.

3.6.3 Solve-for Parameters

Solve-for capability in the BB or DCE mode is limited to a single solve-for vent. Indication of a solve-for vent is accomplished with the solve-for vent flag NVNTSL.

Note: No a priori vent information is input in the batch-to-batch modes. A priori vent force levels are assumed to be zero, and the vent time span is assumed to be that of the data batch.

3.6.4 DC Parameters

User may input via the BTBCTL namelist all parameters associated with the DC iterative process. Inputs are the following:

(a) Maximum DC iterations (MAXIT)

(b) Maximum divergent DC iterations (MAXDV)

(c) Minimum direct elevation angle (MINEL)

(d) Minimum relay elevation angle (RMNEL)

(e) Minimum altitude for TDRS/Shuttle RF link (MINCA)

(f) Convergence criteria (RCONV, VCONV: VTCONV)

Table 3.6. BTBCTL Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
LAPCOV	1	L	Logical element =.TRUE., a priori covariance supplied		.FALSE.
LEDIT	1	L	Logical element =.TRUE., automatic edit desired		.FALSE.
LFORCE	1	L	Logical element =.TRUE., force option on		.FALSE.
MAXDV	1	I	Maximum divergent iterations in DC		1
MAXIT	1	I	Maximum iterations in DC		1
MINCA	1	DP	Minimum altitude of closest approach for TDRS/Shuttle RF link	ER	2.7437444445D-2
MINEL	1	DP	Minimum direct elevation	rad	.87266463D-1
NFBAT	1	I	Number of first batch to process		-1
NLBAT	1	I	Number of last batch to process		-1
NVNTSL	1	I	Number of solve-for vents =0, no solve-for vents =1, solve for single vent		0
RCONV	1	DP	Position convergence criterion	ER	1.0D-8
RMNEL	1	DP	Minimum relay elevation angle	rad	.87266463D-1
VCONV	1	DP	Velocity convergence criterion	ER/hr	1.0D-5
VTCONV	1	DP	Solve-for vent convergence criterion	lbs	1.0D-4

3.7 TRAJ NAMELIST

The TRAJ namelist variables are associated with the control of trajectory and trajectory-related output. Input in the TRAJ namelist is required when a propagation of vehicle state is called for in the TONLY mode (IDCM = 4), or in the SB mode with the LTPROP option (propagation of updated state).

3.7.1 Trajectory Parameters

Trajectory-related inputs in the TRAJ namelist are the following:

(a) Trajectory start time (TSTART)

(b) Trajectory stop time (TSTOP)

(c) Trajectory printout time delta (DELTAT)

Table 3.7. TRAJ Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
DELTAT	1	DP	Trajectory printout time delta	hrs	1.0
TSTART	1	DP	Propagation start time	hrs from epoch	0.D0
TSTOP	1	DP	Propagation stop time	hrs from epoch	0.D0

3.8 SOLFOR NAMELIST

The SOLFOR namelist allows the user to input a priori values for the solve-for parameters selected for the current OD case. Input is required for the SOLFOR namelist only in the case that solve-for parameters are included in a superbatch OD solution. Note: A batch-to-batch OD solution in which a vent is included does not require SOLFOR input. In that setting, a priori vent force levels are assumed to be zero, and vent start and stop times are identified with the times of the first and last valid observations, respectively, of each data batch.

3.8.1 A Priori Solve-for Parameters

A priori solve-for inputs are the following:

(a) A priori solve-for vent inputs

(i) A priori vent force levels (VTFORC)

(ii) Solve-for vent start and stop times (VTSTRT, VTSTOP)

(b) A priori solve-for drag multiplier (DKFACT)

(c) A priori solve-for relay bias values (BIAS)

