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TRACE-D USERS' MANUAL

JULY 1969

S. G. Santarelli

Prepared for

DIRECTORATE OF PLANNING AND TECHNOLOGY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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Project 7070
Prepared by
THE MITRE CORPORATION
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FOREWORD

This report was prepared by The MITRE Corporation for the Directorate of Planning and Technology, Electronic Systems Division, Air Force Systems Command, L.G. Hanscom Field, Bedford, Massachusetts, under Contract F19628-68-C-0365.

REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

ANTHONY P. TRUNFIO
Technical Advisor
Development Engineering Division
Directorate of Planning and Technology

ABSTRACT

This report describes the MITRE version of the TRACE-D program now in operation. While the primary function of TRACE-D is orbit determination, options are also available in the program for trajectory prediction and observational data generation. A functional description of these features is contained in this report along with a complete user's manual and a brief program description.

PREFACE

The program described herein is a modified version of the TRACE-D program originally developed by the Aerospace Corporation in Los Angeles. Although the modifications made were many and included conversion of the program to FORTRAN IV and STRAP, restructuring of the program logic, and the addition of minor options and features, the basic functions (i.e., orbit determination, trajectory prediction, and observational data generation) remain intact.

The people involved in various aspects of the effort, in addition to the uthor, were Dr. K. K. Maitra, G. M. Hyder, P. E. Shifres, and S. Schwartz. A great deal of appreciation is due to K. W. Hubbard, C. C. Tonies, and other members of the Flight Mechanic's Department of the Aerospace Corporation whose cooperation in obtaining the program and unlimited assistance throughout the task were invaluable.

This report is intended solely as a user's guide to the TRACE-D program, and therefore contains only a brief functional description of the analytics. For the reader seeking the mathematical details and arguments the ideal reference is the original document[1] issued by the Aerospace Corporation (see [1]).

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[1] Material from this Aerospace document has been freely incorporated into this report wherever pertinent and is not to be taken as original.

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Section 1.

BASIC INFORMATION

1.1 Introduction

This document is intended as a user's manual and therefore does not discuss the theory and mathematical details of TRACE-D except in a functional context. Section 1 of this report presents some program history, a brief summary of the modification process, and a statement of the program's present status. Section 2 specifies the functional capabilities of TRACE-D while Sections 3 and 4 describe input and output (patterned after the original TRACE-D document) and Section 5 contains programming information. Wherever pertinent, throughout the report, material from the Aerospace documentation has been freely incorporated.

1.2 Program History

The TRACE-D orbit determination program was developed by the Aerospace Corporation as a multipurpose, flexible computational tool for application to problems in orbit analysis. A major design objective was that the program be able to provide answers to a wide range of problems relating to orbit and system design, space vehicle performance, and force model analysis. It was not and is not a "real time" program and therefore it is most effective for post-flight analysis and also for research and investigative purposes. The program has been used extensively and successfully by the staff at Aerospace in just such an environment.

TRACE-D was originally written in FORTRAN II and FAP for use on the IBM 7094 computer in the "CHAIN" multi-coreload mode of operation. About thirty-percent of the program consisted of machine language (FAP) subroutines including the numerical integration package. The status of the program at the time of its release to us was reported to be operational for all functions.

1.3 Modification Process

The primary objective of this effort was to produce a version of TRACE-D operable on the IBM 7030 computer here at MITRE. To accomplish this, two separate yet simultaneous endeavors were carried out; one being to get the original TRACE-D program to run successfully on a nearby 7094 installation, and the other the actual conversion of routines to FORTRAN IV and STRAP and the reconstruction of the program. Upon completion of this phase, the next step was the checkout and "debugging" of the 7030 version of the program. This task was greatly facilitated and accelerated by running test cases for all options with both versions (7094 and 7030) of TRACE-D and checking all results.

Having accomplished the primary objective satisfactorily, work began on minor adjustments and additions to the program. Such features as observation residual plotting, an expanded earth geopotential capability, and a dynamic constraint matrix capability for site location adjustments were implemented. At the present time the program is operational on the 7030 computer and has produced meaningful and significant results for many MITRE orbit-related problems.

Section 2.
MAJOR PROGRAM FUNCTIONS

2.1 Trajectory Prediction

Basic to all the functions of the TRACE-D program is the generation of a time history (either in a forward or backward direction; see Section 3) of the position and velocity of a space vehicle in an inertial frame of reference. However, this inertial ephemeris as well as its associated ground track and altitude history are, in many instances, of interest in themselves. Thus, these computations are performed and printed out in the trajectory prediction mode of TRACE-D.

The motion of a space vehicle is generated by numerical integration of the appropriate differential equations of motion. Using a Cowell formulation (i.e., expressing the total acceleration vector as three components in a cartesian system $[\ddot{x}, \ddot{y}, \ddot{z}]$) three non-linear second-order differential equations are derived. A predictor-corrector numerical integration procedure based on "eighth-order differences" is used to obtain position (x, y, z) and velocity $(\dot{x}, \dot{y}, \dot{z})$ at any time t based on the known position and velocity at some initial time t_0.

The total acceleration vector, mentioned above, is actually a sum of the effects of the perturbing forces that comprise the TRACE-D dynamic model. The earth geopotential effects (gravity) are included in the form of a spherical harmonic expansion with provision for zonal harmonics J_2 through J_{15} and all tesseral and sectorial terms through $J_{15,\ 15}$. Effects due to other bodies in the solar system (Sun, Moon, Venus, Mars, Jupiter) are computed from inverse-square law formulas and positions of the other bodies are obtained from tabulated coordinates stored on magnetic tape (planetary tape). Acceleration due to atmospheric drag is assumed to be directly proportional to the square of the velocity of the vehicle relative to the air. The atmospheric density is obtained from one of two different model atmospheres that are incorporated into the program according to the user's choice. Instantaneous changes in the inertial velocity vector may be applied at specific times to simulate maneuvers such as orbit adjust or vehicle separation. Also, an included low-thrust acceleration term may be used to simulate thrust tailoff in cases involving large engines, long-term constant thrust, or, in some instances, leaking tanks or valves.

Although all of the above effects are programmed into the TRACE-D equations of motion, the actual model that is employed may include some, all, or none of these perturbations. The user has the option to choose the model by setting a series of indicators. The comparative listing of associated input and output quantities given in Table 1 suggests the range of potential application. Complete instructions for preparation of trajectory mode input data and a sample of a typical trajectory mode output listing are given in Sections 3 and 4.

2.2 Observation Generation

The object of the data generation function is to generate various forms of simulated measurements from a given definition of the ephemeris of a vehicle and the location of observing stations on the earth's surface. These measurements may be any of twenty different types from up to one hundred different sites and may be generated at user-specified frequencies. Both "clean" and "noisy" data are available, the latter being generated by adding noise of specified variances and biases to the "clean" measurements. Upon user request, the visibility function (i.e., the rise and set times) of a vehicle with respect to one or more stations may be obtained without printout of any intermediate data. When data is generated, it may be written on magnetic tape or punched on cards and is formatted such that it is readily available as input to the orbit determination process.

This option lends itself well to many applications, two of which are the following: studies of the effects of specific data imperfections on orbit determination convergence behavior and the fitting of data using a different force model than that used to generate the data giving insight into the real-world problem of fitting live data with programmed (and always less than perfect) dynamic models.

Since the calculations performed for this option encompass all the calculations of the trajectory prediction mode, the input quantities include all those listed in Table 1 plus the additional information in Table 2. Available output quantities are listed in Table 2 also, but a more specific list of available data types with definitions is included in Sections 3 and 4.

2.3 Orbit Determination

Orbit determination is the primary function of the TRACE-D program and encompasses both the trajectory prediction and observation generation modes. Stated in simplest form the orbit determination problem consists of extracting information from observations (possible 20 types) of a space vehicle. The data is generally collected by a network of tracking stations on the surface of the earth. Nearly always, the information to be extracted includes the orbital elements but may include many other parameters of the dynamic model and of the tracking system.

The process of extraction in TRACE-D takes the form of a generalized least-squares differential correction procedure. More specifically, the goal is to determine values for a set of parameters (from the dynamic and/or observational model) such that the differences between the actual input measurements and corresponding values computed from the model (usually termed observation residuals) will be minimized in a least-squares sense. The solution set may be comprised of not more than one hundred parameters, of which not more than sixty may be trajectory-related parameters (i.e., initial conditions, geopotential coefficients, etc.). The amount of data that may be fitted is restricted only by the nature of the problem and not by the program.

Table 1.

Input/Output Quantities Associated with TRACE-D Trajectory Mode

Input Data		Output Data
1. Earth-model constants		1. Satellite inertial position and velocity in rectangular and spherical coordinates
2. Atmosphere model constants		
3. Solar system constants		2. Magnitudes of geocentric-radius and inertial-velocity vectors.
4. Units conversion factors		3. Latitude and longitude of sub-vehicle point
5. Numerical integration-control constants		4. Altitude above earth
6. Epoch time	Items Printed Out at Regular Time Intervals	5.* Differences between two trajectories in rectangular, spherical, classical element, and orbit-plane coordinates
7. Position and velocity or orbital elements at epoch time		
8. Satellite ballistic coefficient		6.* Time difference between corresponding points of two trajectories
9. Time, magnitude, and direction of velocity increments		7.* Magnitudes of distance and velocity difference vectors for two trajectories

* Associated with a trajectory differencing

Table 1 (cont.)

Input Data	Output Data	
10. Interval, amplitude, and decay rate of low thrust 11. Table of time points where output is to occur 12. Parameter selection indicators 13. Tape-unit numbers for trajectory differencing 14. Latitudes and longitudes where special printouts are to occur		8.** Partial derivatives of trajectory position with respect to differential-equation parameters 9.** Differences between changes in position and velocity produced by perturbing parameters and changes predicted by corresponding calculated partial derivatives
	Items Printed Out at Special Time Points	10. At time when vehicle crosses ascending node: Output Items 1 through 4 above Classical orbital elements Mean and true anomaly Nodal regression rate Rate of advance of the line of apsides Apogee and perigee radius and altitude Keplerian, anomalistic, and nodal periods

** Refer to the partial derivatives of trajectory position with respect to selected parameters.

Table 1 (cont.)

Input Data	Output Data	
15. Minor option indicators	Items Printed Out at Special Time Points	10. (continued) Revolution number Nodal period Nodal period decay Nodal regression (this set obtained by simple differencing rather than by formula) 11. At time of the event Orbit adjust magnitude and direction Magnitude of low thrust at start and stop times and at ascending node times 12. At the time when the flight path angle passes through ninety degrees (roughly at apogee and perigee): Output Items 1 through 4 above 13. At the time when the vehicle reaches local maximum or minimum altitude (when h = 0): Output Items 1 through 4 above

Table 2.

Input/Output Quantities Associated with TRACE-D Observation Generation Mode

INPUT DATA	OUTPUT DATA
1. All input listed in Table 1.	1. Computed observations
2. Site location coordinates	2. Rise-set times (per station)
3. Visibility function indicator	*3. Observation uncertainties
4. Observation types	
5. Observation frequencies	
6. Noise information	
7. Output mode (card, tape)	
8. Refraction specifications	
9. Uncertainty matrix for adBARV at epoch	

* Is the propagation and effect of input 9 above.

In fact, TRACE-D is capable of fitting observational data from six vehicles in a single orbit determination procedure. It allows for estimation of the trajectory initial conditions and drag coefficients associated with five satellites in addition to the usual parameters in a single satellite run.

The list of all possible input for the orbit determination mode is quite extensive as can be seen from Table 3. This is, of course, due to the comprehensive model programmed into TRACE-D for the purpose of wider and more varied applications. However, flexibility has not been sacrificed for completeness, so that the program is easily adaptable to either a non-real or more-real environment by simple input adjustment. The input and output capabilities of orbit determination are listed in Table 3 and described in detail in Sections 3 and 4. Table 4, which follows, is a complete list of all possible parameters that may be differentially corrected in TRACE-D.

Table 3.

Input/Output Associated with

Orbit Determination Mode

INPUT	OUTPUT
1. All input in Table 1.	1. Chronological list of all observations by satellite
2. Parameters in solution set	2. Variational equation solutions
3. Initial conditions for satellites 2-6	3. Trajectory printouts
4. Bounds for parameter correction	4. Observation partial derivatives
5. Station locations	5. Residuals
6. Data errors and biases	6. Station and observation type RMS summary
7. Data editing criterion	7. Computed and predicted RMS
8. Refraction correction indicators	8. Corrections
9. Iteration count	9. Covariance matrix
10. Constraint matrix for parameters	10. Correlation matrix
11. Observations from all vehicles	11. Solution set
12. Tape specifications	12. Tape of residuals

Table 4.

Parameter List*

1. Initial position and velocity components in either spherical, rectangular, or classical element form for up to six independent space vehicles.
2. Reciprocal of ballistic coefficients for up to six different satellites.
3. Up to six velocity increments (KICKS) for one satellite.
4. Amplitude and time constant for an exponentially decaying low thrust.
5. Zonal harmonic coefficients J_2 through J_{10} and all tesseral harmonics $J_{2,1}$ through $J_{6,6}$.
6. Constant biases on all types of observations.
7. Scale factors for range and range-rate observations.
8. Time biases (i.e., biases in reported times at which observations were made).
9. Latitudes, longitudes and altitudes above sea level of observing stations.

* On any one run up to 100 of listed quantities may comprise the solution set with not more than 60 from types 1-5.

Section 3.

Usage

3.1 Preliminary Facts

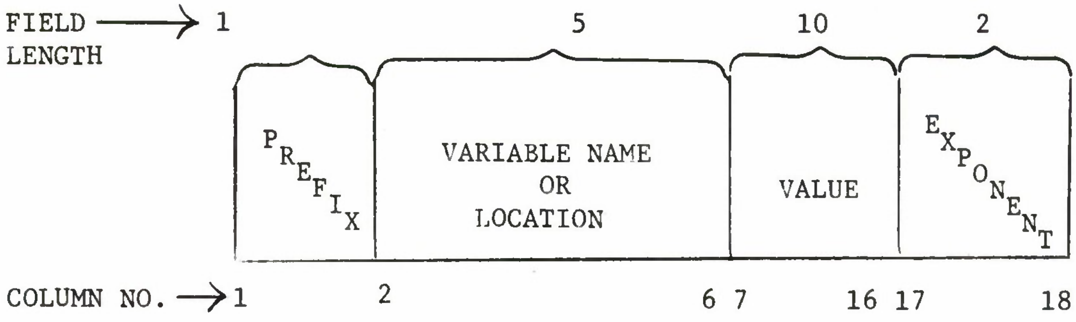
In order to run the TRACE-D program the user need not concern himself with the internal elements of the program[1] nor worry about handling a cumbersome deck of cards. The entire program is stored on tape and can be used simply by attaching an appropriate data deck to the small basic running deck supplied by MITRE and submitting the job for execution. The basic running deck contains only tape usage information and the necessary instructions to trigger execution, therefore it is never necessary for the user to alter it in any way. Due to the varied tape requirements for each of the major functions, there are three versions of the basic running deck and the appropriate one must be used for each option exercised.

The input to the TRACE-D program falls into two categories: one which follows the normal FORTRAN IV rules of input and the other which is interpreted by a special routine in the program. The former method is used for all observing-station data (only a fraction of total input) and needs no description, while the latter method is used for all remaining input and requires a brief explanation.

The input routine accepts each piece of data from a data card in a field of eighteen columns in length with four distinct subfields as shown on the following page.

---

[1] The user who is curious or interested in the actual programming facts will find these concisely presented in Section 5.



1. Prefix Field - The prefix field is one column in length and can occupy columns 1, 19, 37, or 55. The mode of the input that follows is dictated by what is punched (or not punched) in the prefix field. The following are the permissible prefixes.

Prefix	Data-Modes
blank	Floating point number, number contains or implies a decimal point.
I	Fixed point number, no decimal point.
D	Hollerith information, data is not a number but a sequence of characters which can extend into the exponent field.
G	Used in connection with integration parameters, basic constants and the earth model. It indicates that card contains a symbolic name followed by a comment.
H	Followed by 1 or 2 in column 2. This is simply a header card to be printed at various places on the output. The number 1 indicates columns 1-80 and 2 indicates columns 81-132 on the printout.

2. Location Field - The location field is 5 columns in length and starts in columns 2, 20, 35 and 56. The information punched in the location field is either a symbolic name or a subscript. A symbolic

name defines a location in core where the data is stored. In the case of a subscript, it is used with respect to the immediately preceding symbolic name. Therefore, whenever a symbolic name is the name of a table, a subscript of 1 is attached to that name and those subscripts greater than 1 indicate storage relative to the start of the table. All names and subscripts should be left-adjusted within the field.

3. Value Field - The value field, 10 columns in length, starts in columns 7, 25, 43, or 61. This field together with the exponent field contains the numerical or hollerith data which is to be input. In the event the data is an integer (prefix = I) the exponent field is ignored. If the data is a floating point number (prefix column is blank, not punched) the decimal point, whenever it is not punched within the value field, is assumed to be after the last digit. Whenever hollerith data is input (prefix = D) the exponent field becomes an extension of the value field thus allowing for a total of twelve characters in the hollerith quantity. All data in the value field must be left-adjusted.

4. Exponent field - The exponent field, two columns in length, starts in columns 17, 35, 53, and 71. This field allows for a range of floating point numbers from 10^{-19} to 10^{-99}. An exponent of - 10 or smaller must start with the letter J (i.e., J0 = - 10, J5 = - 15, etc.). As in the value field the characters in the exponent field must be left-adjusted.

Although the input routine will accept four input fields per card, it is not necessary to use all four. One field used per card is just as correct since the rest of the card is ignored.

In addition to the precise field format there are a few other rules of input preparation.

1. The actual order of the data cards is almost immaterial, the only restriction being that all values with subscripts in the location field are placed in the input deck relative to the last previous symbolic name.

2. Any input which does not apply to the immediate run or is to have

a value of zero need not be specified.

3. In the case of two appearances of the same location symbol, the last one to appear defines the effective input.

4. The basic input units are feet, degrees, and seconds. Therefore, whenever the units are not stated then they are a combination of the basic set.

With the preceding basic description and the details on input preparation that follow, the user should have sufficient knowledge to use the TRACE-D program successfully.

3.2 Basic Data

The term "basic data" is defined as the data that is common to all the principal TRACE-D functions. This includes the constants for the integration procedure, the necessary physical constants, function indicator, trajectory specifications (like epoch time, initial conditions) and force model inputs.

3.2.1 Constants

The constants constitute two lengthy lists of input and involve quite a bit of keypunching. Because of this, there is available a standard set, in card deck form, which may be used as is, or altered for specific entries. This facility reduces the user's card preparation time and eliminates possibility of error.

In the event that the constants must be punched they must be formatted as shown on the following page.

3.2.1.1 Lines 1 - 19 Standard Set of Integration Constants[1]

LINE #	PREFIX	NAME OR SUBSCRIPT	VALUE	EXPONENT
	Cols. 1,19,37,55	Cols. 2,20,38,56	Cols. 7,25,43,61	Cols. 17,35,53,71
1	G	INTEG		
2	I	1	1	
3	I	2	2	
[2] 4	I	4	1	
5	I	5	1	
6		11	1.00002516	
7		23	1.	J0
8		26	1.	
9		30	1.	
10		31	.015625	
11		32	64.	
12		33	1.	- 7
13	I	34	4	
14	I	35	1	
15	I	36	0	
16		37	.001	
17		38	0.	
18		40	2820.1763	
19	I	41	1	

---

[1] For definitions of the constants consult Table 5.

[2] Notice that there are entries missing in the INTEG list, like the 3rd one, for instance. This is because these entries are either not necessary for all options or are used by the program and not available to the user. This is true in both constants lists.

3.2.1.2 Lines 20 - 46 Standard Set Physical Constants[1]

LINE #	PREFIX	NAME OR SUBSCRIPT	VALUE	EXPONENT
	Cols. 1,19,37,55	Cols. 2,20,38,56	Cols. 7,25,43,61	Cols. 17,35,53,71
20	G	C		
21		1	.43752691	- 2
22		2	.55303935	- 2
23		6	.5	
24		8	.43752691	- 2
25		9	1.	
26		13	3280.8399	
27		14	57.2957795	
28		15	20925738.	
29		16	332951.3	
30		17	.0122999	
31		18	.814979	
32		19	.107821	
33		20	317.887	
34		21	95.129	
35		22	23454.865	
36		23	3443.9336	
37		24	20925738.	
38		25	348762.3	
39		26	32.174	
40		30	348762.3	
41		31	1.5	
42		32	1.0471976	
43		33	3.14159265	
44		34	298.3	
45		35	300000.	
46		36	82505.922	

---

[1] For definitions of constants consult Table 5.

Table 5.

INTEG and C Constants Lists

INTEG	PARAMETERS OF THE TRAJECTORY INTEGRATION	
1	1	Formulation. 1 - Cowell (eqs. of motion), 2 - Encke (note: the Encke-T formulation is presently not available)
2	2	Differential equation subroutine. 1 - AMRK, 2 - COW
3		angle in degrees for changing mean to true equinox
4	1	Sun (4-9) are selectors for other-body perturbations
5	1	Moon If tape unit number at numb(18) is not zero,
6	0	Venus the perturbations are included or omitted
7	0	Mars according as the selector is non-zero or zero
8	0	Jupiter
9	0	Saturn
10	C(22)	Sun (10-15) are interpolation scale factors for use using contents of C(22), the number of earth-radii in an astronomical unit:
11	1.00002516	Moon
12	C(22)	Venus
13	C(22)	Mars
14	C(22)	Jupiter
15	C(22)	Saturn
16	0	Similar velocity scale factors. (not now used, and
thru		all zero).
21	0	
22		(used internally - Encke)
23	IE-10	E Bar, COW subroutine truncation error control parameter.
24		(used internally - Encke)
25		(used internally - Encke)
26	1.	A, see COW writeup.
27-29		(not used)
30	1.	Initial time step size.
31	.015625	Minimum time step size (1/64)
32	64.	Maximum time step size
33	1E-7	Kepler equation convergence criterion.
34	4	Ratio of Cowell step size to Runge-Kutta step size
35	1	if 1, do not recompute perturbations for corrector. if 2, do.
36		Flag for perturbation computation (used if INTEG(35) = 1).
37	.001	Least squares convergence criterion (relative)
38	0	Least squares convergence criterion (absolute)
39		(not used)
40	2820.1763	Speed of light (earth-radii/minute)
41	1	If non-zero, round position and velocity vectors for acceleration computation. If zero, truncate

Table 5 (cont.)