Table 3.8. SOLFOR Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
BIAS	9	DP	A priori relay bias values (in order of bias flags in ISLVBI array)	MHz	9*0.D0
DKFACT	1	DP	A priori drag multiplier		1.0
VTFORC	(3,3)	DP	A priori solve-for vent forces		
VTFORC(1,J)(J=1,2,3)			Thrust along X_{BY}-axis of J-th vent	lbs	3*0.D0
VTFORC(2,J)(J=1,2,3)			Thrust along Y_{BY}-axis of J-th vent	lbs	3*0.D0
VTFORC(3,J)(J=1,2,3)			Thrust along Z_{BY}-axis of J-th vent	lbs	3*0.D0
VTSTRT	3	DP	Solve-for vent start times (in order of vents in VTFORC array)	hrs from epoch	3*0.D0
VTSTOP	3	DP	Solve-for vent stop times (in order of vents in VTFORC array)	hrs from epoch	3*0.D0

3.9 COVARS NAMELIST

User input of a priori covariances and associated parameters is accomplished via the COVARS namelist. Input is required only in the case that the a priori covariance option is selected by the user (LAPCOV = .TRUE. in SBCTL or BTBCTL).

3.9.1 State Covariance Reference Frames

The user may select the reference frames both for input and display of the vehicle state covariance:

(a) State covariance input reference frame (ICOV

(b) State covariance display reference frame (IDIS)

3.9.2 Covariance Matrix Elements

The user may specify the elements of the a priori covariance matrix with with the following inputs:

(a) A priori state covariance (SSCOV)

(b) A priori vent covariance (SCVNT)

(c) A priori drag covariance (SDRAG)

(d) A priori relay 2- or 3-way relay Doppler bias covariance (SCVB23)

(e) A priori relay hybrid Doppler bias covariance (SCVBH)

The actual a priori covariance matrix constructed from these elements will be a block diagonal matrix Λ of maximum dimension 15x15. The blocks on the diagonal are input by the user from the above list, and the order of the diagonal follows the solution vector order:

$$
\Lambda = \begin{bmatrix}
SSCOV & & & & & \bigcirc \\
 & SCVNT & & & & \\
 & & \ddots & & & \\
 & & & SDRAG & & \\
 & \bigcirc & & & SCVB23 & \\
 & & & & & SCVBH
\end{bmatrix}
$$

Note: In the case of multiple vents specified in the solution vector, SCVNT is used as the a priori covariance for each vent.

3.9.3 KGAMMA Downweighting

The user may take the option to downweight the constructed a priori covariance matrix (KGAMMA downweight option). Parameters associated with this option are:

(a) KGAMMA covariance multiplier (FKGAMMA)

(b) Number of times KGAMMA PBI is depressed (NPBI)

Table 3.9. COVARS Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
FKGAMA	1	R	KGAMMA covariance multiplier		2.0
ICOV	1	I	Input reference frame for state covariance =1, M50 coordinates =2, UVW coordinates =3, classical orbital elements		1
IDIS	1	I	Display reference frame for state covariance =0, M50 coordinates only =1, M50 coordinates, UVW coordinates, and classical orbital elements		0
NPBI	1	I	Number of times Kgamma PBI is depressed		0
SCVB23	1	DP	A priori relay 2- or 3-way Doppler bias covariance		0.D0
SCVBH	1	DP	A priori relay hybrid Doppler bias covariance		
SCVNT	6	DP	A priori vent covariance matrix (lower triangular portion, by rows)		6*0.D0
SDRAG	1	DP	A priori drag covariance		0.D0
SSCOV	21	DP	A priori state covariance matrix (lower triangular portion, by rows)		21*0.D0

3.10 ATOEDT NAMELIST

The ATOEDT namelist allows the user to set the parameters governing the operation of the automatic editor. The editor is called in the DCE mode and in the BB mode with edit option on.

The edit function sequence is as follows: gross pre-edit, D1 (divided first differences) edit, D2 (divided second differences) edit, re-edit, and edit state testing. The user may set the controlling parameters for each of these edit functions. In addition, the user specifies the number of times the editor is called by the OD executive in the Bench Program.

3.10.1 Edit Loop Limit

An edit loop consists of an edit pass of the current residuals of a data batch followed by a DC on the edited data batch. The number of edit loops called for is set by the user via the MXELOP variable.