INTEG	PARAMETERS OF THE TRAJECTORY INTEGRATION
42	Reserved for later use

C CONSTANTS		
1	.0043752691	Earth rotation rate (rad/min)
2	.0055303935	Gm, earth gravitation constant (ER**3/min**2)
3		Option for speed of light correction
4		B=1-E, relative semi-minor axis of ellipsoid (computed in CSET)
5		B**2/A**2 = (1-E)**2 (computed in CSET)
6	.5	Factor for decreasing bounds in L. S. solution
7		2*E-E**2 (computed in CSET)
8	.0043752691	Atmosphere rotation rate (rad/min)
9	1.	Earth radius
10		Input N for N-sigma residual editor
11		Input scale factor for N-sigma residual editor
12		If input non-zero, go thru 1^{st} iteration twice for sums
13	3280.8399	Feet/kilometer
14	57.2957795	Angle conversion factor
15	20925738.	A, earth radius in feet
16	332951.3	Relative mass of sun
17	.0122999	Moon
18	.814979	Venus
19	.107821	Mars
20	317.887	Jupiter
21	95.129	Saturn
22	23454.865	Earth-radii/astronomical unit
23	3443.9336	Nautical miles (6076.1155 ft)/earth radius
24	20925738.	I/0 distance conversion factor
25	348762.3	I/0 velocity conversion factor
26	32.174	Go (used for CDA/W and thrust/W)
27		Input parameter difference for trajectory differencing
28		Input threshold for percent difference for trajectory differencing
29		Constant for doppler rate
30	348762.3	Ft/sec per Er/min
31	1.5	Factor for increasing bounds in L. S. solution
32	1.0471976	Rad/min per deg/sec
33	3.14159265	PI
34	298.3	Reciprocal of E = ellipticity
35	300000.	Critical altitude (ft)
36	82505.922	Deg/day per rad/min
37-39		Direction cosines of body axis for look angle

3.2.2 Functions to be Performed

LINE #

47	D	ITIN	1234	

[1]

Line 47 contains the ordered list of all functions to be performed during a single run. Selection of functions is governed in accordance with the following code numbers.

Code numbers Functions

12 → Orbit Determination

3 → Trajectory Prediction

4 → Data Generation

Up to twelve functions may be selected in any one run, i.e., the program will perform twelve specified functions in one continuous machine job. The example above specifies that an orbit determination be carried out first followed by a trajectory prediction and then a data generation.

3.2.3 Trajectory Specifications

3.2.3.1 Lines 48-54 Epoch

48	I	YEAR	1963	
49	I	MNTH	6	
50	I	DAY	15	
51		TZNE	0	
52		HR	12	
53		MIN	45	
54		SEC	15.5	

---

[1] Please notice that the field labels are no longer specified (i.e., Prefix, Value, etc.) but they are, of course, implied by the divisions.

In the usual case, wherein the year, month, and day are input with the year positive, the X-axis is directed to the vernal equinox. Alternatively, if the year is input negative, the X-axis would be directed to the longitude of Greenwich. The hour, minute, and second entries refer to midnight of zone time. Greenwich Mean Time is Time Zone 0.

3.2.3.2 Lines 55-61 Initial Conditions

55	I	ICTYP	2	
56		IC	126.1	
57		2	31.23	
58		3	89.	
59		4	14.	
60		5	22600114	
61		6	25117.3	

Line 55 indicates which of the ten IC types (1, 2, ..., 9, 0) are entered in Lines 56 through 61. The alternative ICTYP entries are characterized as follows:

a. IC Type 1 Earth-centered inertial cartesian coordinates (x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$ in units of feet and feet per second) (see Section 3.1.1.1).

b. IC Type 2 Spherical coordinates (α, δ, β A, R, v) in units of degrees, feet, and feet per second (see Section 3.1.1.2). In Line 14, negative r is interpreted as height above the earth's surface in feet. In Line 15, if v is negative, cifcular velocity is computed and used.

c. IC Type 3 Orbital elements (a, e, i, Ω, ω, τ) in units of feet, degrees, and minutes (see Section 3.1.1.3).

d. IC Type 4 Same as Item b above, with longitude λ replacing right ascension α.

e. IC Type 5 No IC's input. The last trajectory point of the immediately preceding case is used.

f. IC Type 6 No IC's input. The corrected initial conditions from the last previous tracking run are used.

g.	IC Type 8	Either Type 1 or 2 above, but in units of earth radii, minutes, and radians. Type number is entered at CPRAM (see Section 5.1.2.2).
h.	IC Type 9	Same as Type 1 above, but in units of earth radii and earth radii per minute.
i.	IC Type 0	No IC's input. For a tracking run, two R, A, E sets are used from the data to calculate a set of initial conditions (see Section 3.6.6).

3.2.4 Force Model Inputs

3.2.4.1 Lines 62-68 Drag and T Matrix

62		DRAG	.01	
63	I	2	1	
64		4		
65		4		
66		6	-8.6	
67		7	-55.5	
68	I	TMATX	4	

Line 62 contains the drag parameter $C_D A/W$ in square feet per pound and Line 63 contains the atmosphere model specification (ARDC 59 or Lockheed/ Jacchia). The ARDC model will be used when DRAG(2) is 0 and the Lockheed/Jacchia model when DRAG (2) is 1. If line 63 is a 1, Lines 64 and 65 contain quantities used in the Lockheed/Jacchia model.

Lines 64 and 65 contain d_1 and d_2, respectively. These are values of certain constants in the Lockheed-Jacchia atmospheric density expressions. (Consult reference 1 for details).

An entry in Line 68, TMATX, will cause the T matrix (the 3 × 3 matrix describing the dependence of drag force upon vehicle position) to be used in the variational equations in accordance with the following options:

a. TMATX = 0 T matrix is not used.

b. TMATX = 1 Input $\partial\rho/\partial h$ is used with no earth flattening.

c. TMATX = 2 Input $\partial\rho/\partial h$ is used with earth flattening.

d. TMATX = 3 $\partial\rho/\partial h$ is calculated with no earth flattening.

e. TMATX = 4 $\partial\rho/\partial h$ is calculated with earth flattening.

Also, with TMATX non-zero, Lines 66 and 67 should contain input values for $\partial\rho/\partial h$. Lines 66 and 67 contain $\partial\rho/\partial h$ for altitudes between 76 and 108 n. mi. and between 108 and 376, respectively. It should be noted that input values for $\partial\rho/\partial h$ must be used with the ARDC 1959 model. If a variable C_D term is desired, the drag table option may be utilized. In this case, the drag parameter may be considered to consist of the product of two terms, $(C_DA/W) \times C_D'$, wherein C_DA/W is a constant which can be differentially corrected by the use of the variational equation and C_D' may be considered a function of Mach number below a certain altitude and as a function of altitude at points above that altitude. Alternatively, C_D' may be considered a function of time. In either case, use of the drag table is necessary.

When the drag table is not used, input of C_DA/W into the DRAG location does not change usual TRACE operation. In this case, C_D' is automatically set equal to 1. If the drag table is used, the following additional inputs are required:

a.	DRAG(10)	If DRAG(10) = 0, tables not used. If DRAG(10) = 1, Mach and altitude tables used. If DRAG(10) = 2, time table only used.
b.	DRAG(11)	Altitude above which altitude table is used and below which Mach table is used (needed if (DRAG(10) = 1).
c.	DRAG(12) = 0	Used by interpolation routine.

	DRAG(13) through (35)	Altitude table, or time table if DRAG(10) = 2 (h_1, $C'_D(h_1)$, h_2, $C'_D(h_2)$ . . . , h_n, $C'_D(h_n)$, 0, 0, or t_1, $C'_D(t_1)$, t_2, $C'_D(t_2)$, . . . , t_n, $C'_D(t_n)$, 0, 0).
d.	DRAG(36) = 0	Used by interpolation routine.
	DRAG(37) through (59)	Mach table (stored as noted in Item c. above).

3.2.4.2 Lines 69-75 Other Body Perturbations

68	I	CTAPE	7	

If perturbations due to other bodies in the solar system are to be included in the trajectory calculations, a planetary coordinate tape must be mounted and the logical-tape unit number 7 must be entered at CTAPE.

69	G	C		
70	I	4	1	
71	I	5	1	
72	I	6	0	
73	I	7	0	
74	I	8	0	
75	I	9	0	

Lines 69-75 contain the C constants that indicate which bodies are being considered. The six bodies corresponding to C(4) through C(9) are the Sun, Moon, Venus, Mars, Jupiter, and Saturn. Entering a 1 in C(4) implies that the Sun is to be considered, while entering a 0 in C(9) implies that Saturn is ignored. Therefore, in the example above only the Sun and Moon are used in the other-body perturbation computation.

3.2.4.3 Lines 76-79 Exponential Thrust

76		THRST		
77		2		
78		3		
79		4		

If an exponential thrust is to be used, the quantities T_1 in units of force/mass = ft/sec^2, T_2 in units of min^{-1}, and t_s and t_f in seconds from midnight of epoch date must be input at THRST, THRST(2), THRST(3), and THRST(4) locations, respectively.

3.2.4.4 Lines 80-96 Gravity Perturbations

80	I	IFLAG		
81	I	28	0	

Lines 80 and 81 above contain the input quantity IFLAG(28) = 0. This is an indicator that must be set in order to clear storage for the earth model that is to be specified.

82	I	IOB	10	
83	I	2	6	
84	I	3	10	
85	I	4	6	

Lines 82-85 define the number of terms to be used in the earth geopotential expansion. IOB(1) is the number of zonals and IOB(2) is the index of tesserals. Therefore, in the example above, 10 zonals will be used and tesseral terms up to and including the 6,6 term. Lines 84 and 85 specify IOB(3) and (4) which are the number of terms to be used in the V-matrix. The V-matrix is a measure of the dependence of the gravitational force upon vehicle position and is included as one of the many necessary calculations for the observation partial derivatives (for differential correction).

If these two values are set to zero the V-matrix calculations are ignored. For a derivation of the V-matrix and its implications Appendix B of Reference 1 is recommended.

86		OBJZ		
87		2	1,826	-2
88		3	2,485	-6

Lines 86-88 specify the zonal coefficients in the following order:

OBJZ (1)	not used
(2)	J_2
(3)	J_3 etc.

89		OBJT		
90		2	1.556	-6
91		3	2.26	-6
92		4	1.72	-6
93		OBLT		
94		2	16.18	
95		3	35.62	
96		4	108.2	

Lines 89-96 specify the tesseral coefficients and the lambdas to be used, in the following order:

OBJT	J_{nm}	OBLT	τ_{nm}
(1)	J_{21}	(1)	τ_{21}
(2)	J_{22}	(2)	τ_{22}
(3)	J_{31}	(3)	τ_{31}
(4)	J_{32}	(4)	τ_{32}
(5)	J_{33}	(5)	τ_{33}
(6)	J_{41}	(6)	J_{41}
	etc.		etc.

3.2.5 Miscellaneous Inputs

3.2.5.1 Lines 97-100 Instantaneous Orbit Adjusts

97		PKICK	89020.31	
98		2	200.	
99		3	0	
100		4	62.	

Instantaneous orbit adjusts are input at PKICK. Line 97 contains t_1 (time of first orbit adjust, OA_1) in seconds from midnight of epoch; Line 98 contains K (magnitude of velocity change of OA_1) in feet per second; Line 99 contains θ (yaw angle for OA_1) in degrees, and Line 100 contains θ_p (pitch angle for OA_1) in degrees.

The TRACE-D program will accommodate up to six orbit adjusts. Additional cards may be added as necessary for OA_2 through OA_6.

3.2.5.2 Lines 101-107 Extra Kicks

101	I	NXK	3	
102		XKICK	63456	
103		2	.2	
104		3	88721	
105		4	10.	
106		5	101018	
107		6	.02	

Up to fifty fixed orbit adjusts (i.e., instantaneous changes of the in-track velocity component) may be input at XKICK. It should be noted that these orbit adjusts are not parameters for differential correction, but are applied in the equations of motion only and are independent of the PKICK inputs. The number of extra kicks ($\leq$ 50) is input at NXK, and the table of times and ΔV values is input beginning at XKICK. The format is time, ΔV, time, ΔV, etc., in units of seconds from midnight of epoch day and feet per second, respectively.

3.2.5.3 Line 108 Print Code

108	D	PRCDE	1	2	3	4	5	6	7	8	9	10	11	12

The print-code entry consists of two BCD words accommodating six character positions each. Entry of an X at any of these twelve positions will initiate corresponding outputs in accordance with the following:

a. (1) Trajectory (trajectory only option).
b. (2) Residuals (tracking only option).
c. (3) Partials (tracking only option).
d. (4) A^TA after each iteration (tracking only option).
e. (5) Variational equations (trajectory only option).

f. (6) Orbital elements (trajectory only option).

g. (7) Do not print station locations (tracking and data generation).

h. (8) Not used.

i. (9) Special trajectory prints[1]

j. (10) Orbital elements at ascending nodes only (trajectory only option).

k. (11) Not used.

l. (12) Suppress all trajectory print except ascending nodes (trajectory only option)[2]

3.2.5.4 Line 109 Equinox Precession Corrections

109			DALFG	.0002	

The rotational position of the earth with respect to the inertial system is characterized by the right ascension of Greenwich at midnight on the day of epoch (α_g) and is computed with respect to the mean equinox of epoch date. An additional factor for correcting to true equinox of epoch date optionally may be input at DALFG in units of degrees.

3.2.5.5 Lines 110-113 Direction of Integration

The TRACE-D program is capable of generating a time history of position and velocity in a forward or backward direction in any one run.

The inputs which determine this direction are INTEG(30), INTEG(31), INTEG(32). If these inputs are negative then backward integration from epoch time is assumed by the program. If positive,

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[1] Prints will occur at times of maximum and minimum altitude above the oblate earth, at times when the flight-path angle equals 90 degrees and at special latitudes and longitudes if values are entered (see Section 3.3.6).

[2] If the option to write a binary trajectory tape (B7) has been selected, the writing of that tape is controlled by the PRTIM entries (see Section 3.3.1).

as in the standard case, forward integration from epoch is performed.

110	G	INTEG	
111	30		-1.
112	31		-.01
113			-10.

The example shown above indicates to the program that backward integration must be performed starting at epoch with an initial time step of -1. minute (see Table 5 for the explanation of INTEG constants), a minimum time step of -.01 minutes and a maximum time step of -10. minutes.

When performing any of the three basic options, these inputs may be set negative. In trajectory generation a time history back from epoch will be produced. In the observation generation mode, observations previous to epoch may be generated. In the orbit determination mode, data previous to epoch may be fit. Generally this makes TRACE-D a more flexible program by making the position of epoch and the known initial conditions less rigid.

It should be noted that both backward and forward integration can not be performed in the same run but two runs would have to be made, each with a different direction of integration.

3.2.5.6 Line 114 Primary Scratch Tape

114	I	PTAPE	4

PTAPE is the number of the primary scratch tape that the program requires and 4 is its only permissible value. This card must be included in every data deck.

3.3 Trajectory-Only Data

In addition to the basic data previously described, the following data is relevant to the trajectory generation.

3.3.1 Lines 1-7 Print Time Vector Option

	1	I	PRTIM		
n	2	I	2		
t_0	3		3		
Δt_1	4		4		
t_1	5		5		
Δt_2	6		6		
t_2	7		7		

The above sequence of print times is for outputs selected by PRCDE entries (Line 108, Section 3.2.5.3). As many as nine sets of print intervals may exist (Line 2). In the case of the i^{th} set, output is from t_{i-1} to t_i at intervals of Δt_i, with all times in minutes from midnight of epoch date if PRTIM = 1 or from epoch if PRTIM = 0. Additional cards may be inserted if $3 \leq n \leq 9$. It should be noted that a normal print at epoch is automatic.

3.3.2 Lines 8-15 Variational Equation Partial Derivatives

8	D	CPRAM
9	D	DPRAM
10	D	3
11	D	5
12	D	7
13	D	9
14	D	KPRAM
15	D	3

An X entered in any CPRAM, DPRAM, or KPRAM character position causes the corresponding variational equation to be solved. Printout of the partial derivatives will occur only if an X is entered at Character Position 5 in the PRCDE print code entry location. The ordering of entries in the CPRAM, DPRAM, and KPRAM character position boxes is as follows:

a. CPRAM (Initial Condition Parameters) (Line 8)

The first position specifies which one of three types of initial conditions is applicable, and succeeding positions indicate the particular parameters that are desired in each case. Ordering of CPRAM parameter entries for initial condition (IC) Types 1, 2, and 3 as shown below.

	(IC Type)												
(either)	1	x	y	z	$\dot{x}$	$\dot{y}$	$\dot{z}$	t_0					
(or)	2	α	δ	β	A	r	v	t_0					
(or)	3	a	e	i	Ω	ω	τ	t_0					

Ordering of CPRAM IC Parameter Entries

b. DPRAM and KPRAM (Differential Equation Parameters) (Lines 9 through 15)

The ordering of DPRAM and KPRAM parameter entries is shown below, wherein T_1 and T_2 are the exponential thrust parameters and a_i, K_i θ_{y_i}, and θ_{p_i} are the OA number (1, 2, ..., 6), ΔV magnitude, yaw angle, and pitch angle, respectively.

Sixty differential equation parameters is the maximum number which may be selected for any one run.

DPRAM	DRAG	μ	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{21}
3	J_{22}	J_{31}	J_{32}	J_{33}	J_{41}	J_{42}	J_{43}	J_{44}	J_{51}	J_{52}	J_{53}	J_{54}
5	J_{55}	J_{61}	J_{62}	J_{63}	J_{64}	J_{65}	J_{66}	λ_{21}	λ_{22}	λ_{31}	λ_{32}	λ_{33}
7	λ_{41}	λ_{42}	λ_{43}	λ_{44}	λ_{51}	λ_{52}	λ_{53}	λ_{54}	λ_{55}	λ_{61}	λ_{62}	λ_{63}
9	λ_{64}	λ_{65}	λ_{66}		ω_a	T_1	T_2					

KPRAM	a_1	K_1	θ_{y_1}	θ_{p_1}	a_2	K_2	θ_{y_2}	θ_{p_2}	a_3	K_3	θ_{y_3}	θ_{p_3}
3	a_4	K_4	θ_{y_4}	θ_{p_4}	a_5	K_5	θ_{y_5}	θ_{p_5}	a_6	K_6	θ_{y_6}	θ_{p_6}

Ordering of DPRAM and KPRAM Differential
Equation Parameter Entries

3.3.3 Lines 16-18 Trajectory Comparison Options

16	I	IDIFF	1	
17	I	NTAPE	15	
18	I	DTAPE	14	

Tape units and case indicators required for the trajectory differencing function are as follows:

a. IDIFF = 0 A regular trajectory run is indicated.

b. IDIFF = 1 The reference trajectory will be written on the logical tape specified by NTAPE. If no entry is input at NTAPE, Logical Tape 15 will be used.

c. IDIFF = 2 The differences between the present and reference cases are computed and written on the logical tape specified by DTAPE. If no entry is input at DTAPE, Logical Tape 14 will be used. The difference tape specified by DTAPE is rewound at the beginning of the case.

d. IDIFF = 3 Conditions are the same as when IDIFF = 2 except that the tape specified by DTAPE is not rewound.

e. IDIFF = 4 The tape specified by DTAPE is rewound at the beginning of the case and unloaded upon completion.

f. IDIFF = 5 The tape specified by DTAPE is unloaded upon completion of the case.

The significance of the foregoing options is that if a single-comparison case is to be processed, IDIFF = 1 is used for the reference case and IDIFF = 4 for the perturbed case. If a series of perturbed cases are to be processed, IDIFF = 1 is used for the reference case, IDIFF = 2 for the first perturbed case, IDIFF = 3 for all intermediate cases, and IDIFF = 5 for the last perturbed case.

When this option is used, a special running deck must be obtained which defines the necessary tapes specified above.

3.3.4 Line 19 Revolution Number

19		REV	7	

If an initial value other than zero is desired for the revolution number, it may be input at the REV location. This value must be reinitialized for each individual case.

3.3.5 Line 20 Trajectory Tape Generation

20	I	TTAPE	3	

If TTAPE is non-zero, a binary trajectory tape will be generated on Logical Tape 19 in accordance with the following input options:

a. TTAPE = 0 Tape will not be generated.

b. TTAPE = 1 Tape will be rewound before generating but not unloaded after completion. This entry should be used for the first case when more than one case is involved.

c. TTAPE = 2 Tape will not be rewound before generating and not unloaded after completion. This entry should be used for all intermediate cases.

d. TTAPE = 3 Tape will be rewound before generating and unloaded after completion. This entry should be used when only one case is involved.

e. TTAPE = 4 Tape will not be rewound before generating but will be unloaded after completion. This entry should be used for the last case.

This tape is not suitable for the trajectory-comparison option of the trajectory-only function.

For this option also, a special running deck containing the proper tape definitions must be used.

3.3.6 Lines 21-28 Latitude and/or Longitude Prints

n_1	21	I	LATPR	3	
	22		2	10.	
	23		3	15.	
	24		4	20.	
n_2	25	I	LONPR	3	
	26		2	200.	
	27		3	100.	
	28		4	180.	

Line 21 contains n_1 ($n_1 \leq 10$), or the number of special latitudes at which trajectory prints are requested, and Lines 22 through 24 contain the special latitudes. Additional cards may be added if $4 \leq n_i \leq 10$.

Line 25 contains n_2 ($n_2 < 10$). or the number of special longitudes at which trajectory prints are requested, and Lines 26 through 28 contain the special longitudes. Additional cards may be added if $4 \leq n_2 \leq 10$.

Note that an X must be entered in Character Position 9 of the PRCDE entry if either of the foregoing options are selected.

This concludes the description of trajectory related data. For data deck samples and running deck setups see Section 3.6.

3.4 Observation Generation Data

The following data is pertinent only to the data generation option and is used in conjunction with the basic data (described in Section 3.3).

3.4.1 Lines 1-4 Special Output Option

1		IFLAG		
2	I	6	1	

If IFLAG(6) = 0, all generated data are printed. If IFLAG(6) = 1, rise, maximum elevation, and set times only are printed and the Data-Generation Specification Load Sheet II is not necessary except for listing of a card carrying TR in Columns 1 and 2 (see Section 3.4.5 and 3.4.6).

3	I	14		

If IFLAG(14) = 0, data are generated in time sequence until the available core space (bucket) is full. This output is then separated and printed by station in the same sequence as that of the input station cards. Further data are then generated until the bucket is again full, and the sort/print cycle is repeated. If IFLAG(14) = 1, data are printed as they are generated (i.e., in time sequence).

4	I	ETAPE	6	

If ETAPE is non-zero, a BCD radar observation tape will be generated on the logical tape unit entered at ETAPE. The tape format will be the same as that of the tracking input data, including station locations and TF and TR cards.

3.4.2 Lines 5-23 Vehicle Attitude Specifications

y 5		YAW	1.	
p 6		PITCH	90.	
r 7		ROLL	180.	

Vehicle attitude may be specified by inputting yaw, pitch, and roll angles in degrees in the manner shown above. These entries normally are introduced in conjunction with aspect angle computations.

8	YAW		
9	811	1.	
10	812	120.	
11	813	.01	
12	814	.1	
13	815	0	
14	816	120.	
15	817	121.	
16	818	-.9	
17	819	-9.0	
18	820	0	
19	821	1420.	
20	822	1420.5	
21	823	360.	
22	824	0	
23	825	0	

The time history of vehicle attitude maneuvers may be specified by means of a table entered at YAW(811). The format of this table, which is used in connection with generation of radar aspect angles and may consist of up to three sets of five entries each, is itemized in Table 6.

The yaw-, pitch-, and roll-angle values that make up these input sets of angular rates are assumed to change at the rate given over the time interval defined by the start and stop times. Nominal orientation is zero yaw, pitch and roll which corresponds to the condition where the vehicle body axis is normal to the geocentric radius vector, the nose of the vehicle is in the in-track direction, and the top of the vehicle is in the direction of the extended radius vector.

Vehicle attitude at time of epoch and for the case where the entries in Table 6 are all zero (i.e., when nothing is input) is assumed to be the attitude specified at YAW, PITCH, and ROLL. If gaps in the time entries of the table are present, the angles are held constant at the last computed values.

Table 6.

YAW(811) TABLE FORMAT

Entry	Description
YAW(811)	Start time in minutes from epoch for first set of angular rates.
YAW(812)	Stop time in minutes from epoch for first set of angular rates.
YAW(813)	Yaw rate in degrees per minute.
YAW(814)	Pitch rate in degrees per minute.
YAW(815)	Roll rate in degrees per minute
YAW(816)	Start time in minutes from epoch for second set of angular rates.
YAW(817)	Stop time in minutes from epoch for second set of angular rates.
YAW(818)	Yaw rate in degrees per minute.
etc.	etc.

3.4.3 Lines 24-38 Data Error Inputs

24	B	NOISE 3 7 7 7 7 7 7 7 7	7 7

If NOISE is non-zero (a positive octal number), normally distributed random noise with standard deviation and mean value specified by input at RAPAR is added to the generated data. The entry at NOISE is used to start the random-number generator.

25	M	RAPAR	05,99	
26	D	01,01	H U A B I A S	
27		04,01	.057	
28	D	01,02	A L H B I A S	
29		04,02	200.	

The RAPAR array is used to indicate bias values for measurements to be generated. Line 25 merely indicates to the program that the array is of maximum size 05,99. Lines 26 and 27 specify that for station HU and the azimuth measurements the bias value to be added is .057 degrees. Lines 28 and 29 indicate that for station AL and the height measurement computed from AL the bias value to be added is 200 feet. For additional entries the same two cards are repeated with increased subscripts.

30			SIGMA	200	
31			2	.1	
32			3	.1	
33			4	50.	
34		I	ISIG	1	
35		I	2	2	
36		I	3	3	
37		I	4	112	

Lines 30-37 contain the observation data weighting factors. For each SIGMA entry, a corresponding entry defining the sigma set and data type appears in ISIG Lines 34-37. The ISIG entries are of the form 100I + K, where I is the observation set number and K is the data type. Ten sets, corresponding to $I = 0, 1, 2, \ldots, 9$, may be entered. This selected value of I is the same as the entry in Column 5 of the station location card. (See Section 3,4,5.) The data type, K, must be one of those listed in Table 7.

In the above example, range, azimuth and elevation data would contain noise with a sigma of 200 feet, .1 degree and .1 degree respectively, while height would contain noise with a sigma of 5 feet.

38		REFR		

If elevation is a chosen measurement to be generated, then REFR is the input quantity that allows for elevation refraction correction. The computed elevation, E, is altered to account for refraction, using either

$$E' = E + \eta_{si} \cot E$$

if $E \geq 0.1$ radian, or

$$E' = E + \frac{1}{1000}\,\frac{\eta_{si} \times 10^6}{12+1000E} - \frac{80}{6+1000E}$$

if $E < 0.1$ radian and $\eta_{si} \neq 0$.

REFR contains the η_{si} term, wherein $i = 0, 1, 2, \ldots, 9$. The appropriate value of i is entered on the station card in Column 6 (see Section 3.4.5). Nominally $\eta_{so} = 3.12 \times 10^{-6}$. Rise, set, and maximum elevation values are determined from the geometric E which represents the elevation before refraction correction is applied. Additional cards may be inserted at this location if necessary.

Table 7.

Data Types for ISIG Entries

Data Type (K)	Data Description	Symbol
1	Range	R
2	Azimuth	A
3	Elevation	E
4	Topocentric right ascension	α_T
5	Topocentric declination	δ_T
6	Topocentric hour angle	HA
7	Geocentric right ascension	α_g
8	Geocentric declination	δ_g
10	Argument of latitude	u
11	Cross plane	v
12	Height	h
13	$\hat{x}$	$\hat{x}$
14	$\hat{y}$	$\hat{y}$
15	$\hat{z}$	$\hat{z}$
17	Range difference	P
18	Range difference	Q
19	Range rate	$\dot{R}$
20	$\dot{R}$ difference	$\dot{P}$
21	$\dot{R}$ difference	$\dot{Q}$

3.4.4 Lines 39-45 Orbit Covariance Matrix

39			ATAS	1.	-4
40			3	.5	-7
41			6	2.	-2
42			10	4	-2
43			15	2000.	
44			21	1.	

If observation uncertainties are to be calculated, a covariance matrix for the ADBARV elements at epoch must be input in lower triangular form at ATAS. The order of the elements is Row 1/Column 1 at ATAS(2), Row 2/Column 2 at ATAS(3).

In addition, the following input is needed.

45		D	CPRAM	2XXXXXX	

The CPRAM variable indicates to the program that the covariance matrix has been input and in the ADBARV notation. (For a more complete explanation of the CPRAM variable see Section 3.3.2).

3.4.5 Station Cards

The locations of tracking stations which are associated with the observations to be generated must be input by means of station cards carrying appropriate descriptive information.

Figure 1 on the next page shows the proper fields for the input that is described below:

a. Station ID Columns 1 and 2 (ST).

No two stations may be identified by the same symbol. The three codes that are not permissible as station ID's are TS, TR, TF.

b. Sigma Index Column 5

The sigma index identifies the set of observation sigmas to be applied to data that is generated from this station (see Section 3.4.3).

c. Type of Refractivity Correction Column 6

This indicator selects the type of refractivity correction which is to be applied to elevation readings. (This input depends on previous input. See Section 3.4.3).

d. Latitude Columns 9-17

The latitude of the station is entered in degrees.

e. Longitude Columns 19-27

The east longitude of the station is entered in degrees also.

f. Altitude Columns 29-36

The altitude of the station is entered in feet.

g. P, Q Indicators Columns 38-39 and 41-42

If P, Q, $\dot{P}$, $\dot{Q}$ data (i.e., range difference and range rate difference between a master station and two slave stations) is to be generated these columns must contain the station ID's of the slave stations. Also, it is necessary to enter a station card for each slave station but columns 38-39 and 41-42 are to be left blank.

The station cards must be preceded by two cards with END in columns 1-3, and must be followed by a card with TS in columns 1-2.

3.4.6 Data Limit Specification Cards

a. Station ID (ST) Columns 1-2

b. Data Rate Columns 9-16

Time interval in seconds at which data for a given station are to be generated and testing interval for rise set option.

c. Minimum Elevation Columns 18-23

The minimum elevation at which the vehicle is visible to this station.

d. Maximum Elevation Columns 25-30

The maximum elevation at which the vehicle is visible to this station. Zero value implies a 90 degree limit.

e. Maximum Range Columns 32-40

The maximum range in nautical miles to which the vehicle is visible. Zero value causes this test to be ignored.

f. Start Time Columns 51-58

Start time from midnight of start date in days, hours, and minutes. Zero value implies that epoch is start time.

g. Stop Time Columns 60-67

Stop time from midnight of start date in days, hours, and minutes.

The set of cards must follow the TS card in the deck and themselves be followed by a card with TR in the first two columns.

3.4.7 Data Type Cards

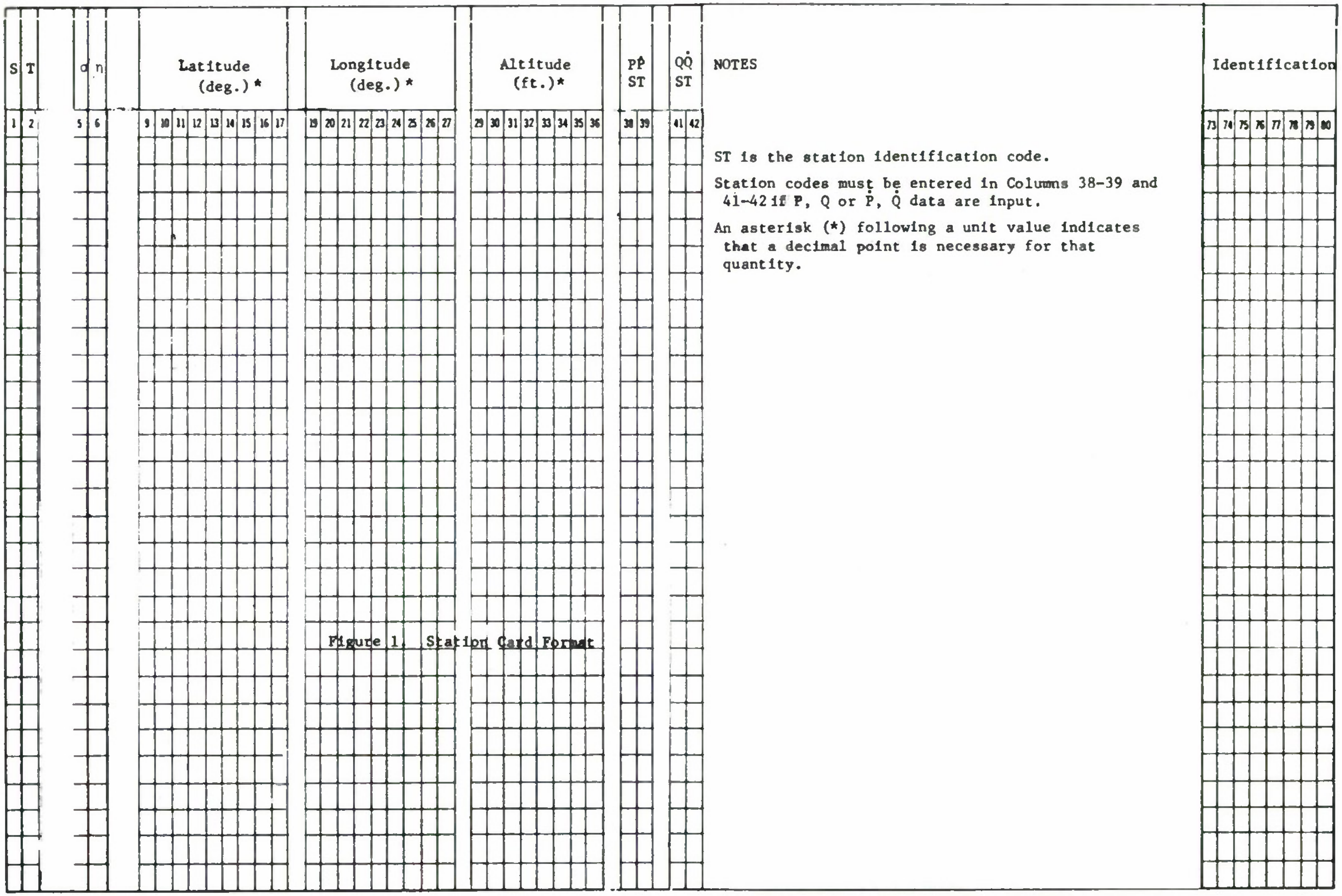
The following set of cards (which are the last in the card deck) specify the exact type of measurements to be generated from each station.

Figure 3 is a card image.

a. Station ID Columns 1-2

b. Observation Types Columns 7-33

An X in the appropriate column will produce specific measurements according to Table 8.



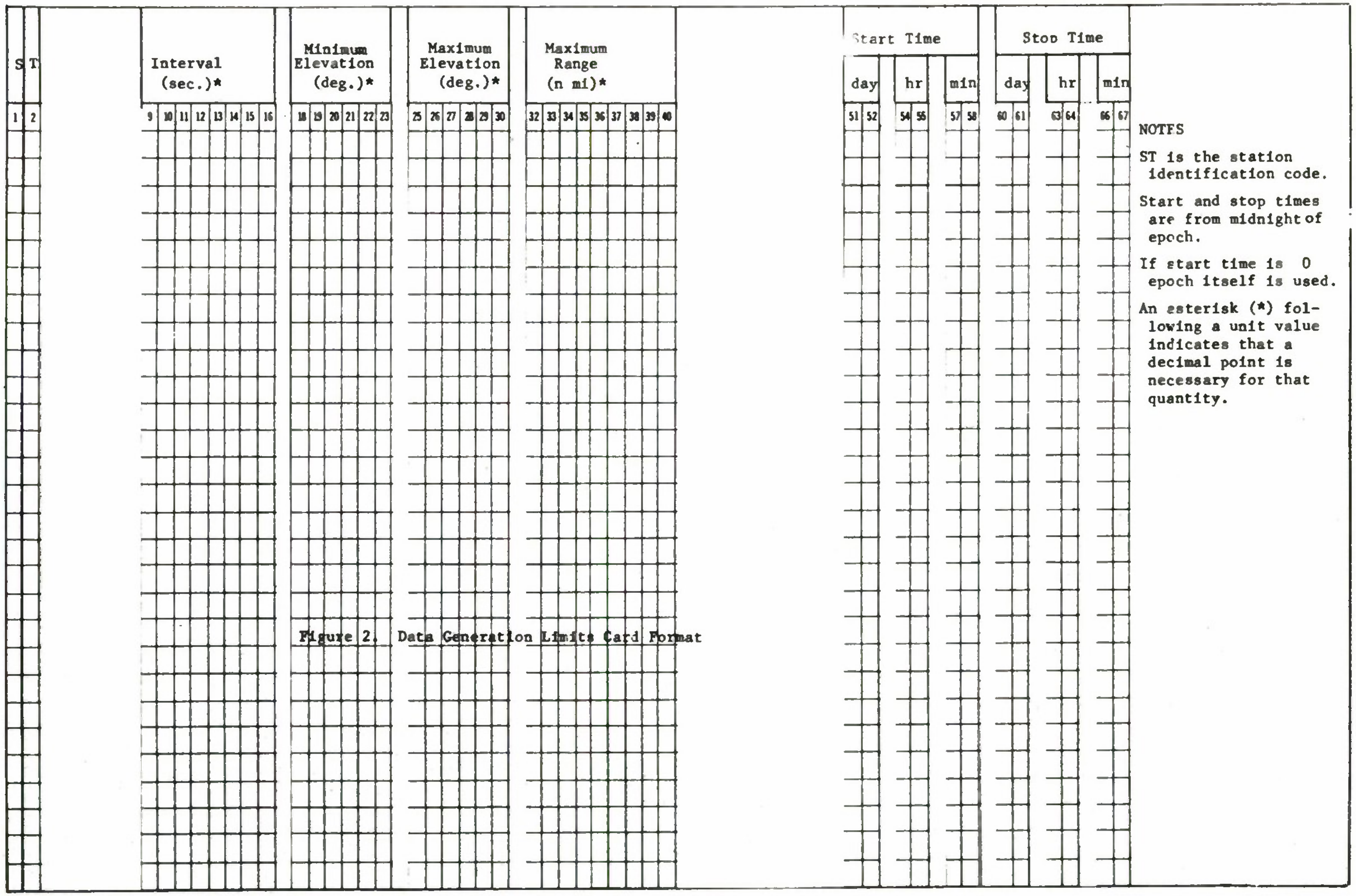
NOTES

ST is the station identification code.

Station codes must be entered in Columns 38-39 and 41-42 if P, Q or Ṗ, Q̇ data are input.

An asterisk (*) following a unit value indicates that a decimal point is necessary for that quantity.

Figure 1. Station Card Format



NOTFS

ST is the station identification code.

Start and stop times are from midnight of epoch.

If start time is 0 epoch itself is used.

An asterisk (*) following a unit value indicates that a decimal point is necessary for that quantity.

Figure 2. Data Generation Limits Card Format

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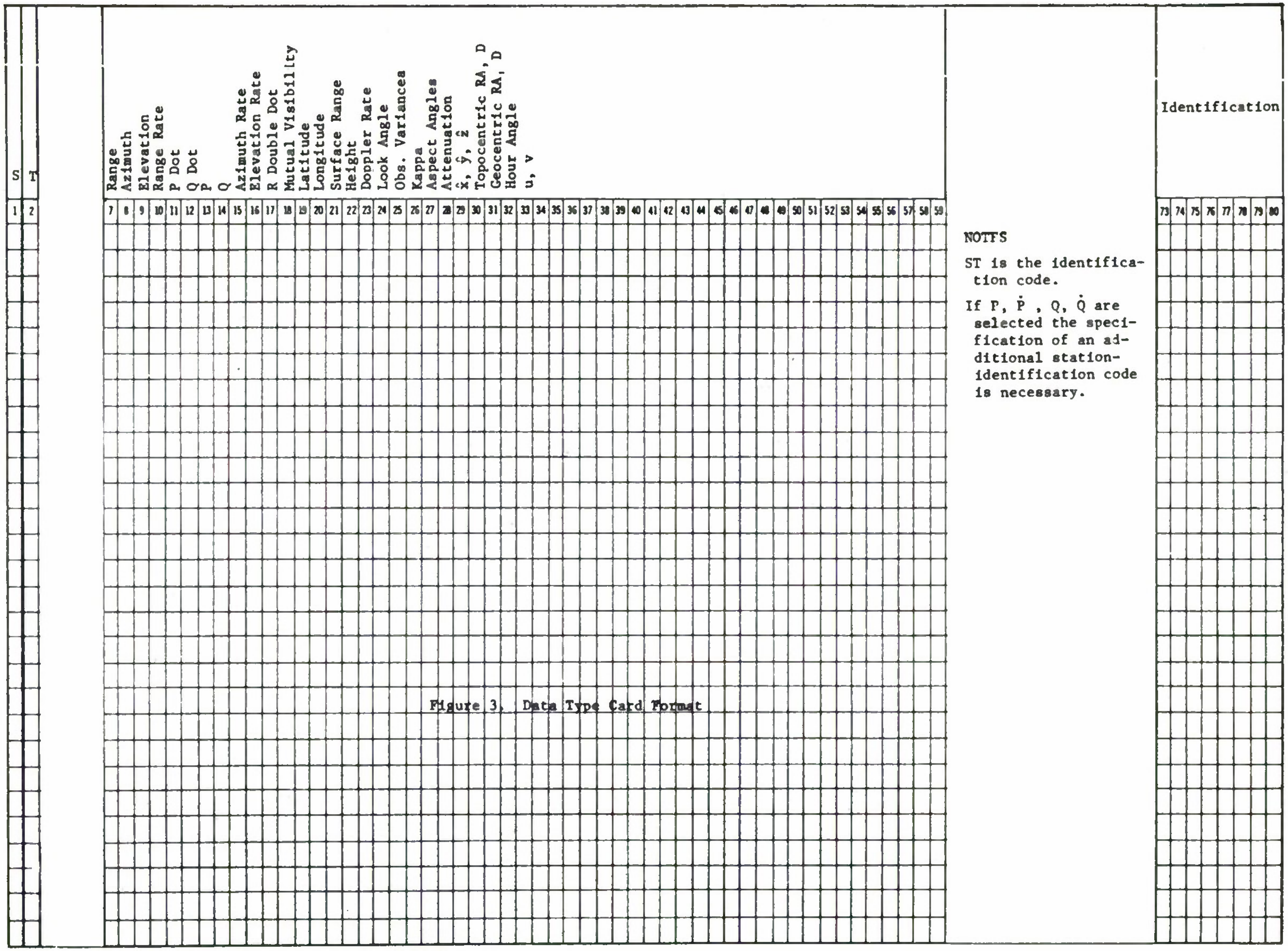


NOTES

ST is the identification code.

If P, $\dot{P}$, Q, $\dot{Q}$ are selected the specification of an additional station-identification code is necessary.