3.10.2 Gross Pre-edit Parameters

Parameters for the gross pre-edit are the following:

(a) Data type edit limits (RMAX)

(b) Percentage of edited points allowed (EDLIM)

3.10.3 D1 Edit Parameters

Parameters for the D1 edit are the following:

(a) Minimum number of points for D1 edit (MIN1)

(b) Minimum editing criteria (RMIN)

(c) D1 edit limit search parameters (DELTA1, DK1, SRCH1)

3.10.4 D2 Edit Parameters

Parameters for the D2 edit are the following:

(a) Minimum number of points for D2 edit (MIN2)

(b) Minimum editing criteria (RMIN)

(c) D2 edit limit search parameters (DELTA2, DK2, SRCH2)

3.10.5 Edit State Testing Parameters

In the edit state tests, each data type is tested for 1) the presence of large data jumps, 2) the presence of large groups of consecutive edited points, and 3) an excessive total number of edited points. Parameters for the edit state tests are the following:

(a) Data discontinuity multiplier (ID)

(b) Maximum number of consecutive edited points (IG)

(c) Percentage of edited points allowed (EDLIM)

Table 3.10. ATOEDT Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
DELTA1	1	DP	D1 edit parameter which determines the largest jump between successive D1b values		.5
DELTA2	1	DP	D2 edit parameter which determines the largest jump between successive D2b values		1.5
DK1	1	DP	D1 edit parameter which determines the largest jump of D1b values relative to the reference D1b.		4.0
DK2	1	DP	D2 edit parameter which determines the largest jump of D2b values relative to the reference D2b.		12.0
EDLIM	1	R	Percentage of edited points allowed (pre-edit, edit state tests)		.8
ID	1	I	Data discontinuity multiplier (edit state tests)		100
IG	1	I	Maximum number of consecutive edited points (edit state tests)		100
MIN1	1	I	Minimum number of points required for D1 edit		3
MIN2	1	I	Minimum number of points required for D2 edit		5
MXELOP	1	I	Maximum number of edit loops		3
RMAX	3	DP	Edit limits for gross pre-edit		
RMAX(1)			Angles edit limit	rads	1.0D0
RMAX(2)			Range edit limit	hrs	1.0D0
RMAX(3)			Doppler edit limit	MHz	1.0D0

Table 3.10. ATOEDT Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
RMIN	3	DP	Minimum editing criteria for D1 and D2 edit		
RMIN(1)			Angles edit minimum	rads	0.D0
RMIN(2)			Range edit minimum	hrs	0.D0
RMIN(3)			Doppler edit minimum	MHz	0.D0
SRCH1	1	R	Level-setting parameter for D1b reference value		.7
SRCH2	1	R	Level-setting parameter for D2b reference value		.7

3.11 MANEDT NAMELIST

The MANEDT namelist furnishes to the user all manual editing and data exclusion options available in the Bench Program. Some options are available in superbatch mode only, and will be indicated by (SB only).

3.11.1 Manual Data Editing Instructions

The user may input all data necessary to perform manual editing via the variable array MEDIT. The MEDIT inputs allow the user to edit batch data by frames.

3.11.2 Data type exclusion Instructions (SB only)

In the SB mode, the user has the option to exclude specific data types from all batches to be processed. Each permissible data type exclusion has its own controlling logical element. If the user desires a certain data type to be excluded, he sets the appropriate logical variable to .TRUE. For example, exclusion of all C-band azimuth data will require the logical element LEXCCA = .TRUE.. See the MANEDT namelist table for a complete listing.

3.11.3 Batch Exclusion Instructions

Two methods are available for exclusion of data batches:

(a) Batch exclusion by batch number. The variable array IEXBAT can be assigned the batch numbers of data batches to be excluded, up to a maximum of 15 batches.

(b) Batch exclusion by station type (SB only). This batch exclusion capability, available in superbatch mode only, is provided to the user for ease in setting up a superbatch OD case in the Bench

Program. Specifically, the user may exclude all C-band, all S-band, or all relay batches from those to be processed. Each type of batch exclusion has its own controlling logical element. Setting the appropriate logical element to .TRUE. will cause the batches of the selected type to be excluded. Logical elements are the following:

(i) LEXCLC - Exclude all C-band batches.

(ii) LEXCLS - Exclude all S-band batches.

(iii) LEXCLR - Exclude all relay batches.

Table 3.11. MANEDT Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
IEXBAT	15	I	Numbers of batches to be excluded		15*0
LEXCCA	1	L	Logical element =.TRUE., exclude azimuth angle in all C-band batches		.FALSE.
LEXCCE	1	L	Logical element =.TRUE., exclude elevation angle in all C-band batches		.FALSE.
LEXCCR	1	L	Logical element =.TRUE., exclude range in all C-band batches		.FALSE.
LEXCHD	1	L	Logical element =.TRUE., exclude hybrid Doppler in all relay batches		.FALSE.
LEXCHR	1	L	Logical element =.TRUE., exclude hybrid range in all relay batches		.FALSE.
LEXCLC	1	L	Logical element =.TRUE., exclude all C-band batches		.FALSE.
LEXCLR	1	L	Logical element =.TRUE., exclude all relay batches		.FALSE.
LEXCLS	1	L	Logical element =.TRUE., exclude all S-band batches		.FALSE.
LEXCRD	1	L	Logical element =.TRUE., exclude 2- or 3-way Doppler in all relay batches		.FALSE.

Table 3.11. MANEDT Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
LEXCRR	1	L	Logical element =.TRUE., exclude 2- or 3-way range in all relay batches		.FALSE.
LEXCSX	1	L	Logical element =.TRUE., exclude X angle in all S-band batches		.FALSE.
LEXCSY	1	L	Logical element =.TRUE., exclude Y angle in all S-band batches		.FALSE.
LEXCSR	1	L	Logical element =.TRUE., exclude range in all S-band batches		.FALSE.
LEXCS2	1	L	Logical element =,TRUE., exclude 2-way Doppler in all S-band batches		.FALSE.
LEXCS3	1	L	Logical element =.TRUE., exclude 3-way Doppler in all S-band Batches		.FALSE.
MEDIT	(4,100)	I	Manual data editing instructions		
MEDIT(1,J) (J=1,2,...,100)			Numbers of batches to be edited		100*(-1)
MEDIT(2,J) (J=1,2,...,100)			Data type(s) to be edited =0, all data types =1, angle 1 =2, angle 2 =3, range =4, Doppler		100*(-1)
MEDIT(3,J) (J=1,2,...,100)			Beginning frame number for editing		100*(-1)
MEDIT(4,J) (J=1,2,...,100)			Ending frame number for editing		100*(-1)

3.12 BRESPL NAMELIST

The BRESPL namelist allows the user to specify the operating parameters for the Batch Residual Plotter. The plotter is activated by the residual print control flag KPR4 in the PRBCTL namelist.

3.12.1 Residual Plotter Units

The user specifies the units for the residuals of each data type. This is done with the IUNITS array.

3.12.2 Residual Plotter Maximum Scale Values

The maximum scale values for each data type to be used by the plotter are input through the variable array RPLOT. Note: Default values for RPLOT are 4xRMS of each data type.

Table 3.12. BRESPL Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
IUNITS	3	H	Names of residual plot units		
IUNITS(1)			Angle units Options are 'MILRAD', 'RAD', or 'DEG'		3HDEG
IUNITS(2)			Range units Options are 'MTRS', 'YDS', or 'FT'		2HFT
IUNITS(3)			Doppler units Options are 'MHZ' or 'HZ'		3HMHZ
RPLOT	4	DP	Residual plot maximum scale values		
RPLOT(1)			Angle 1 maximum scale value =0, RPLOT(1) = 4*RMS	input by IUNITS(1)	0.D0
RPLOT(2)			Angle 2 maximum scale value =0, RPLOT(2) = 4*RMS	input by IUNITS(1)	0.D0
RPLOT(3)			Range maximum scale value =0, RPLOT(3) = 4*RMS	input by IUNITS(2)	0.D0
RPLOT(4)			Doppler maximum scale value =0, RPLOT(4) - 4*RMS	input by IUNITS(3)	0.D0

3.13 BIASCT NAMELIST

The user has the option to apply observation biases to the data types in the batches to be processed in the current OD case.