Figure 3. Data Type Card Format

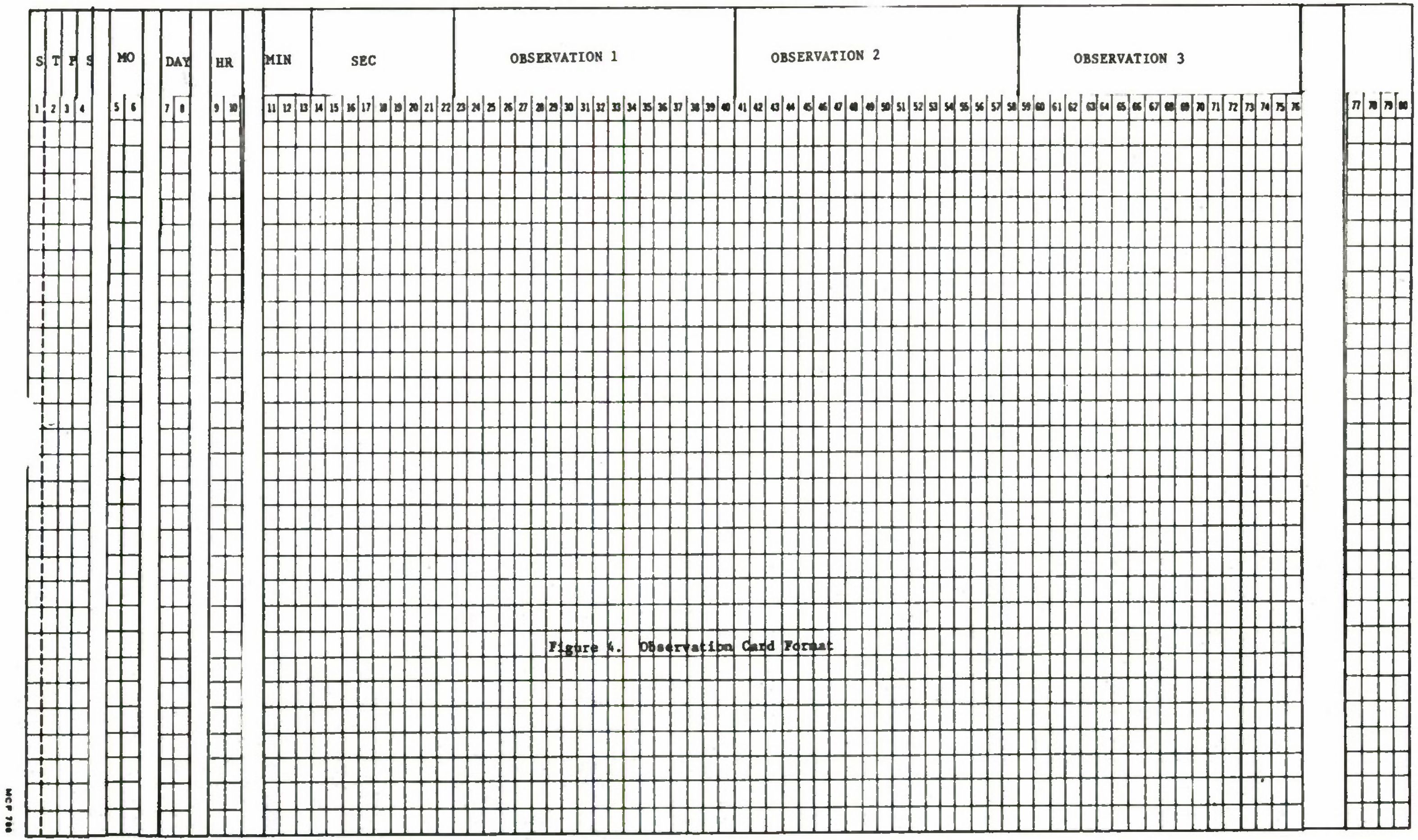


Figure 4. Observation Card Format

Table 8.

Output Quantities Corresponding to Columns 7 through 33 of Data-Generation Type Card

Column	Output Quantity	Unit
7*	Range	n mi (ft on ETAPE)
8*	Azimuth	deg
9*	Elevation	deg
10*	Range rate	ft/sec
11-14*	$\dot{P}$, $\dot{Q}$, P, Q	ft/sec, ft
15	Azimuth rate	deg/min
16	Elevation rate	deg/min
17	Range acceleration	ft/sec^2
18	Mutual visibility (Output will be a list of numbers of stations visible at output time. Stations numbered in order of input on station cards. Number of stations, 8 maximum).	
19	Geodetic latitude of vehicle	deg
20	Longitude of vehicle	deg
21	Surface range from station to subvehicle point	n mi
22*	Altitude of vehicle	n mi (ft on ETAPE)
23	Doppler rate	
24	Look angle (Angle between a vehicle axis and the station/vehicle line of sight. The direction cosines of the vehicle axis in the basic inertial system must be entered in C(37), C(38), and C(39). These quantities	deg

---

* These quantities are output on ETAPE

Table 8 (cont.)

Column	Output Quantity	Unit
	may be input as constant or the user may provide a subroutine (FANG) to compute the direction cosines at each output point).	
25	Observation uncertainties. (If inverse A^TA matrix for initial conditions is input at ATAS, the ADBARV elements are selected as parameters, and if an X is entered in Column 25, the $[A^TA]^{-1}$ is updated to observation times and the standard deviations in the quantities R, A, E, $\dot{R}$, $\dot{A}$, $\dot{E}$ are derived and printed. The uncertainties are only those due to the uncertainty in the ephemeris which is implied by the given $[A^TA]^{-1}$ for the epoch conditions).	Same units as observations
26	Angle kappa (K). (Angle between station line-of-sight and geocentric radius vectors).	deg
27	Aspect angles. (Angle 1 (Φ) is defined as the angle between the vehicle yaw axis and projection of the station line-of-sight vector in the roll plane. Angle 2 (Θ) is defined as the angle between the vehicle roll axis and the line-of-sight vector to the station.	deg
28	Signal attenuation = $-40 \log_{10} R$, where R is slant range in feet	db
29*	$\hat{x}$, $\hat{y}$, $\hat{z}$ (Same rectangular earth-fixed (X through Greenwich) geocentric quantities accepted as Type 5 observations for orbit determination).	n mi (ft on ETAPE)

---

* These quantities are output on ETAPE

Table 8 (cont.)

Column	Output Quantity	Unit
30*	Topocentric right ascension and declination	deg
31*	Geocentric right ascension and declination	deg
32*	Topocentric hour angle	deg
33*	Vehicle-centered argument of latitude and cross-plan angle	deg

---

* These quantities are output on ETAPE

3.5 Orbit Determination Data

This section gives a description of all the pertinent data for a differential correction run to be used in conjunction with the previously described basic data.

3.5.1 Lines 1-14 Multiple Satellite Option

As was mentioned in Section 2, TRACE-D will accept measurements for up to six satellites on any one run. The method of specifying the input for these vehicles is shown below.

Year 1	I	SAT2	1964	
Month 2	I	2	2	
Day 3	I	3	10	
Hour 4		4	3.	
Minute 5		5	30.	
Second 6		6	52.	
ICTYP 7	I	7	2	
IC 8		8	352.	
2 9		9	10.	
3 10		10	90.05	
4 11		11	165.	
5 12		12	22580632.	
6 13		13	25205.3	
DRAG 14		14	.015	

If observations for a second satellite are to be input, Lines 1 through 14 are used for entry of epoch, initial conditions, and drag coefficient for Satellite 2. Lines 1 through 3 contain the year, month, and day, and Lines 4 through 6 contain the hour, minutes, and seconds, Greenwich time. Line 7 indicates the type of initial conditions that may be entered in Lines 8 through 13 (Type 1, 2, 3, 4, 8, or 9). Line 14 contains the drag coefficient (C_DA/W). The input initial conditions

(IC) for satellites 3 to 6 are the same as those noted above except that the symbol SAT2 is replaced by SAT3, SAT4, SAT5, and SAT6, as appropriate.

3.5.2 Lines 15-31 Parameter Specification

The method of selecting the parameter set for the differential correction process is described below.

3.5.2.1 Differential Equation Parameters

15		D	CPRAM 2	x	x	x	x	x	x						
16		D	CPRAM x												
17		D	3												
18		D	5												
19		D	7												
20		D	9												
21		D	PSAT2												
22		D	PSAT3												
23		D	PSAT4												
24		D	PSAT5												
25		D	PSAT6												
26		D	KPRAM												
27		D	3												

An X entered in any CPRAM, DPRAM, PSAT, or KPRAM character position causes the corresponding parameter to be differentially corrected. The ordering of entries in the CPRAM, DPRAM, PSAT, and KPRAM character position boxes is as follows:

a. CPRAM (Initial Condition Parameters for Satellite 1) (Line 15)

The first position specifies which one of these types of initial conditions is applicable, and succeeding positions indicate the particular parameters that are desired in each case. Ordering of parameter entries for IC Types 1, 2, and 3 is as shown in Section 3.3.2.

b. DPRAM (Differential Equation Parameters) (Lines 16 through 20)

The ordering of DPRAM differential equation parameter entries is as shown in Section 3.3.2. However, in this application the T_1 and T_2 parameters are associated with Satellite 1 only.

c. PSAT2 through PSAT6 (Initial Condition and Drag Coefficient Parameters for Satellites 2-6) (Lines 21 through 25)

The ordering of PSAT IC and drag parameter entries for Satellites 2 through 6 is shown below.

PSAT2	α_2	δ_2	β_2	A_2	r_2	v_2	t_{0_2}	DRAG$_2$
PSAT3	α_3	δ_3	β_3	A_3	r_3	v_3	t_{0_3}	DRAG$_3$
PSAT4	α_4	δ_4	β_4	A_4	r_4	v_4	t_{0_4}	DRAG$_4$
PSAT5	α_5	δ_5	β_5	A_5	r_5	v_5	t_{0_5}	DRAG$_5$
PSAT6	α_6	δ_6	β_6	A_6	r_6	v_6	t_{0_6}	DRAG$_6$

It is important to note that only IC Type 2 may be specified for Satellites 2 through 6.

d. KPRAM (Orbit Parameters for Satellite 1) (Lines 26 and 27)

Ordering of KPRAM orbit adjust parameters is as previously shown in Section 3.3.2. It should be noted that the orbit adjusts are for Satellite 1 only.

Sixty trajectory parameters is the maximum number which may be selected for simultaneous solution.

3.5.2.2 Radar Parameters

28	M	RAPAR	05, 99	
29	D	01, 01	BN LAT	
30		03, 01	.01	
31		04, 01		
32	D	01, 02	CK24RBIAS	
33		03, 02	500.	
34		04, 02	750.	
35	D	01, 03	HU TBIAS	
36		03, 03	.001	
37		04, 03	.0035	

Line 28 indicates that the data listed subsequent to RAPAR on the load sheet will be input into a 5 × 99 matrix array which has been preset to zero. The columns of this array correspond to parameters, and the rows correspond to parameter identification (Positions 1 and 2), bounds (Position 3), and bias estimates (Position 4) respectively. Row 5 is currently not used.

Lines 29 through 31 specify the first applicable radar parameter. Line 29 contains the station name (Positions 1 and 2), pass identification (Positions 3 and 4), and parameter name (Positions 5 through 10). Lines 30 and 31 contain the bound and initial value, respectively, in feet, degrees, and minutes except for $\dot{R}$, $\dot{P}$, and $\dot{Q}$, which are in feet per second. If the parameter is station latitude, longitude, or altitude, the initial value is taken from the station location card.

If the pass identification character position is left blank, all data with the indicated station name will be used to correct the parameter. If the pass identification is not omitted, only data that are identified by both the indicated station name and indicated pass identification will be used to correct the parameter. If the radar parameter specified is station latitude, longitude, or altitude, the pass identification is ignored and all data with the station name are used for the parameter correction.

Lines 32 through 34 and Lines 35 through 37 specify the second and third radar parameters respectively. Station names, pass identifications, parameter names, bounds, and initial values are treated in the same manner as the inputs in Lines 29 through 31 described above. Additional cards may be added in cases where more than three radar parameters are involved. Available radar parameters are listed in Table 9.

Note that the total number of parameters which may be selected for simultaneous solution must be less than one hundred.

Table 9.

PARAMETER	SYMBOL
Station latitude	LAT
Station longitude	LONG
Station altitude	ALT
Time bias	TBIAS
Range bias	RBIAS
Azimuth bias	ABIAS
Elevation bias	EBIAS
Topocentric right ascension bias	RTBIAS
Topocentric declination bias	DTBIAS
Topocentric hour angle bias	HABIAS
Geocentric right ascension bias	RGBIAS
Geocentric declination bias	DGBIAS
Argument of latitude (u) bias	UBIAS
Cross plane (v) bias	VBIAS
Height bias	HBIAS
$\hat{x}$ bias	XBIAS
$\hat{y}$ bias	YBIAS
$\hat{z}$ bias	ZBIAS
P bias	PBIAS
Q bias	QBIAS
Range-rate bias	RDBIAS
$\dot{P}$ bias	PDBIAS
$\dot{Q}$ bias	QDBIAS
Range scale factor (K_R)	KR
Range-rate scale factor (K_D)	KD

3.5.3 Lines 38-50 Parameter Bounds

38		BNDS	.5	
39		2	.5	
40		3	.1	
41		4	.5	
42		5	1000.	
43		6	5	
44		7	.05	
45		8		
46		9		
47		10		
48		11		
49		12		
50		13		

A bound must be entered for each parameter selected. These bound entries must be in the same sequence as the parameters. For each iteration of the differential correction process, the change in each parameter is less in absolute value than the corresponding bound if that bound is positive, zero if the corresponding bound is zero, or unrestricted if the corresponding bound is negative.

3.5.4 Lines 51-62 Observation Sigmas

51		SIGMA	100.	
52		2	.5	
53		3	.5	
54		4	1000.	
55		5	200.	
56		6	300.	
57	I	ISIG	1	
58	I	2	2	
59	I	3	3	
60	I	4	113	
61	I	5	114	
62	I	6	115	

The observation sigmas for each observation type must be input in the same manner as was previously well described in Section 3.4.3.

3.5.5 Line 63 Maximum Iterations

63	I	MAXIT	4	

The symbol MAXIT must be input with an integer value to specify a stopping point to the run. If the differential correction process has not converged at the end of MAXIT iterations, the process will be terminated.

3.5.6 Lines 64-66 Residual Editing

64	CEDIT	3	
65	2	.9	
66	3	1	

If CEDIT is zero, no editing is done. If CEDIT is non-zero, residuals will be edited in accordance with the following:

a. CEDIT < 0 Residuals greater than (input sigma × |CEDIT|) will be discarded.

b. CEDIT > 0 Residuals greater than (statistical sigma from the previous iteration × CEDIT) will be discarded. No editing is done on Iteration 1. Sigmas are computed for the first five data types encountered for each station.

Line 65 represents a scale factor such that if CEDIT(2) is non-zero, CEDIT is replaced by (CEDIT × CEDIT(2)) at the end of each iteration. If CEDIT(2) is zero, CEDIT is not modified.

Line 66 is a special option wherein if CEDIT(3) is non-zero, Iteration 1 will be repeated with editing performed with the sigmas computed during the first pass through Iteration 1. This will allow editing to be done on all iterations with computed sigmas.

Sigmas (rms) for the first five data types for each station are computed and printed at the end of each iteration regardless of the residual-editing option selected.

3.5.7 Data Correction Factors

3.5.7.1 Lines 67 and 68 Elevation Angle Refraction

67			REFR		
68			2	4.0	-6

A table of refraction indices η_i, which may contain up to ten values, may be input starting at REFR. The entry used to compute refraction corrections for radar elevation observations is determined by the type number contained in Column 6 of the corresponding station location card. A zero in Column 6 causes the entry at REFR to be used, a 1 in Column 6 causes the entry at REFER + 1 to be used, etc.

If the table contains no entries, the value 312.0×10^{-6}, which is built in at location REFR, will be used to compute refraction corrections for all data whose station location cards contain zero in Column 6. All other positions of the table are assembled as zeros.

3.5.7.2 Range Refraction Correction

69			RREFC	1	

Refraction corrections to all range observations will be computed and applied if RREFC is non-zero.

3.5.7.3 Line 70 Propagation Time Correction

70			SLT	-2820.1763	

The velocity to be used in calculating the observation time correction due to propagation time is entered at SLT in units of earth radii per minute. In the absence of an entry, no correction will be applied. If an entry is present the correction will be applied to times associated with R, A, E, $\dot{R}$, h, P, Q, $\dot{P}$ and Q data only.

3.5.8 Lines 71, 72 Data Tape Options

71		I	IBCDI	6	
72		I	IBINI	1	

If the radar observation and station location information is to be input via a BCD tape other than the normal FORTRAN system input tape, the tape number must be specified at IBCDI as 11. If a binary tape containing compacted radar data produced by a previous run is to be input, IBINI must be specified.

3.5.9 Lines 73, 74 True Equinox Correction

73		DALFG	-.004	
74		2		

An additive factor may be applied to the computed right ascension of Greenwich at midnight of epoch day by entering the appropriate value in units of degrees at DALFG for Vehicle 1, at DAFLG(2) for Vehicle 2, etc. This entry usually is used to correct from mean to true equinox reference coordinates.

3.5.10 Lines 75-78 Proximity Indicator

ϕ^*	75		ANOM1	
λ	76		2	
h	77		3	
R_0	78		4	

During an orbit determination run, an indicator may be obtained whenever the trajectory passes within a given distance (range) of a point on the surface of the earth by input of geodetic latitude (deg), east longitude (deg), and altitude (n mi) of the point at ANOM1 and the succeeding two positions and of the testing distance (the range from the point to the vehicle) at AMON1(4). Testing and printing is done for up to three such sets of input at AMON1, ANOM2, and ANOM3.

3.5.11 Lines 79 on Parameter Constraint Options

There are two different parameter constraint options available in TRACE-D. Both are described below in detail.

3.5.11.1 General Constraint Matrix

Option 1 allows the user to apply linear constraints to any of the variables in the parameter set, and to specify these constraints by means of an input matrix set up as shown below.

79	I	KNST 4	
80	I	BLIST 1	
81		1	
b_{11} 82		1	
83	I	2	
84	I	2	
b_{22} 85		1	
86	I	3	
87	I	3	
b_{33} 88		1	
89	I	4	
90	I	4	
b_{44} 91		1	
92	I	5	
93	I	1	
b_{51} 94		-1	
95	I	6	
96	I	2	
b_{62} 97		.5	
98		5	
99	I	5	
c_{51} 100		6	
101	I	7	
102	I	5	
103		1	

The clearest explanation of how this constraint matrix works is an example. Therefore, in the case shown above it is assumed that n parameters are to be solved for where $(p_1, p_2, \ldots, p^n) = P$. The ordering of the P_i corresponds to the order of the X's for the CPRAM, DPRAM, and KPRAM and the RAPAR arrays, respectively. Further assuming that these parameters are to be subjected to m linear constraints, which, for example for $n = 6$ and $m = 2$ might be $p_1 + p_5 = 6$, $p_2 - 2p_6 = 0$, KNST above would be equal to $(n - m) = 4$, or the number of effective (unconstrained) parameters.

The BLIST constraint matrix is represented by the factor B in the expression $p = B\bar{p} + c$, where the $\bar{p}$ are the effective parameters. In connection with the foregoing example, this expression would assume the form

$$\underbrace{\begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \end{bmatrix}}_{p} = \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & .5 & 0 & 0 \end{bmatrix}}_{B} \times \underbrace{\begin{bmatrix} \bar{p}_1 \\ \bar{p}_2 \\ \bar{p}_3 \\ \bar{p}_4 \\ \\ \\ \end{bmatrix}}_{\bar{p}} + \underbrace{\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 6 \\ 0 \end{bmatrix}}_{c}$$

Pertinent constraints are applied by input of the augmented $(n + 1)$ by $(n - m + 1)$ matrix

$$\begin{bmatrix} B & c \\ 0 & 1 \end{bmatrix}$$

in the BLIST array. If a_{ij} is an element of this augmented matrix, then i, j, and a_{ij} would be input. The inputs for the example given above would be as indicated in Lines 79-103. KNST (line 70) is input as 4 and then the BLIST matrix follows. Lines 80, 81, and 82 specify that BLIST (1, 1) is a 1 and lines 83, 84, and 85 that BLIST (2, 2) is a 1, etc. Elements of the matrix not input are assumed to be zero. In this way any subset of the set of parameters may be linearly constrained and the constraint matrix may be input to the program in the exact same manner.

3.5.11.2 Special Application to Station Location

The other option available is a specific case of the general constraint matrix which is applicable in the following type of problem. Consider a differential correction run with data from a tri-static system and a set of parameters including the latitudes, longitudes and altitudes of the three stations. In such a case, by choosing this constraint option, the correction of the station coordinates can be performed such that the baseline distances are held constant.

Mathematically, this implies that three constraining equations[1] are applied to the nine station locations; more specifically they are of the following form.

$$\Delta\phi_1 = a_1\ \Delta\theta_1 + a_2\ \Delta H_1 + a_3\ \Delta\theta_2 + a_4\ \Delta H_2 + a_5\ \Delta\phi_3 + a_6\ \Delta H_3$$

$$\Delta\phi_2 = b_1\ \Delta\theta_1 + b_2\ \Delta H_1 + b_3\ \Delta\theta_2 + b_4\ \Delta H_2 + b_5\ \Delta\phi_3 + b_6\ \Delta H_3$$

$$\Delta\theta_3 = c_1\ \Delta\theta_1 + c_2\ \Delta H_1 + c_3\ \Delta\theta_2 + c_4\ \Delta H_2 + c_5\ \Delta\phi_3 + c_6\ \Delta H_3$$

where

(θ_1, ϕ_1, H_1)

(θ_2, ϕ_2, H_2) are the three sets of latitude, Longitude, and altitude for Stations 1, 2, and 3.

(θ_3, ϕ_3, H_3)

and a_i, b_i, c_i $i = 1, \ldots, 6$ are the 18 coefficients of the three equations.