3.13.1 Observation Data Bias Instructions

The data types to be biased and the batches in which the bias is to be applied are the information input via the variable array BIASIN. Bias may be applied to a data type in a single batch, to a data type in all batches from a particular ground station, or to a data type in all relayed batches having a particular forward or return link ID.

3.13.2 Observation Data Bias Values

The observation biases to be applied to the data types indicated in BIASIN are input via the variable array BIASV.

Table 3.13. BIASCT Namelist

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
BIASIN	(5,20)	H,I	Observation data bias instructions		
BIASIN(1,J) (J=1,2,...,20)		H	Data type bias flags Flag options are: 'SX' , S-band X angle 'SY' , S-band Y angle 'SR' , S-band range 'S2D', S-band 2-way Doppler 'S3D', S-band 3-way Doppler 'A' , C-band azimuth 'E' , C-band elevation 'CR' , C-band range 'R2R', Relay 2- or 3-way range 'R2D', Relay 2- or 3-way Doppler 'RHR', Relay hybrid range 'RHD', Relay hybrid Doppler		20*6Hb̸
BIASIN(2,J) (J=1,2,...,20)		I	Number of data batch in which J-th data type is to be biased. (If BIASIN(2,J) = 0, the J-th data type will be biased in all batches from the station or TDRS vehicle indicated below.)		20*0
BIASIN(3,J) (J=1,2,...,20)		H	Station ID (All data batches from this station will have the J-th type biased.)		20*0
BIASIN(4,J) (J=1,2,...,20)		H	Forward link TDRS ID. (All relayed batches with this forward link ID will have the J-th data type biased.)		20*3Hb̸
BIASIN(5,J) (J=1,2,...,20)		H	Return link TDRS ID. (All relayed batches with this return link ID will have the J-th data type biased.)		20*3Hb̸

Table 3.13. BIASCT Namelist (Concluded)

VARIABLE	DIM	TYPE	DESCRIPTION	UNITS	DEFAULT
BIASV	20	DP	Observation bias values. (The value prescribed in BIASV(J) will be that bias applied to the J-th data type.)	rads, hrs, or MHz	20*0.D0

4. PROGRAM RUN PROCEDURE

This section gives the logical unit assignments for the OPS Bench Program, and provides the program deck setup for a Bench Program run.

4.1 TAPE UNITS

The OPS Bench Program requires the following two tapes for any program run:

(a) Program Tape

(b) Planetary Ephemeris Tape

The current ephemeris tape in use is the JPL Tape PE50D. The PE50D tape is assigned to logical unit 13.

There are two optional tapes:

(a) Observation Data Batch Tape

(b) Station Characteristics Tape

These tapes are required input for a batch-to-batch or superbatch OD case, and may be omitted for a trajectory only case. The Data Batch Tape is assigned to logical unit 9; the Station Characteristics Tape is assigned to logical unit 10.

4.2 PROGRAM DECK SETUP

Figure 4-1 on the following page provides an illustration of the program deck setup for an OPS Bench Program run.