With the equations in this particular form, it seems that the general constraint option could be applied easily. However, there are two reasons for the separate treatment of this application that are not immediately apparent. First, the constants a_i, b_i, c_i $i = 1, \ldots, 6$ are functions of the current station location[2] and are not easily and accurately calculable by the user. Second, since

---

[1] The detailed derivation of this particular form of the constraining equations is not given here but may be found in Reference 3.

[2] The exact expressions for the coefficients can be found in Reference 3.

the constants are functions of the current station locations, they must be reevaluated every time the station locations change (i.e., after every iteration of the correction process the constants must be reset since the station locations have been adjusted). In other words, the type of constraint matrix needed here is a dynamic one that is adaptable to change throughout the estimation procedure. It is now obvious that the general constraint matrix of Section 3.5.11.1 is too rigid for this purpose.

Thus, added to the TRACE-D program is the capability to compute these necessary constants from input information, insert them into the appropriate location of the constraint matrix, recompute the constants as a function of the new station locations after each iteration and adjust the constraint matrix accordingly. Once the user has set up the appropriate input the rest is performed by the program.

The input necessary is best described with an example. Consider a differential correction run with data from three stations and a parameter set consisting of the ADBARV elements, drag, and station locations. To employ the fixed baseline distance constraints on the station locations consider B in the following expression.

$$\Delta\rho' = B\ \Delta P + c$$

There are 16 parameters to be estimated but there are 3 constraint equations, therefore there are 13 effective or unconstrainted parameters. B is then of dimension 16 × 13 and looks like this:

$$\overset{[\Delta\rho']}{\begin{bmatrix} \Delta\alpha \\ \Delta\delta \\ \Delta B \\ \Delta A \\ \Delta R \\ \Delta V \\ \Delta \text{ drag} \\ \Delta \text{ lat}_1 \\ \Delta \text{ long}_1 \\ \Delta \text{ alt}_1 \\ \Delta \text{ lat}_2 \\ \Delta \text{ long}_2 \\ \Delta \text{ alt}_2 \\ \Delta \text{ lat}_3 \\ \Delta \text{ long}_3 \\ \Delta \text{ alt}_3 \end{bmatrix}} = \overset{[B]}{\begin{bmatrix} 1&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&1&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&1&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&a_1&a_2&a_3&a_4&a_5&a_6 \\ 0&0&0&0&0&0&0&1&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&1&0&0&0&0 \\ 0&0&0&0&0&0&0&b_1&b_2&b_3&b_4&b_5&b_6 \\ 0&0&0&0&0&0&0&0&0&1&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&1&0 \\ 0&0&0&0&0&0&0&c_1&c_2&c_3&c_4&c_5&c_6 \\ 0&0&0&0&0&0&0&0&0&0&0&0&1 \end{bmatrix}} \overset{[\Delta\rho]}{\begin{bmatrix} \Delta\alpha \\ \Delta\delta \\ \Delta B \\ \Delta A \\ \Delta R \\ \Delta V \\ \Delta \text{ drag} \\ \Delta \text{ long}_1 \\ \Delta \text{ alt}_1 \\ \Delta \text{ long}_2 \\ \Delta \text{ alt}_2 \\ \Delta \text{ lat}_3 \\ \Delta \text{ alt}_3 \end{bmatrix}} + \overset{[c]}{\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}}$$

The quantities a_i, b_i, c_i, $i = 1, \ldots, 6$ are, of course, the coefficients in the constraint equations which are unknown to the user.

This B matrix is input in exactly the same manner as the general constraint matrix except that each element that is a coefficient (either a_i, b_i, c_i) must be input with a value of - 10,000. This is merely to indicate to the program the position in the matrix of these terms.

Lines 104 on show the appropriate format for the necessary input of this case.

104		NUMB	
105	I	44	-1
106	I	KNST	13
107	I	BLIST	1
108	I		1
109			1
110	I		2
111	I		2
112	⋮		1
113	⋮		
114	etc.		
115			

116	I	8	
117	I	8	
118	I	-10,000.	
119	I	8	
120	I	9	
121		-10,000.	
	etc.		

Lines 104 and 105 specify the quantity NUMB(44) which must be input as a - 1 to choose this constraint option. Line 106 is the number of unconstrained parameters in the parameter set. Lines 107 on are the non-zero elements of the B matrix entered in order.

3.5.12 Station Identification Cards

The locations of tracking stations or of points on the surface of the earth which are associated with observations must be input by means of station cards carrying appropriate information indicating the manner in which the corresponding observations are to be processed. These cards were previously discussed in Section 3.4.5 and shown in Figure 1, but the format is included again here for completeness.

a. Columns 1 and 2 (ST): Station identification symbol. No two stations may be identified by the same symbol or any one station by the symbol TS.

b. Column 5: Sigma index identifying observation-sigma set to be applied to data from corresponding station. The sets of sigmas are input with the base data.

c. Column 6: Type of refractivity correction to be used for elevation readings from this station. Refractivities are numbered in their input order within the base data (see Line 67, REFR).

d. Columns 9 through 17: North latitude of station in degrees.

e. Columns 19 through 27: East longitude of station in degrees.

f. Columns 29 through 36: Altitude of station in feet.

g. Columns 38/39 and 41/42: If a station reports P, Q, or $\dot{P}$, $\dot{Q}$ data, Columns 38/39 and 41/42 contain the two letter symbols for the associated station(s) of the tracking configuration. Each such associated station must be represented by a separate station card, but it is not necessary for Columns 38/39 and 41/42 to be filled out on the latter.

These cards must be preceded by a card with END in Columns 1-3 and followed by a card with TS in Columns 1 and 2.

3.5.13 Observation Data Cards

The observations to be processed must be the last set of cards in the deck and must follow the station location cards.

Since the number of observations that may be input to TRACE-D is unlimited, there is a flocking procedure that must be followed. A flock of data consists of 200 or less observation cards for a single satellite. There is no limit to the number of flocks that can be stacked; however, each flock must be followed by a card with TF in Columns 1 and 2 and the times associated with the observations of a flock can never be earlier than the latest time of the previous flock. This means that the data is not time sorted within a flock but the flocks are sorted according to earliest and latest times therein contained.

The contents of an observation card is formatted in the following way, as shown in Figure 4.

a. Columns 1 and 2 (ST): Station Identification, symbol which must correspond to a station location card.

b. Columns 3 and 4: Pass identification (optional).

c. Columns 5 through 21: month (columns 5 and 6), day (columns 7 and 8), hours (columns 9 and 10) minutes (columns 11 and 12), and seconds (columns 13-21), of the corresponding observations relative to Greenwich Mean Time.

d. Column 22: Observation set number.

e. Columns 23-76: Observation 1 (columns 23-40), Observation 2 (columns 41-58), Observation 3 (columns 59-76).

f. Column 77: Card number indicating observations, variances, or covariances.

The observation set (d) number and the card number (f) are the two indicators that define exactly what type of observations are contained on each card. Table 10 gives a complete listing of all types according to observation set number and card number.

After the last observation card in the deck, a TF card is not necessary, however a card with TR in Columns 1 and 2 plus an END card must be attached as the last two cards of the deck. If data from more than one satellite are to be used, the Satellite 1 data are set up in the same manner except that the TR card must be replaced by a TT card. The data for Satellite 2 are then similarly arranged. If Satellite 2 is the last vehicle, corresponding data are followed by a TR card and an END card: if it is not the last satellite, data are followed by a TT card. Data for Satellites 3 through 6, as applicable, are added in the same manner. A TR card rather than a TT card must follow the data corresponding to the last satellite, and an END card must follow the TR card. See Section 3.6 for a picture of the correct setup.

3.6 Input Deck Arrangements

Since the basic running deck to be used for each function to be performed can be obtained, the user need not concern himself with its contents. Therefore in each of the Figures the separate parts of this deck are ignored and it is labeled totally as the basic running deck. The categories of data used are described in detail in previous sections (for instance, Basic Data is explained in Section 3.2, etc.).

Observation Set Number (Column 22)	Observation Card Type (Column 77)	Field 1	Field 2	Field 3
1	0	Slant range(R)	Azimuth (A)	Elevation(E)
1	1	Variance(R)	Variance(A)	Variance(E)
1	2	Covariance(R,A)	Covariance(R,E)	Covariance(A,E)
2	0	Topocentric right ascension(α_T)	Topocentric declination(δ_T)	Topocentric hour angle (HA)
2	1	Variance(α_T)	Variance(δ_T)	Variance(HA)
2	2	Covariance(α_T,δ_T)		Covariance(δT,HA)
3	0	Geocentric right ascension(α_g)	Geocentric declination(δ_g)	
3	1	Variance(α_g)	Variance(δ_g)	
3	2	Covariance(α_g,δ_g)		
4	0	Argument of latitude(u)	Cross plane(v)	Altitude(h)
4	1	Variance(u)	Variance(v)	Variance(h)
4	2	Covariance(u,v)	Covariance(u,r)	Covariance(v,h)
5	0	$\hat{x}$	$\hat{y}$	$\hat{z}$
5	1	Variance($\hat{x}$)	Variance($\hat{y}$)	Variance($\hat{z}$)
5	2	Covariance($\hat{x}$,$\hat{y}$)	Covariance($\hat{x}$,$\hat{z}$)	Covariance($\hat{y}$,$\hat{z}$)
6	0	Slant range(R)	Range difference(P)	Range difference(Q)
6	1	Variance(R)	Variance(P)	Variance(Q)
6	2	Covariance(R,P)	Covariance(R,Q)	Covariance(P,Q)
7	0	Range rate($\dot{R}$)	Range rate difference($\dot{P}$)	Range rate differences($\dot{Q}$)
7	1	Variance($\dot{R}$)	Variance($\dot{P}$)	Variance($\dot{Q}$)
7	2	Covariance($\dot{R}$,$\dot{P}$)	Covariance($\dot{R}$,$\dot{Q}$)	Covariance($\dot{P}$,$\dot{Q}$)

Table 10. Observation Types and Indicators

3.6.1 Trajectory Prediction Deck Arrangement

When the function to be performed is a single trajectory prediction (function code ITIN = 3), the arrangement is as in Figure 5.

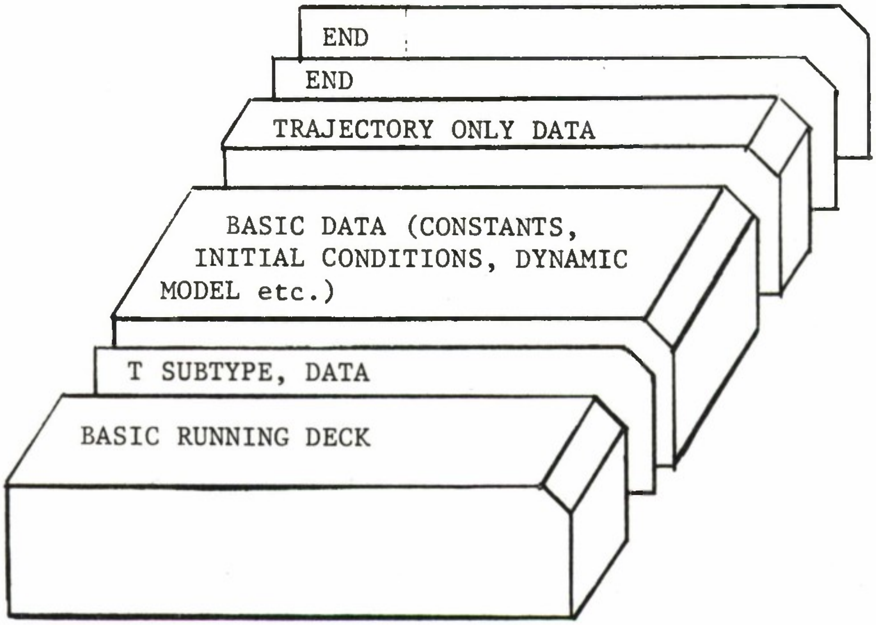


Figure 5.
TRAJECTORY PREDICTION DECK ARRANGEMENT

When several trajectory predictions are to be done in one run (function code ITIN = 333, etc.) then the deck arrangement is merely an extension of that for the single case (Figure 6).

3.6.2 Observation Generation Deck Arrangement

Figure 7 and Figure 8 show the correct data setup for a single data generation run (function code ITIN = 4) and several cases (function code ITIN = 4.4, etc.) respectively.

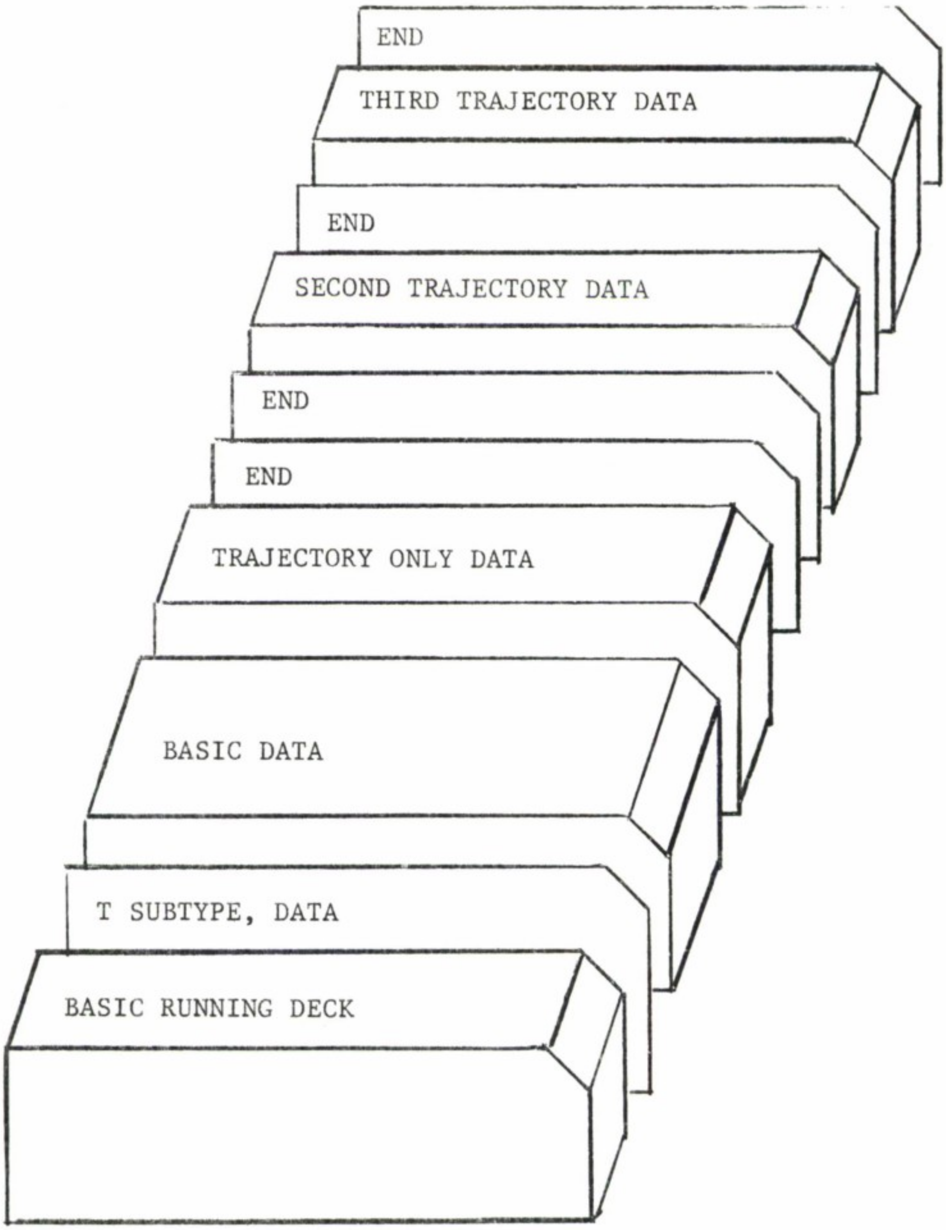


Figure 6.

MULTIPLE TRAJECTORY PREDICTIONS DECK ARRANGEMENT

Figure 7.

DECK ARRANGEMENT FOR
OBSERVATION GENERATION
SINGLE CASE.

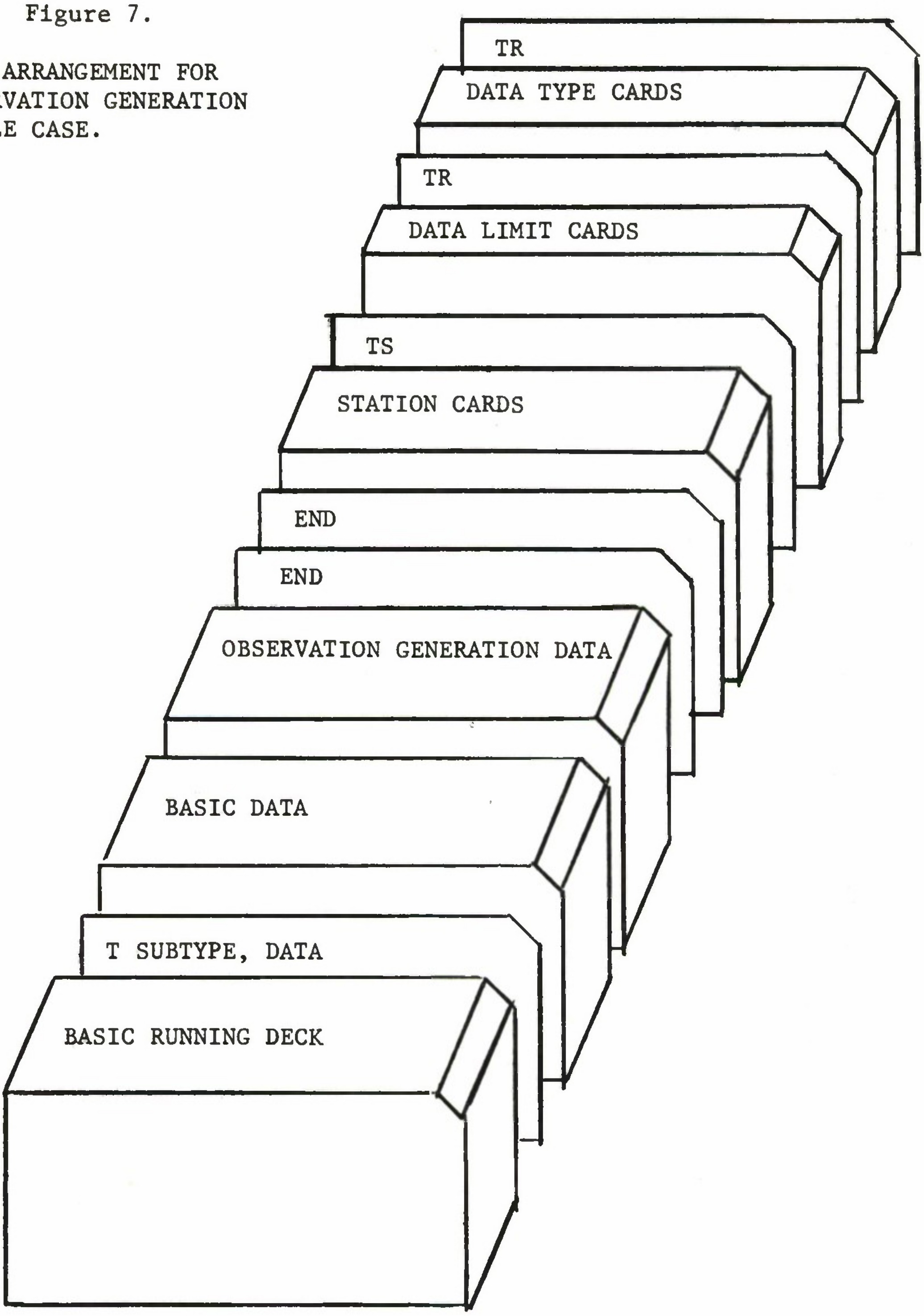
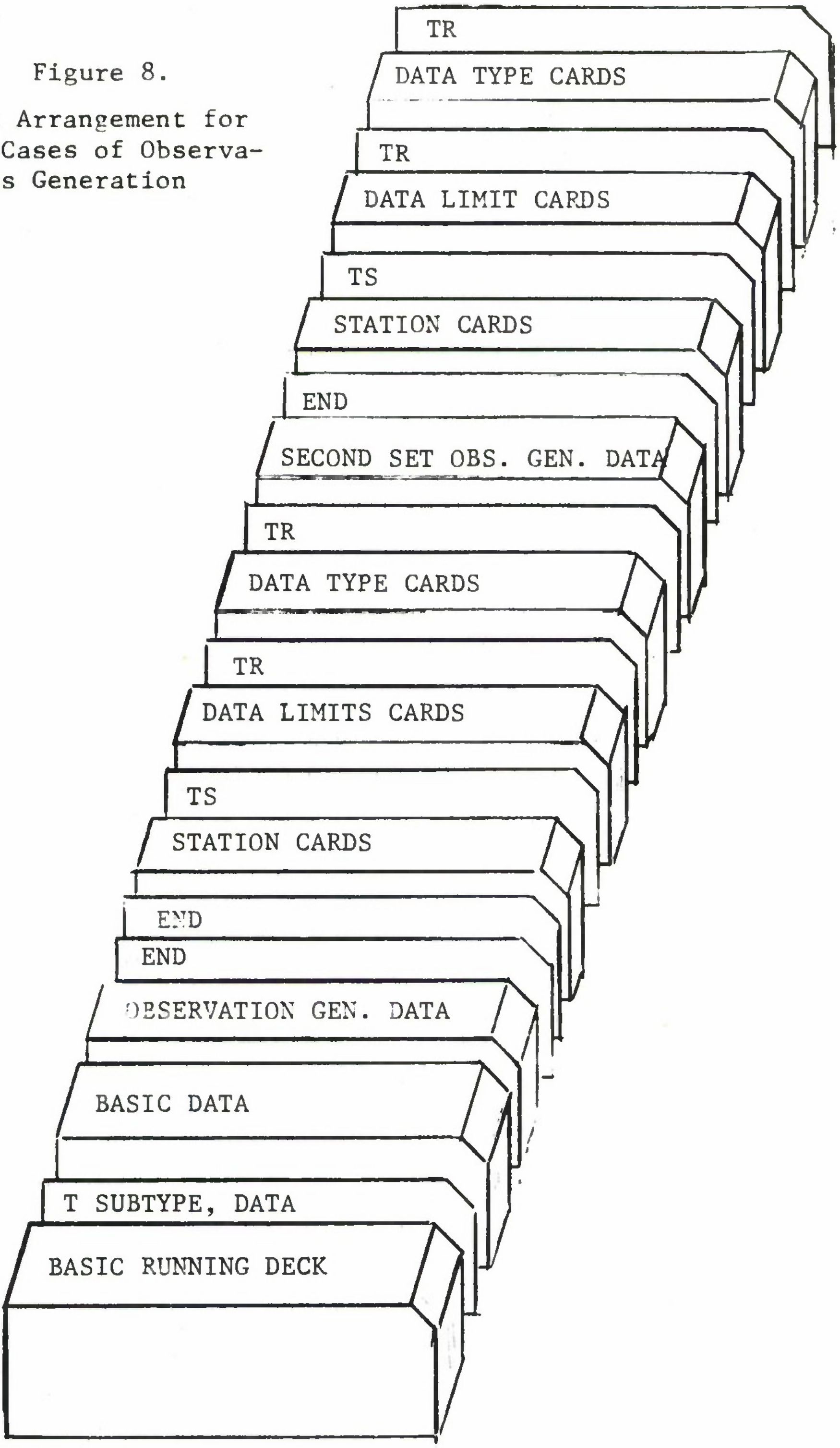


Figure 8.

Deck Arrangement for Two Cases of Observations Generation



3.6.3 Orbit Determination Deck Arrangement

There are several different deck setups that are permissible for an orbit determination run (function code ITIN = 12) according to the choice of several suboptions.

Figure 9 is the simplest deck setup and applies when the observation data is being input on tape (i.e., IBCDI input variable is used).

Figure 10 is the ordinary deck setup for a single case when the observation data is attached to the deck. Figure 11 is the deck setup for two such stacked cases.

Figure 12 is the appropriate data arrangement for the situation of multiple satellites (in this case three satellites).

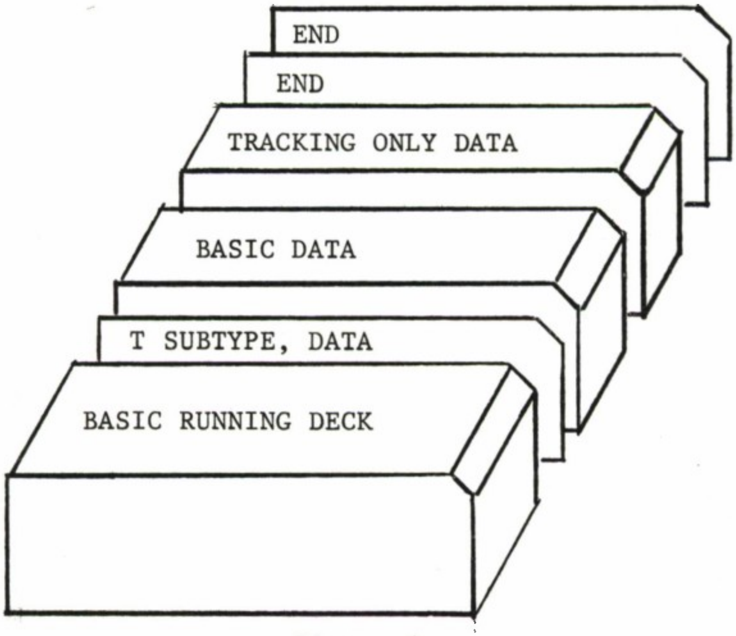


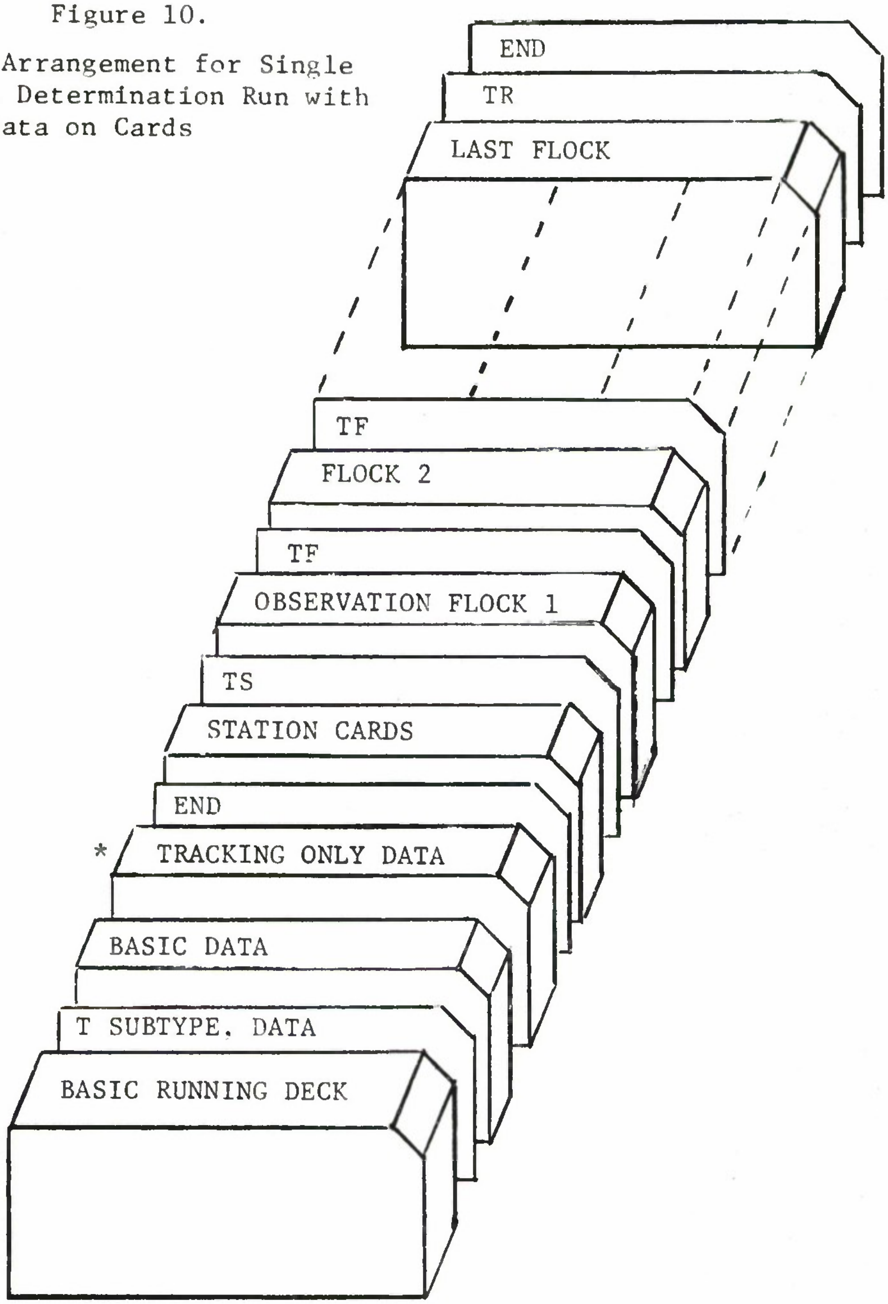
Figure 9.

Deck Arrangement for Orbit Determination with Input Tape*

* Note that the BCD tape of observations must contain as its first set of cards the station cards followed by a TS card and then the observations in proper flocks followed by TF cards with a TR card replacing the TF card of the last flock.

Figure 10.

Deck Arrangement for Single Orbit Determination Run with All Data on Cards



* Note that the word "tracking" is used interchangeably with the words "Orbit Determination".

Figure 11.

Deck Arrangement for Two Orbit Determination Cases All Data on Cards

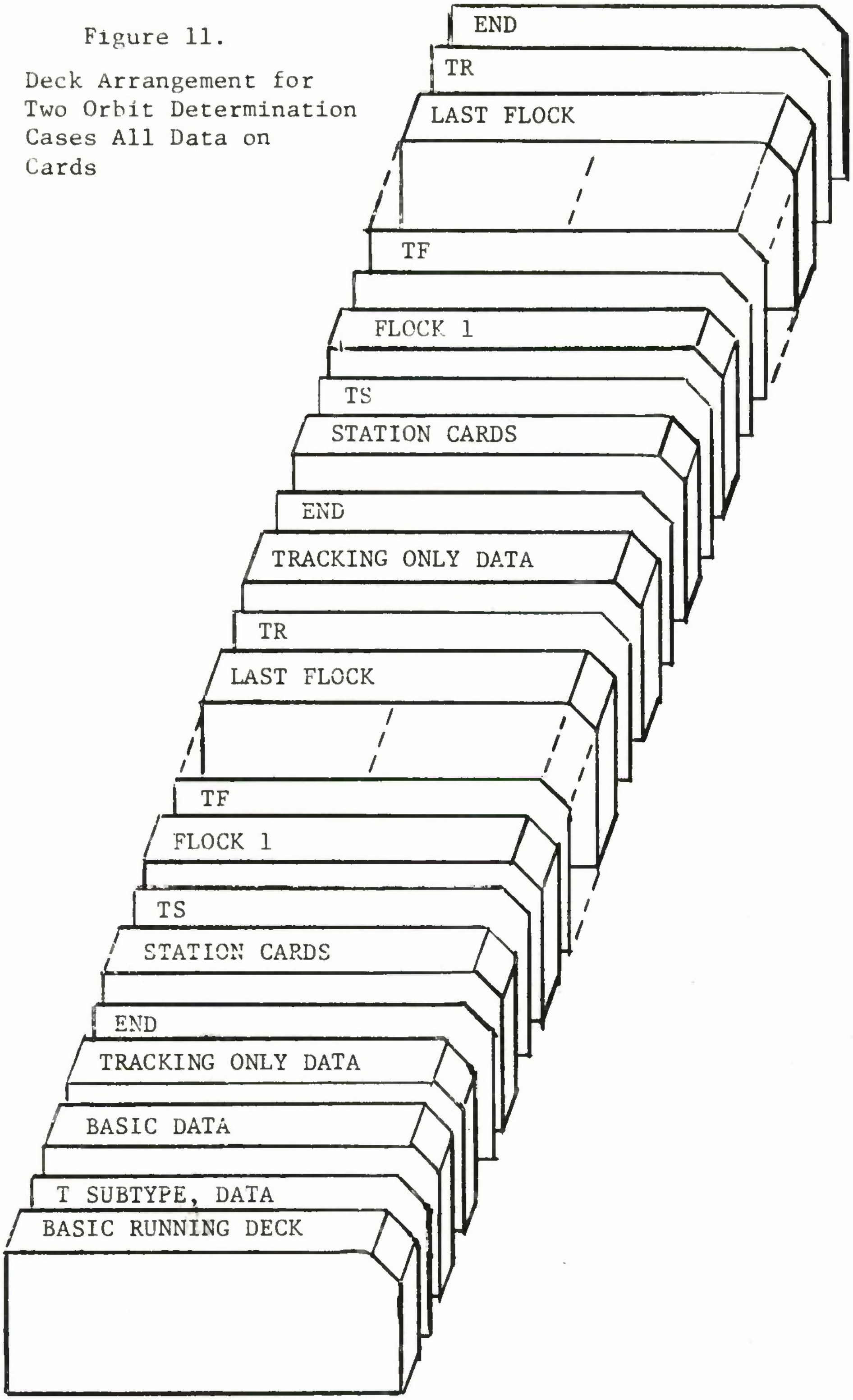
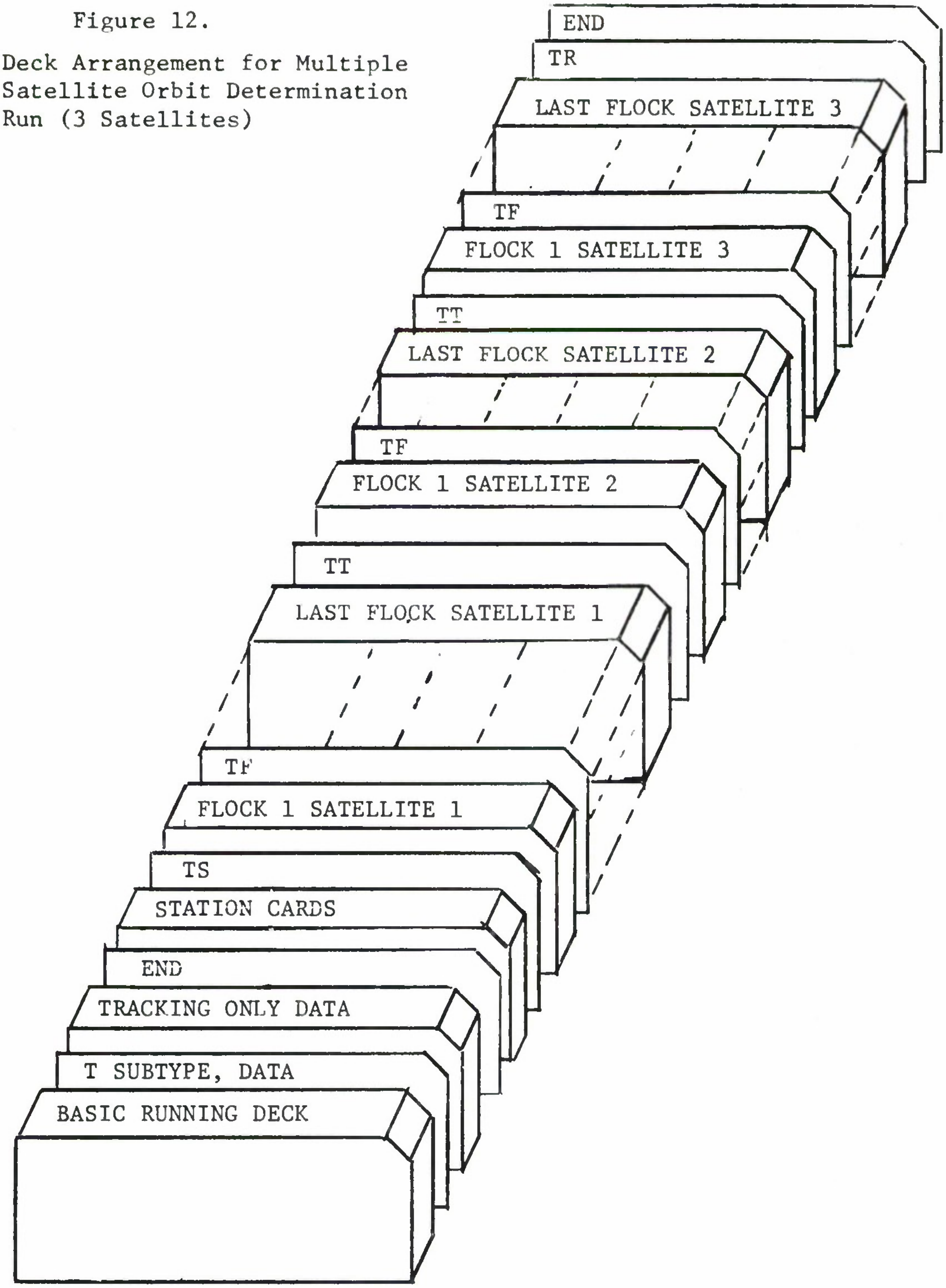


Figure 12.

Deck Arrangement for Multiple Satellite Orbit Determination Run (3 Satellites)



3.6.4 Sample Input Decks

Figures 13, 14, and 15 are listings of sample data decks for trajectory prediction, observation generation, and orbit determination. Besides giving the user an idea of what a typical deck looks like, they may also be used to familiarize the user with the operation of TRACE-D before he creates his own input. Another reason for running a test case of this sort is to determine the status of the program tape, for it is possible for the contents of a tape to deterioriate and no longer be useful[1].

It is not to be assumed that these sample cases exercise all the possible options of TRACE-D, but rather that they exhibit typical input and output. A complete description of the output obtained from these runs is included in Section 4.

---

[1] In this instance, there is no cause for alarm. MITRE has the capability to create a new and correct program tape in 24 hours.

Figure 13.

```
T          SUBTYPE.DATA
GINTEG       TRACE-D STANDARD INTEGRATION CONSTANTS
I1     1              I2     2               I3     0
 4     1               5     1               11     1.00002516
 23    .1         -9
 26    1
 30    1               31    .015625         32     64             33    1          -7
134    4              135    1               37     .0001          38    0.
 40    2820.18012     141    1
GC            TRACE-D STANDARD PHYSICAL CONSTANTS    10/ 1/65
 1     .437526904-2    2     .5530370    -2   6     .5
 8     .437526904-2    9     1.               10    10
 13    3280.8399       14    57.2957795       15    20925738
 16    332951.3        17    .01229853        18    .514979
 19    .107821         20    317.887          21    95.129
 22    23454.865       23    3443.93355       24    20925738
 25    348762.3        26    32.174           30    348762.3
 31    1.5             32    1.0471976        33    3.14159265
 34    298.3           35    300000.          36    82505.922
 NUMB                  42    3443.9336
I1FLAG                128    0
I1OB   14              I2    15               I3    14             I4    15
 OBJZ
 2     1082.645   -6  3     -2.546       -6  4     -1.649      -6
 5     -.210      -6
 6     .646       -6
 7     -.333      -6  8     -.270        -6
 9     -.053      -6
 10    -.054      -6  11    .302         -6  12    -.357       -6  13    -.114      -6
 14    .179       -6
 OBJT
 2     .1765980   -5  3     .2110765     -6  4     .3108429    -6  5     .2390598   -6
 6     .7017339   -6  7     .1652        -6  8     .5210912    -7  9     .4986992   -8
 10    .1111605   -6  11    .1083012     -6  12    .1717943    -7  13    .2122685   -8
 14    .1507404   -8  15    .4264694     -7  16    .4633369    -7  17    .1291007   -8
 18    .1967936   -8  19    .4477079     -9  20    .3729502    J0  21    .1839230   -6
 22    .3972437   -7  23    .35430592    -8  24    .3887152    -9  25    .3299649   J0
 26    .1515140   J0  27    .2052417     J1  28    .6820109    -7  29    .3849809   -8
 30    .3762496   -9  31    .2771455     -9  32    .2341330    J0  33    .8894014   J1
 34    .1641761   J2  35    .3418347     J2  36    .7640382    -7  37    .2440136   -8
 44    .8609215   J4  45    .1013471     -6  46    .6724120    -8  47    .4173952   -9
 48    .7857074   J0  55    .3251625     -7  66    .1006653    -6  67    .4704701   -8
 77    .2783799   J5
 89    .1717936   J5  90    .3549629     J4  91    .8360389    -8
```

Figure 13 (cont.)

```
101   .1059143   K0
102   .1326684   J9 104   .1974783   K1
113   .5398041   J8 116   .1393759   J9 117   .1492896   K0  118   .5702221   K2
OBLT
2     165.2042      3     7.823267      4     161.8799      5     23.63307
6     219.3494      7     31.73482      8     115.8047      9     25.74411
10    232.5121      11    169.9065      12    59.74292      13    41.60563
14    56.95252      15    209.876       16    140.3382      17    50.04699
18    66.28621      19    47.13021      20    42.58828      21    38.37493
22    12.06147      23    1.37273       24    53.46592      25    7.078959
26    27.20422      27    8.598698      28    139.0856      29    28.15497
30    57.94327      31    45.80993      32    22.83747      33    15.51001
34    15.09665      35    19.70539      36    5.856014      37    48.25990
44    13.95194      45    309.8056      46    100.9007      47    68.25838
48    59.07748      55    164.1975      66    203.5371      67    91.41733
77    14.87681
89    11.44440      90    9.804658      91    160.5400
101   30.31227      102   23.00277      104   13.72105      113   27.04833
116   15.65423
117   16.80139      118   20.10848
DITIN 3
IICTYP2
IC    358.2
2     -25.5
3     90.35
4     47.18
5     22999226.
6     24797.530
IPRTIMO
I2    1             3     0.            4     5.
5     60.
6     30.           7     90.
DRAG  .008
I2    1
3     6.83          4     -15.684
IYEAR 1967          IMNTH 7
IDAY  8             TZNE  0.
HR    15.           MIN   0.            SEC   0.
DPRCDEX    X
IPTAPE4
END
END
```

Figure 14

```
T          SUBTYPE.DATA
GINTEG       TRACE-D STANDARD INTEGRATION CONSTANTS
I1    1              I2    2              I3    0
 4    1               5    1              11    1.00002516
 23    .1         -9 26    1              30    1
 31   .015625        32    64             33    1
I34   4             I35    1              37    .001
 38   0.             40    2820.1763     I41    1
GC
 1    .437526904-2 2    .5530370   -2 6     .5
 6    .5             8    .43752695 -2
 9    1.            10    10
 13   3280.8399     14    57.2957795    15    20925738
 16   332951.3      17    .0122999      18    .814979
 19   .107821       20    317.887       21    95.129
 22   23454.865     23    3443.9336     24    20925738
 25   348762.3      26    32.174        30    348762.3
 31    1.5          32    1.0471976     33    3.14159265
 34   298.3         35    300000.       36    82505.922
ITMATX4
 DRAG .01           I2    1             3     6.83
 4    -15.684
 RREFC1.
GC    STANDARD DECK FOR GUIERS 6.TH ORDER EARTH MODEL        10/15/65
 1    .043752695-1 2    .55304505 -2 15    20925741.
 24   20925741.     OBJT                2     1.723       -6
 3    1.856      -6 4    .4482      -6 5     .1643       -6
 6    .7278      -6 7    .1536      -6 8     .05719      -6
 9    .004781    -6 10   .1509      -6 11    .05329      -6
 12   .005842    -6 13   .004093    -6 14    .0008462    -6
 15   .06611     -6 16   .03746     -6 17    .01166      -6
 18   .002256    -6 19   .0003328   -6 20    .00005153 -6
 OBLT               2    -13.18        3     5.31
 4    -13.33        5    16.00         6     -136.68
 7    27.47         8    -1.10         9     36.01
 10   -81.86        11   -2.60         12    -3.45
 13   58.25         14   -15.32        15    157.21
 16   113.15        17   -1.75         18    60.74
 19   -17.75        20   -14.34        OBJZ
 2    1082.76    -6 3    -2.693     -6 4     -1.56       -6
 5    -.006      -6 6    .39        -6 7     -.633       -6
 8    0.            9    .210       -6I108   9
I2    6            I3    9            I4     6
DITIN 4            IYEAR 1965          IMNTH 3
```