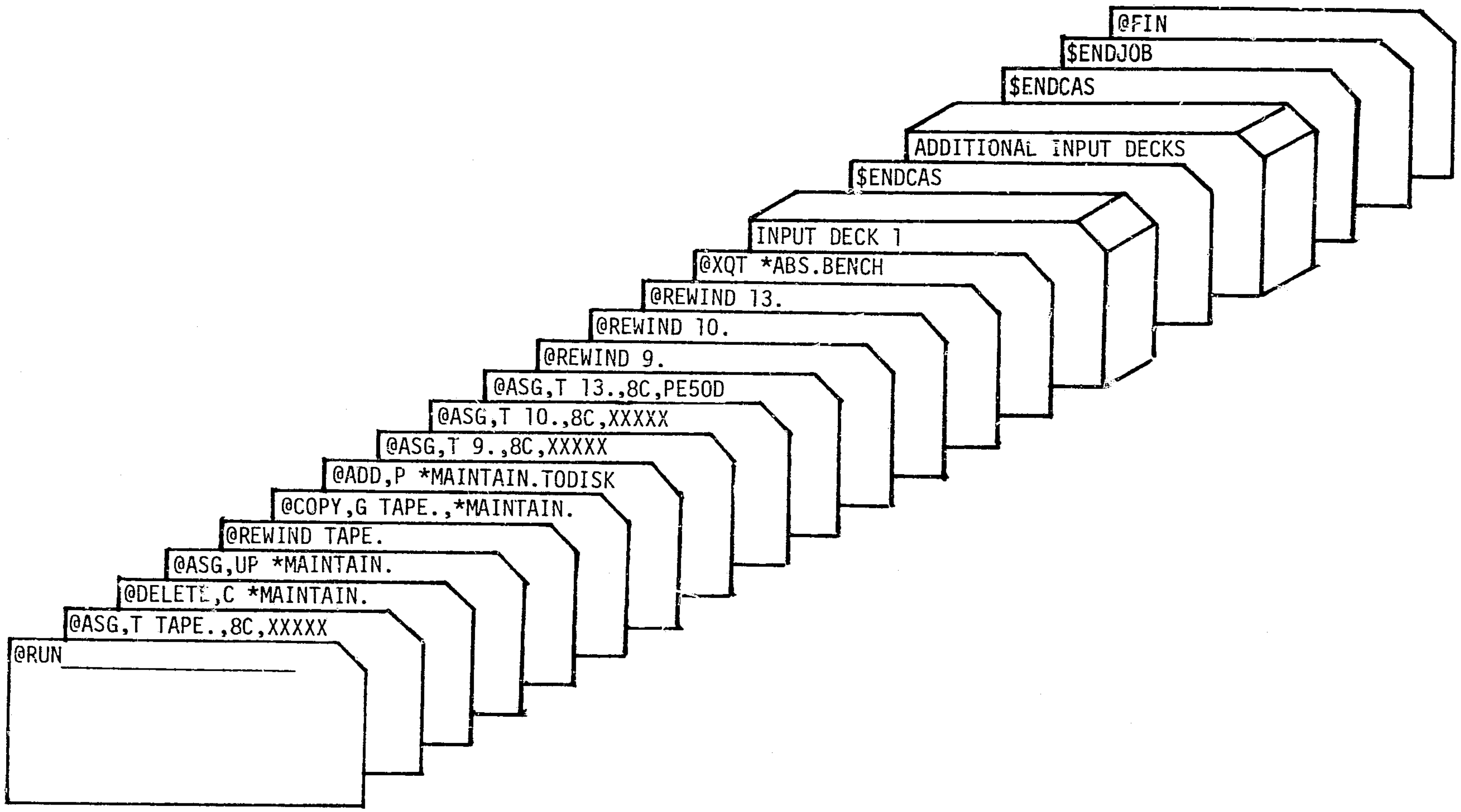

Figure 4.1. Program Deck Setup

5. PROGRAM OUTPUT: SAMPLE CASES (TBD)

This section is intended to contain several sample cases which illustrate typical OPS Bench Program runs. Each case will include the following:

(a) Case description

(b) List of program options employed in that case

(c) Listing of card input for that case

(d) Output print generated in the execution of that case

The user will find in these sample cases all the types of printed output available from the Bench Program: printout of card input and data batches, DC printout, trajectory printout, and the various elements of display printout.