Figure 14 (cont.)

```
IDAY   23
IICTYP4
 IC    -60.
 2     0.           3    90.
 4     25.
 5     -607612.     6    -1.
IPTAPE4
BNOISE1             IISIG 1          I2    2
I3     3            I4   4           I5    5
I6     6            I7   7           I8    8
I9     13           I10  14          I11   15
I12    19            SIGMA100.        2    .1
 3     .1           4    .05          5    .05          6     .05
 7     .05          8    .05          9    1000.
 10    1000.        11   1000.        12   .1
END
MRAPAR05.99
D01.01BB  RBIAS     03.011000.
END
AA        75.0      300.0     1000.
BB        45.0      240.       100.
CC        0.        315.0      500.
DD        0.         15.0     200.0
EE        -15.0     135.0      100.
FF        -65.0      75.0     5000.0
TS
AA        15.                                               70    24
BB        15.                                               70    24
CC        15.                                               70    24
DD        15.                                               70    24
EE        15.                                               70    24
FF        15.                                               70    24
TR
AA     XXXX           X       XXXXX
BB     XXXX                   XXXXX
CC     XXXX          X        XXXXX
DD     XXXX                   XXXXX
EE     XXXX                XX XXXXX
FF     XXXX                   XXXXX
TR
```

Figure 15

```
T          SUBTYPE.DATA
GINTEG        TRACE-D STANDARD INTEGRATION CONSTANTS
I1      1           I2    2             I3     0
 4      1            5    1             11     1.00002516
 23     .1        -9
 26     1
 30     1            31   .015625        32    64          33    1          -7
134     4           135   1              37    .0001       38    0.
 40     2820.18012  141   1
GC            TRACE-D STANDARD PHYSICAL CONSTANTS    10/ 1/65
 1      .437526904-2 2    .55304203 -2  6      .5
 8      .437526904-2 9    1.            10     10
 13     3280.8399    14   57.2957795    15     20925738
 16     332951.3     17   .01229853     18     .814979
 19     .107821      20   317.887       21     95.129
 22     23454.865    23   3443.93355    24     20925738
 25     348762.3     26   32.174        30     348762.3
 31     1.5          32   1.0471976     33     3.14159265
 34     298.3        35   300000.       36     82505.922
 NUMB                42   3443.9336
DITIN 12
DPRCDE X X
I1CTYP2
 IC     23.11454
 2      26.51516
 3      89.88977
 4      45.73312
 5      24780836.7
 6      23765.259
1MAXIT1
1YEAR 1967
1MNTH 7
IDAY  8
 TZNE 0
 HR     14.
 MIN    45.
 DRAG   .2849        I2    1
 3      6.83          4    -15.684
I1OB    10           I2    6            I3     10
I4      6
 OBJZ
 2      .1082645   -2
 3      -.2546000  -5
 4      -1.649     -6
```

Figure 15 (cont.)

```
5     -.210     -6 6    .646      -6 7     -.333     -6
8     -.270     -6 9    -.053     -6 10    -.054     -6
OBJT               2    1.5664    -6 3     1.7287    -6
4     .3025     -6 5    .1966     -6 6     .5234     -6
7     .1372     -6 8    .04166    -6 9     .009378   -6
10    .1247     -6 11   .05846    -6 12    .02219    -6
13    .001605   -6 14   .001029   -6 15    .09572    -6
16    .02928    -6 17   .001037   -6 18    .001500   -6
19    .000381   -6 20   .000140   -6
OBLT               2    -15.50       3     -1.43
4     -32.30       5    32.31        6     -133.53
7     35.75        8    -2.75        9     26.09
10    -164.13      11   -24.19       12    58.58
13    32.27        14   -15.79       15    99.46
16    -38.87       17   0.0          18    -19.96
19    -25.28       20   -16.92
SIGMA22.96
2     .06056
3     22.96
4     .06056
5     22.96
6     .06056
IPTAPE4
IISIG 101
I2    119
I3    201
I4    219
I5    301
I6    319
DCPRAM2XXXXXX
DDPRAMXXXX
BNDS  1.5
2     1.5
3     .3
4     .75
5     4920.
6     492.
7     .15
8     .1         -7
9     .1         -7
10    .1         -7
END
MH   1    42.617373 288.50853 223.0970
BD   2    42.505961 285.76481 -91.8640
```

Figure 15 (cont.)

```
BH   3    42.645973 289.90644 +154.199
TS
MH    7 8145316.7706017   -17007.799540638
MH    7 8145321.2185237   -16953.515419959
MH    7 8145325.5664477   -16893.817585227
MH    7 8145329.9603707   -16841.864501236
MH    7 8145334.4422917   -16781.986876605
MH    7 8145338.7262187   -16723.026246665
MH    7 8145342.5561527   -16668.616601036
MH    7 8145343.5394681  8494671.751891473
MH    7 8145346.4340867   -16612.446522233
MH    7 8145350.2880207   -16554.962598321
MH    7 8145354.0479567   -16497.401902913
MH    7 8145357.9418897   -16436.200131176
MH    7 8145358.5792151  8245884.580015854
MH    7 81454 1.7558247   -16374.666010437
MH    7 81454 5.5157637   -16312.415026127
MH    7 81454 9.2756987   -16248.541010438
MH    7 8145410.9870091  8043320.997374223
MH    7 8145413.0356387   -16183.004265009
MH    7 8145416.7955787   -16115.793963192
MH    7 8145420.5955147   -16046.087926446
MH    7 8145422.4548211  7858498.293914379
MH    7 8145424.3554517   -15975.296587883
MH    7 8145428.1153907   -15902.686679719
MH    7 8145431.8753317   -15828.202099680
MH    7 8145434.1106331  7673186.286040589
MH    7 8145435.6352727   -15751.774606226
MH    7 8145439.3952127   -15673.353674529
MH    7 8145443.1551527   -15592.931758462
MH    7 8145445.5784501  7493579.593139116
MH    7 8145446.9150947   -15510.397637783
MH    7 8145450.6750367   -15425.733267663
MH    7 8145454.4349787   -15338.886154829
MH    7 8145456.8582741  7319714.402892145
MH    7 8145458.1949217   -15250.050524889
MH    7 81455 1.9548637   -15158.382217763
MH    7 81455 5.7148057   -15064.618438243
MH    7 81455 8.1381001  7148905.314970903
MH    7 81455 9.4747457   -14968.425524830
MH    7 8145513.2346877   -14869.749999939
MH    7 8145516.9946297   -14768.547572134
MH    7 8145519.4179301  6981341.469786883
MH    7 8145520.7545717   -14664.727034090
```

Figure 15 (cont.)

```
MH    7 8145524.5145167   -14558.236876605
MH    7 8145528.2744597   -14449.018372653
MH    7 8145530.8857601  6814605.019683455
MH    7 8145532.0344047   -14336.992453991
MH    7 8145535.7943507   -14222.113188861
MH    7 8145539.5542967   -14104.283136425
MH    7 8145542.3535951  6651813.746672701
MH    7 8145543.3142427   -13983.450459300
MH    7 8145547.0741897   -13859.567585288
MH    7 8145550.8341377   -13732.533792613
MH    7 8145553.6334361  6495847.080016261
MH    7 8145554.5940857   -13602.290026126
MH    7 8145558.354036"   -13468.763779519
MH    7 81456 2.1139867   -13331.885498642
MH    7 81456 4.9132821  6344314.041960785
MH    7 81456 5.8739347   -13191.593175827
MH    7 81456 9.6338827   -13047.799540638
MH    7 8145613.3938307   -12900.444881855
MH    7 8145616.1931331  6197545.177123089
MH    7 8145617.1537817   -12749.447178482
MH    7 8145620.9137307   -12594.758858202
MH    7 8145624.673682'   -12436.287401556
MH    7 8145627.4729891  6055927.460570700
MH    7 8145628.4336357   -12273.993438301
MH    7 8145631.8175937   -12124.569553790
MH    7 8145656.8006431  5714590.387114810
MH    7 8145657.4792947   -10883.785433053
BH    7 8145657.4792947   -11177.128936945
MH    7 81457 1.2392527   -10685.356955347
BH    7 81457 1.2392527   -10985.440616785
MH    7 81457 4.9992117   -10482.535761116
BH    7 81457 4.9992117   -10789.370406805
MH    7 81457 8.7591717   -10275.271653532
BD    7 81457 8.7591717   -10406.458661375
BH    7 81457 8.7591717   -10588.925853012
MH    7 8145711.0884891  5564041.174498868
MH    7 8145712.5191337   -10063.540682374
BH    7 8145712.5191337   -10384.057414709
MH    7 8145716.2790977    -9847.312335968
BD    7 8145716.2790977    -9987.448490798
BH    7 8145716.2790977   -10174.793635128
MH    7 8145720.0390627    -9626.570538043
BD    7 8145720.0390627    -9771.381561637
BH    7 8145720.0390627    -9961.031495988
```

Figure 15 (cont.)

```
MH   7 8145722.3683761 5453289.173186419
MH   7 8145723.7990317   -9401.292979001
BD   7 8145723.7990317   -9550.736220479
BH   7 8145723.7990317   -9742.778215229
MH   7 8145727.0889977   -9200.437007844
BD   7 8145727.0889977   -9354.033136427
BH   7 8145727.0889977   -9548.052165329
MH   7 8145731.3189557   -8937.069553792
BD   7 8145731.3189557   -9096.087598383
BH   7 8145731.3189557   -9292.640748024
MH   7 8145733.6482721 5350155.314940820
MH   7 8145735.0789207   -8698.130249321
BD   7 8145735.0789207   -8861.911417305
BH   7 8145735.0789207   -9060.719816267
MH   7 8145738.8388877   -8454.659120738
BD   7 8145738.8388877   -8623.455380558
BH   7 8145738.8388877   -8824.287401556
MH   7 8145742.5988557   -8206.674540639
BD   7 8145742.5988557   -8380.480971097
BH   7 8145742.5988557   -8583.324803113
MH   7 8145744.9281751 5255145.669280096
MH   7 8145746.3588267   -7954.190944850
BD   7 8145746.3588267   -8132.829068213
BH   7 8145746.3588267   -8337.750656127
MH   7 8145749.4608047   -7742.543635130
BH   7 8145749.4608047   -8131.803398932
MH   7 8145753.8787677   -7435.911417305
BH   7 8145753.8787677   -7833.289698153
MH   7 8145756.2080871 5168704.527526415
MH   7 8145757.6387377   -7170.207020938
BH   7 8145757.6387377   -7574.386154860
MH   7 81458 1.3987087   -6900.222440958
BH   7 81458 1.3987087   -7311.076443552
MH   7 81458 5.1586817   -6626.022637784
BH   7 81458 5.1586817   -7043.491797864
MH   7 81458 7.4880091 5091246.948790910
MH   7 81458 8.9186567   -6347.699803144
BD   7 81458 8.9186567   -6556.983267694
BH   7 81458 8.9186567   -6771.640091836
MH   7 8145812.5446367   -6075.487532765
BD   7 8145812.5446367   -6289.579724401
BH   7 8145812.5446367   -6505.478674530
MH   7 8145816.4386167   -5779.078412056
BH   7 8145816.4386167   -6215.483267694
```

Figure 15 (cont.)

```
MH    7 8145818.7679401  5023233.398925128
MH    7 8145821.2865907    -5404.372703403
BD    7 8145821.2865907    -5630.134186327
BH    7 8145821.2865907    -5848.448818892
MH    7 8145823.9585737    -5195.242782116
BD    7 8145823.9585737    -5424.551837265
BH    7 8145823.9585737    -5643.421587914
MH    7 8145827.7185517    -4897.978674531
BD    7 8145827.7185517    -5132.214238822
BH    7 8145827.7185517    -5351.723425179
MH    7 8145830.0478801  4965042.486846300
BD    7 8145830.0478801  5012599.803130797
BH    7 8145830.0478801  4995518.011779438
MH    7 8145831.4785337    -4597.302821517
BD    7 8145831.4785337    -4836.414370060
BH    7 8145831.4785337    -5056.453412056
MH    7 8145835.2385177    -4293.425853014
BD    7 8145835.2385177    -4537.234251946
BH    7 8145835.2385177    -4757.695209950
MH    7 8145838.9985057    -3986.493438288
TF
BD    7 8145838.9985057    -4234.887795269
BH    7 8145838.9985057    -4455.634842515
MH    7 8145841.3278321  4917039.402862144
BD    7 8145841.3278321  4961818.208648054
BH    7 8145841.3278321  4942276.738799478
MH    7 8145842.7584917    -3676.690288708
BD    7 8145842.7584917    -3929.666666657
BH    7 8145842.7584917    -4150.414041996
MH    7 8145846.5184747    -3364.213910743
BD    7 8145846.5184747    -3621.639435679
BH    7 8145846.5184747    -3842.224081352
MH    7 8145850.2784607    -3049.265091851
BD    7 8145850.2784607    -3310.935695529
BH    7 8145850.2784607    -3531.279527545
MH    7 8145854.0384497    -2732.049868762
BD    7 8145854.0384497    -2997.869094476
BH    7 8145854.0384497    -3217.771653533
MH    7 8145854.2997901  4874828.936980719
BD    7 8145854.2997901  4916232.545897969
BH    7 8145854.2997901  4893819.619384345
MH    7 8145857.7984417    -2412.770997360
BD    7 8145857.7984417    -2682.662401557
BH    7 8145857.7984417    -2901.898622036
```

Figure 15 (cont.)

```
MH    7 81459 1.5584367    -2091.681430444
BD    7 81459 1.5584367    -2365.384842515
BH    7 81459 1.5584367    -2583.833661422
MH    7 81459 5.7884277    -1728.552493438
BD    7 81459 5.7884277    -2006.360564291
BH    7 81459 5.7884277    -2223.667322829
MH    7 81459 8.3997591  4845091.108886094
BD    7 81459 8.3997591  4882650.951415570
BH    7 81459 8.3997591  4857161.154845925
MH    7 81459 9.5484177    -1404.350393690
BD    7 81459 9.5484177    -1685.668963253
BH    7 81459 9.5484177    -1901.723097108
MH    7 8145913.3084117    -1079.074803144
BD    7 8145913.3084117    -1363.636154853
BH    7 8145913.3084117    -1578.378280841
MH    7 8145917.0684087     -752.939304460
BD    7 8145917.0684087    -1040.523950130
BH    7 8145917.0684087    -1253.791994750
MH    7 8145920.8284087     -426.215879263
BD    7 8145920.8284087     -716.666994750
BH    7 8145920.8284087     -928.166338582
MH    7 8145921.9357471  4832679.461913471
BD    7 8145921.9357471  4866340.157470290
BH    7 8145921.9357471  4837948.622008667
MH    7 8145924.5884107      -99.171587926
BD    7 8145924.5884107     -392.191272965
BH    7 8145924.5884107     -601.836286090
MH    7 8145928.3784097      230.581036744
BD    7 8145928.3784097      -64.978018373
BH    7 8145928.3784097     -272.511482939
MH    7 8145932.1384077      557.538713906
BD    7 8145932.1384077      259.744094485
BH    7 8145932.1384077       54.458989501
MH    7 8145934.7197491  4835563.877929160
BD    7 8145934.7197491  4865462.664031525
BH    7 8145934.7197491  4834413.188934121
MH    7 8145935.8984087      884.088254586
BD    7 8145935.8984087      584.356955375
BH    7 8145935.8984087      381.427165352
MH    7 8145939.6584137     1209.959317572
BD    7 8145939.6584137      908.599081360
BH    7 8145939.6584137      708.104658786
MH    7 8145943.8584217     1572.849081352
BD    7 8145943.8584217     1269.870734990
```

Figure 15 (cont.)

```
BH   7 8145943.8584217     1072.327099726
MH   7 8145946.1877641  4850222.375304724
BD   7 8145946.1877641  4876679.429107042
BH   7 8145946.1877641  4843354.790008049
MH   7 8145948.0484327     1933.403871380
BD   7 8145948.0484327     1629.105314948
BH   7 8145948.0484327     1434.749999992
MH   7 8145951.8084357     2255.420275569
BD   7 8145951.8084357     1950.168963231
BH   7 8145951.8084357     1758.819225714
MH   7 8145955.5684427     2575.734251946
BD   7 8145955.5684427     2269.760498673
BH   7 8145955.5684427     2081.488845125
MH   7 8145957.6557901  4876194.192870570
BD   7 8145957.6557901  4899150.426482634
BH   7 8145957.6557901  4863629.035399981
MH   7 8145959.3284527     2894.118110210
BD   7 8145959.3284527     2587.678149581
BH   7 8145959.3284527     2402.614829376
MH   7 815 0 3.0884657     3210.351706013
BD   7 815 0 3.0884657     2903.638123333
BH   7 815 0 3.0884657     2721.910761133
MH   7 815 0 6.8484807     3524.234580040
BD   7 815 0 6.8484807     3217.569553778
BH   7 815 0 6.8484807     3039.201443538
MH   7 815 0 8.9358271  4912595.636443626
BD   7 815 0 8.9358271  4932098.687652342
BH   7 815 0 8.9358271  4894511.450103209
MH   7 815 010.6084957     3835.544947475
BD   7 815 010.6084957     3529.190288693
BH   7 815 010.6084957     3354.292650893
MH   7 815 014.3685077     4144.094160080
BD   7 815 014.3685077     3838.201443538
BH   7 815 014.3685077     3666.901902854
MH   7 815 018.1285227     4449.713910728
BD   7 815 018.1285227     4144.511154830
BH   7 815 018.1285227     3976.858923867
MH   7 815 020.2158751  4959522.047210072
BD   7 815 020.2158751  4975564.665343767
BH   7 815 020.2158751  4936068.044585795
MH   7 815 021.8885397     4752.191272944
BD   7 815 021.8885397     4447.928805738
BH   7 815 021.8885397     4283.965551138
MH   7 815 025.6485587     5051.377624631
```

Figure 15 (cont.)

```
BD   7 815 025.6485587     4748.261154800
BH   7 815 025.6485587     4588.059383154
MH   7 815 029.4085807     5347.116797834
BD   7 815 029.4085807     5045.252952695
BH   7 815 029.4085807     4888.933398932
MH   7 815 031.8719351  5018746.915984593
BD   7 815 031.8719351  5031255.183715188
BH   7 815 031.8719351  4989900.393676407
MH   7 815 033.1686047     5639.257545888
BD   7 815 033.1686047     5338.932086557
BH   7 815 033.1686047     5186.435039341
MH   7 815 036.9986227     5933.008530140
BD   7 815 036.9986227     5634.471128583
BH   7 815 036.9986227     5485.930118054
MH   7 815 040.7586437     6217.502296537
BD   7 815 040.7586437     5920.948162675
BH   7 815 040.7586437     5776.171915978
MH   7 815 043.9040091  5090921.423858105
BD   7 815 043.9040091  5099845.669249987
BH   7 815 043.9040091  5056728.182372580
MH   7 815 044.9586707     6530.578740120
BD   7 815 044.9586707     6236.347112805
BH   7 815 044.9586707     6095.967191547
MH   7 815 048.7186957     6806.551181048
BD   7 815 048.7186957     6514.459645599
BH   7 815 048.7186957     6378.108267665
MH   7 815 052.4787237     7078.336942196
BD   7 815 052.4787237     6788.751968443
BH   7 815 052.4787237     6656.162401527
MH   7 815 055.5600901  5171103.772948697
BD   7 815 055.5600901  5176625.852996039
BH   7 815 055.5600901  5131899.540648845
MH   7 815 056.2387537     7345.880905449
BD   7 815 056.2387537     7058.797900200
BH   7 815 056.2387537     6930.158792585
MH   7 815 059.9987877     7609.087926447
BD   7 815 059.9987877     7324.712926447
BH   7 815 059.9987877     7199.950459271
MH   7 815 1 3.7588157     7867.925196796
TF
BD   7 815 1 3.7588157     7586.324146956
BH   7 815 1 3.7588157     7465.447178393
MH   7 815 1 6.8401781  5257859.514403833
BD   7 815 1 6.8401781  5260174.606292054
```

Figure 15 (cont.)

```
BH    7 815 1 6.8401781 5214070.603636997
MH    7 815 1 7.5188437    8122.322834610
BD    7 815 1 7.5188437    7843.663057655
BH    7 815 1 7.5188437    7726.558726966
MH    7 815 111.2788747    8372.245078623
BD    7 815 111.2788747    8096.620406776
BH    7 815 111.2788747    7983.298556387
MH    7 815 115.0689077    8619.612860798
BD    7 815 115.0689077    8346.987860857
BH    7 815 115.0689077    8237.502952694
MH    7 815 118.8289417    8860.457349002
BD    7 815 118.8289417    8591.197178423
BH    7 815 118.8289417    8485.350393593
MH    7 815 119.6242891 5366496.719115616
BD    7 815 119.6242891 5365318.110198558
BH    7 815 119.6242891 5317782.283416079
MH    7 815 122.6129777    9098.269356846
BD    7 815 122.6129777    8832.220800399
BH    7 815 122.6129777    8730.143700718
MH    7 815 126.3730157    9330.004921137
BD    7 815 126.3730157    9067.309711218
BH    7 815 126.3730157    8968.818569481
MH    7 815 130.1730557    9559.574474990
BD    7 815 130.1730557    9300.414370000
BH    7 815 130.1730557    9205.468503892
MH    7 815 133.5364211 5496434.055083341
BD    7 815 133.5364211 5491595.702086584
BH    7 815 133.5364211 5442693.471099318
MH    7 815 133.9330907    9782.182086526
BD    7 815 133.9330907    9526.528215170
BH    7 815 133.9330907    9435.012467145
MH    7 815 137.7871267   10005.643044530
BD    7 815 137.7871267    9753.615157365
BH    7 815 137.7871267    9665.611876547
MH    7 815 141.5471637   10219.110236107
BD    7 815 141.5471637    9970.648293912
BH    7 815 141.5471637    9885.977690219
MH    7 815 145.3072027   10428.093175767
BD    7 815 145.3072027   10183.123359500
BH    7 815 145.3072027   10101.818241356
MH    7 815 146.3205521 5625886.089202367
BD    7 815 146.3205521 5617857.086577942
BH    7 815 146.3205521 5567863.188934012
MH    7 815 149.0672427   10632.640091775
```

Figure 15 (cont.)

```
BD    7 815 149.0672427    10391.355642973
BH    7 815 149.0672427    10313.204068123
MH    7 815 152.8272847    10832.774278102
BD    7 815 152.8272847    10595.088582574
BH    7 815 152.8272847    10520.081364749
MH    7 815 156.6173287    11030.091535328
BD    7 815 156.6173287    10796.124671815
BH    7 815 156.6173287    10724.212926446
MH    7 815 157.9861881  5751823.622008629
BD    7 815 157.9861881  5741009.711272369
BH    7 815 157.9861881  5690133.136443336
MH    7 815 2   .3773717   11221.512467085
BD    7 815 2   .3773717   10991.209973632
BH    7 815 2   .3773717   10922.284776805
MH    7 815 2 4.2014207    11411.817585169
BD    7 815 2 4.2014207    11185.169291256
BH    7 815 2 4.2014207    11119.246062933
MH    7 815 2 8.3674687    11614.185367344
BD    7 815 2 8.3674687    11391.668635069
BH    7 815 2 8.3674687    11328.860236108
MH    7 815 2 9.8208171  5886674.212554225
BD    7 815 2 9.8208171  5873193.569518377
BH    7 815 2 9.8208171  5821524.179747825
MH    7 815 212.1275117    11792.444881795
BD    7 815 212.1275117    11573.566272854
BH    7 815 212.1275117    11513.571522175
MH    7 815 215.8875547    11966.633202015
BD    7 815 215.8875547    11751.365157424
BH    7 815 215.8875547    11694.017060278
MH    7 815 220.0236047    12153.583661316
BD    7 815 220.0236047    11942.331364750
BH    7 815 220.0236047    11887.836286007
MH    7 815 221.2997951  6023854.396300691
BD    7 815 221.2997951  6007901.541960904
BH    7 815 221.2997951  5955575.688933976
MH    7 815 223.7836517    12319.373031436
BD    7 815 223.7836517    12111.740485488
BH    7 815 223.7836517    12059.779855547
MH    7 815 227.5436997    12481.275262413
BD    7 815 227.5436997    12277.156167922
BH    7 815 227.5436997    12227.710957942
MH    7 815 242.9092391  6297622.965850138
BD    7 815 242.9092391  6277370.177123344
BH    7 815 242.9092391  6224033.038024572
```

Figure 15 (cont.)

```
MH   7 815 252.1960267     13451.150590418
BD   7 815 252.1960267     13269.581036685
MH   7 815 255.2440667     13560.611876545
BD   7 815 255.2440667     13381.692585168
BH   7 815 255.2440667     13348.261482833
MH   7 815 259.0041177     13692.635170518
BD   7 815 259.0041177     13517.040682314
BH   7 815 259.0041177     13485.424868642
MH   7 815 3 2.7641687     13821.411089180
BD   7 815 3 2.7641687     13648.956364690
BH   7 815 3 2.7641687     13619.210629819
MH   7 815 3 4.5295311   6589499.901518962
BD   7 815 3 4.5295311   6565339.074767280
BH   7 815 3 4.5295311   6511265.748015802
MH   7 815 3 6.5242217     13947.020669220
BD   7 815 3 6.5242217     13777.706692813
BH   7 815 3 6.5242217     13749.744422494
MH   7 815 310.2842737     14069.526574670
BD   7 815 310.2842737     13903.421587883
BH   7 815 310.2842737     13877.105642913
MH   7 815 314.0443277     14188.993110178
BD   7 815 314.0443277     14025.900918482
BH   7 815 314.0443277     14001.330708562
MH   7 815 315.8096931   6748148.654815082
BD   7 815 315.8096931   6722111.843779430
BH   7 815 315.8096931   6667728.379241424
MH   7 815 317.8043827     14305.507545827
BD   7 815 317.8043827     14145.435367344
BH   7 815 317.8043827     14122.393044530
MH   7 815 321.5644377     14419.122375249
BD   7 815 321.5644377     14262.004921137
BH   7 815 321.5644377     14240.514763652
MH   7 815 325.3244927     14529.902558981
BD   7 815 325.3244927     14375.769028781
BH   7 815 325.3244927     14355.728346346
MH   7 815 327.0898581   6910747.342498240
BD   7 815 327.0898581   6882935.334624562
BH   7 815 327.0898581   6828283.891020845
MH   7 815 329.0845497     14637.905839799
BD   7 815 329.0845497     14486.576771555
BH   7 815 329.0845497     14468.010498583
MH   7 815 332.8446067     14743.215879141
BD   7 815 332.8446067     14594.769684970
BH   7 815 332.8446067     14577.565944789
```

Figure 15 (cont.)

```
MH    7 815 337.0346707    14857.481299101
BD    7 815 337.0346707    14712.082020938
BH    7 815 337.0346707    14696.371719001
MH    7 815 338.7460331  7082608.464537685
BD    7 815 338.7460331  7053073.622008696
BH    7 815 338.7460331  6998254.921233382
MH    7 815 340.8347287    14958.344488023
BD    7 815 340.8347287    14815.736548482
BH    7 815 340.8347287    14801.311351595
MH    7 815 344.5947877    15055.630577264
BD    7 815 344.5947877    14915.664041875
BH    7 815 344.5947877    14902.468503831
MH    7 815 348.3548467    15150.477690218
BD    7 815 348.3548467    15013.160761057
TF
BH    7 815 348.3548467    15001.161089121
MH    7 815 350.4022111  7258079.166655875
BD    7 815 350.4022111  7226923.884490048
BH    7 815 350.4022111  7171943.011748140
BD    7 815 352.1149037    15108.292650818
BH    7 815 352.1149037    15097.360564170
MH    7 815 352.114903''   15242.949146806
BD    7 815 355.8749617    15200.868110119
BH    7 815 355.8749617    15191.113845048
MH    7 815 355.8749617    15333.080380497
BD    7 815 359.6350187    15291.283792554
BH    7 815 359.6350187    15282.527558920
MH    7 815 359.6350187    15420.961614071
BD    7 815 4 3.3950767    15379.297900138
BH    7 815 4 3.3950767    15371.667978940
MH    7 815 4 3.395076'    15506.632217763
BD    7 815 4 8.0951507    15486.382873951
BH    7 815 4 8.0951507    15479.983595668
MH    7 815 4 8.0951507    15610.690288602
BD    7 815 410.9151937    15548.895013033
BH    7 815 410.9151937    15543.189960537
MH    7 815 410.9151937    15671.555117963
BD    7 815 414.6752537    15630.648293851
BH    7 815 414.6752537    15625.808726905
MH    7 815 414.6752537    15750.909120617
BD    7 815 418.4353137    15710.228674410
BH    7 815 418.4353137    15706.309383152
MH    7 815 418.4353137    15828.269028781
MH    7 8164730.6465557   -17539.915026186
```

Figure 15 (cont.)

```
MH     7 8164734.5704857   -17499.509186265
MH     7 8164734.7698161  8636694.520933860
MH     7 8164738.1664227   -17461.455380558
MH     7 8164741.9263557   -17420.572178481
MH     7 8164745.6862897   -17378.532152174
MH     7 8164746.0496161  8640011.646911034
MH     7 8164749.4462237   -17335.312007782
MH     7 8164753.2061577   -17290.874999998
MH     7 8164756.9660917   -17245.211286066
MH     7 8164757.3294171  8444773.425170239
MH     7 81648    .7260267   -17198.274278162
MH     7 81648 4.4859627   -17150.004593133
MH     7 81648 8.2458967   -17100.393700836
MH     7 81648 8.6092211  8251104.855620212
MH     7 8164812.0058307   -17049.391732214
MH     7 8164815.7657647   -16996.995734809
MH     7 8164819.5256997   -16943.101706026
MH     7 8164819.8890251  8059156.660094117
MH     7 8164823.2856337   -16887.695866105
MH     7 8164827.0455687   -16830.776574730
MH     7 8164830.8055047   -16772.262139080
MH     7 8164831.1688321  7869046.062987763
MH     7 8164834.5654377   -16712.106627225
MH     7 8164838.3253747   -16650.266404150
MH     7 8164842.0853107   -16586.702427743
MH     7 8164842.4486411  7680961.876617118
MH     7 8164845.8452467   -16521.368110178
MH     7 8164849.6051837   -16454.212598441
MH     7 8164853.7171137   -16378.610564289
MH     7 8164853.7284521  7495052.526244734
MH     7 8164857.1250577   -16314.214566884
MH     7 81649    .8849947   -16241.262139021
MH     7 81649 4.6449327   -16166.276246605
BD     7 81649 4.6449327   -16232.407808361
MH     7 81649 5.0082651  7311539.566893685
MH     7 81649 8.4048707   -16089.182742713
BD     7 81649 8.4048707   -16157.326771615
MH     7 8164911.7888157   -16017.973097083
BD     7 8164911.7888157   -16088.047900258
BH     7 8164911.7888157   -16165.283136366
MH     7 8164916.2880811  7130592.421233359
MH     7 8164916.3007427   -15920.201115488
MH     7 8164919.6846877   -15844.732611476
BD     7 8164919.6846877   -15919.783464489
```

Figure 15 (cont.)

```
MH    7 8164923.4446287   -15758.648950098
BD    7 8164923.4446287   -15835.988188921
MH    7 8164927.2045687   -15670.154855607
BD    7 8164927.2045687   -15749.922572134
MH    7 8164927.5579001 6952442.585295983
MH    7 8164930.9645097   -15579.190616785
BD    7 8164930.9645097   -15661.680774151
BH    7 8164930.9645097   -15745.266732214
MH    7 8164934.7244517   -15485.679790018
BD    7 8164934.7244517   -15570.657480238
BH    7 8164934.7244517   -15655.693897603
MH    7 8164937.9204027   -15404.130577383
BH    7 8164937.9204027   -15577.519028840
MH    7 8164938.8477221 6777355.314909954
MH    7 8164942.5963317   -15281.318569540
BD    7 8164942.5963317   -15372.062992035
BH    7 8164942.5963317   -15459.887467204
MH    7 8164947.0782627   -15159.574146925
BD    7 8164947.0782627   -15254.576115427
MH    7 8164949.4822247   -15092.621719060
BD    7 8164949.4822247   -15188.787729619
MH    7 8164950.1275481 6605573.326720275
MH    7 8164953.8061557   -14969.174868761
BD    7 8164953.8061557   -15068.604330717
BH    7 8164953.8061557   -15160.727034031
MH    7 8164957.2841027   -14866.995078682
BD    7 8164957.2841027   -14969.642060278
BH    7 8164957.2841027   -15062.845800458
MH    7 81650     .8960467   -14758.098753212
BD    7 81650     .8960467   -14863.678477584
BH    7 81650     .8960467   -14958.409776865
MH    7 81650  1.4073771 6437383.792601565
MH    7 81650  4.8039867   -14636.990813612
TR
END
```

Section 4.

SAMPLE OUTPUT

4.0 This section presents the actual output from the test cases described in Section 3.6.4 whose input is listed in Figures 13, 14, and 15. Each test case is covered separately and the code numbers next to certain sections of the ouptut correspond to the numbered paragraphs of the explanation that follows.

Due to lack of space only pieces of the total output are shown; however, the full actual output is available.

4.1 Trajectory Prediction Output

The following sequenced paragraphs describe the different parts of trajectory prediction test case output shown in Figures 16 to 19.

1. The constants used in the program (c, INTEG, NUMB, IFLAG) are printed out here in exact input card image.
2. These numbers are the geopotential inputs printed out exactly as read in.
3. The last part of the input data printed out is all the trajectory-only input.
4. Program name and identification of the particular Aerospace version.
5. The Epoch time for this run.
6. Indicators printed out giving the logical flow from segment to segment and old and new function numbers.
7. Card image of last END card in the deck.
8. Trajectory initial conditions in three coordinate systems. Initial-condition values as shown are the result of transformations which have been applied to the input values. The transformation for the input coordinate set (a. δ, β, A. r, v in this case) consists of conversion from decimal to octal numbers,

conversion of units from feet, degrees, and seconds to earth radii, radians, and minutes, and performance of corresponding inverse conversions for output. The two other types of elements sets also require accomplishment of coordinate-system transformations in addition to the number- and units-systems conversions noted above. Accuracy of the values as printed therefore is subject to numerical roundoff errors.

Quantities in the left-hand column are position and velocity components in the basic vernal equinox coordinate system, with units of feet and of feet per second. The center column gives the usual ADBARV spherical system coordinates (i.e., Type-2 initial conditions in units of feet, feet per second, and degrees). The right-hand column from top to bottom contains orbit semi-major axis, eccentricity, inclination, right ascension of ascending node, argument of perigee, and time of last perigee passage in minutes from midnight of epoch day. Other units are feet and degrees.

9. Identification of atmosphere model to be used in computing drag force. LOCKHEED and ARDC 1959 refer to the Lockheed-Jacchia and the ARDC 1959 model atmospheres, respectively.
Reciprocal of ballistic coefficient, C_DA/W.
Ballistic coefficient, W/C_DA. d_1 and d_2 are values of certain constants in the Lockheed-Jacchia atmosphere density expressions.

10. The product GM, or the universal gravitational constant times the mass of the earth (frequently designated by μ), expressed in units of earth radii cubed per minute squared.
Unitless coefficients of the zonal harmonic terms in the earth potential field expansion (i.e., J_2 through J_{15}).
Coefficients and longitudinal arguments of tesseral and sectorial terms in earth potential field expansion, with J indicating a coefficient and L an argument in degrees. The digits following J or L are the

associated Legendre polynomial degree and order, respectively.

11. Names of solar-system bodies included in computation of perturbative accelerations. In this case none are used.

12. Trajectory method indicator. The Cowell formulation of the equations of motion is the only trajectory method available in the present TRACE-D program.

    Numerical integration parameters. The Gauss-Jackson method (subroutine DE02) is the only integration method available in the present TRACE-D program.

13. The indices N_1 and N_2 input in the IOB array respectively indicate the highest-degree zonal term and the highest-degree and -order tesseral term. No term higher than those indicated by these input numbers will be computed, regardless of the model coefficients and arguments that are input to the physical constants region.

14. Physical constants and units conversion factors. Decimal and octal equivalents are given for the following quantities.

a.	OMEGA E(ω_e)	Earth rotation rate in radians per minute,
b.	ALPHA G(α_g)	Right ascension of Greenwich at midnight of the day of epoch in radians,
c.	FT/KM	Feet per kilometer,
d.	E.R/A.U.	Earth radii per astronomical unit,
e.	I-O, DISTANCE	Input/output units conversion factor in feet per earth radius,
f.	G	Acceleration due to gravity in feet per second squared,
g.	DEG/SEC// RAD/MIN	Units conversion factor in degrees per second/radians per minute,

h.	RELATIVE MASS (SUN)	Mass of sun relative to mass of earth,
i	(VENUS)	Mass of Venus relative to mass of earth,
j.	(JUPITER)	Mass of Jupiter relative to mass of earth,
k.	GM	Earth gravitational constant (μ) in earth radii cubed per minute squared,
l.	EARTH RADIUS-FT	Number of feet per earth radius for internal calculations (rather than I-0),
m.	N.M/E.R	Number of natuical miles per earth radius,
n.	I-0, VELOCITY	Conversion factor for input/output in feet per second/earth radii per minute,
o.	FT/SEC//E.R./MIN.	Units conversion factor in feet per second/earth radii per minute,
p.	1/EPS	Earth flattening (reciprocal of earth ellipticity),
q.	(MOON)	Mass of moon relative to mass of earth,
r.	(MARS)	Mass of Mars relative to mass of earth,
s.	(SATURN)	Mass of Saturn relative to mass of earth.

15. Date and time of day (Greenwich Mean Time) with which the quantities in the print block following are to be associated.

16. Minutes from epoch, minutes from midnight of current day, system time (i.e., seconds from midnight of current day), and current integration step size in minutes.

17. x, y, z, r: Componenents and magnitude of the radius vector from geocenter to satellite in the basic coordinate system in units of feet.

18. $\dot{x}$, $\dot{y}$, $\dot{z}$, v: Components and magnitude of the inertial velocity vector with respect to the basic coordinate

system in units of feet per second.

19. Geodetic latitude, in degrees, of the point where the radius vector intersects the ellipsoidal surface of the earth, geographic longitude measured east from Greenwich in degrees, altitude of the satellite above the oblate earth in natuical miles, and geodetic latitude of the subvehicle point in degrees. All latitude quantities are considered positive north of the equator and negative south of the equator.

20. α, δ, β, A: Right ascension of satellite position, declination of satellite position, flight path angle, and inertial azimuth of velocity vector in units of degrees.

21. Revolution number, nodal period in minutes, nodal period decay rate in minutes per revolution, and nodal regression rate in degrees per revolution. Due to the fact that the nodal period is calculated by simple subtraction of ascending-node crossing times, this quantity cannot be determined until two ascending node crossings have been detected. Also, since the nodal-period decay rate is computed by differencing the nodal-period values at successive ascending nodes, this rate cannot be calculated until three ascending nodes have been crossed. The nodal regression rate is computed by differencing values of right ascension at successive ascending nodes.

4.2 Observation Generation Sample Output

Figures 20 to 24 contain the output from the observation generation test case. There are numbered descriptions corresponding to the number codes on the output; however, only the output that has not been previously described in Section 4.1 is covered here. Therefore, Figures 20 and 21 are included for completeness but need no further description (see Section 4.1 for this information).

1. Bias inputs for data and last END card.

2. Sigmas. In the case of a data generation run, the sigma table is used for the purpose of sepcifying the standard deviation of random noise which is to be applied to the generated data. Interpretation of the printed output shown is otherwise the same as described under section for Data Generation.

3. Station locations, latitude, longitude, and altitude.

4. Data Limit Specifications. The eight columns from left to right contain station identification, data interval, minimum elevation angle, maximum elevation angle, maximum range in nautical miles, and data-generation start and stop times in days, hours, and minutes from midnight of epoch day.

   The information shown indicates that the following specifications have been given to the program:

   a. Observations are to be generated for station AA at 15-second intervals whenever the computed local elevation angle is above zero degrees.

   b. No maximum elevation angle is assumed and no maximum range is to be considered (data generated for all ranges and for all elevation angles greater than zero).

   c. Station AA is assumed to be active during the time interval from epoch until a time 24 hours after midnight of epoch day.

   In the case of this particular data generation run, the corresponding Specification-I input items for Stations BB through FF are identical to those for Station AA. However, this need not be true in general, inasmuch as each station is independent of the others with respect to these input items.

5. Parameter indication. The message indicates that the range bias parameter has been selected for Station BB. In the case of a data generation run, radar parameters are selected only for the purpose of applying biases to the generated data, in this case a range bias on Station BB data. The message alluding to the correction of parameters therefore should be ignored.

6. Data Types. These headings define the format of the table appearing beneath them. The purpose of this table is to define the types of data which are to be generated for each station. Except for the station-identification column header, which is printed vertically, the headings appear in two horizontal rows, with the top row displaying the symbols RANGE on the left and LONG. on the right and the second row the symbols SUR.R on the left and U, V on the right. The individual headings are interpreted in accordance with the following:

Heading	Description or Symbol	Units
RANGE	Range	n mi
AZMTH	Local azimuth angle	deg
ELEV.	Local elevation angle	deg
R. DOT	Range rate	ft/sec
P. DOT	Range-rate difference	ft/sec
Q. DOT	Range-rate difference	ft/sec
P	Range difference	ft
Q	Range difference	ft
AZ. DT	Rate of change of local azimuth	deg/sec
E. DOT	Rate of change of local elevation	deg/sec
R. DDT	Second time derivative of range	ft/sec^2
MU. VIS	Mutual visibility	(indicator)
LAT	Latitude of sub-vehicle point	deg
LONG	Longitude of sub-vehicle point	deg
SUR. R	Surface range, station to sub-vehicle point	n mi
HIGHT	Altitude above oblate earth	n mi
DOPLR	Doppler frequency shift	cps
LOOK	Look angle	deg
VARI	Variances	Same as corresp. observations
KAPPA	Angle between radius vector and local vertical	deg
ASPCT	Aspect angles	deg
ATTEN	Signal attenuation	db
X, Y, Z	$\hat{x}$, $\hat{y}$, $\hat{z}$	n mi
T-R, D	Topocentric right ascension and declination	deg
HR, ANG	Topocentric hour angle	deg
U, V	Horizon-scanner angles, u, v	deg

The two horizontal lines associated with each station are the line containing the station-identification symbol and the line immediately below it. An X on the first line of a Y on the second line indicate that the corresponding quantity as defined by the table header is to be generated. In the present example, the indicated data types for Station AA are range, azimuth, elevation, range rate, height (altitude), $\hat{x}$, $\hat{y}$, $\hat{z}$, topocentric hour angle, and horizon-sensor angles u and v.

7. Segment transfer messages.
8. Rise message. The time when the satellite becomes visible from a particular station (at the specified minimum elevation angle) is obtained by interpolation and printed in the manner shown along with the local azimuth angle for the corresponding time.
9. Time corresponding to generated data. The time shown is to be associated with the data quantities appearing on the line to the right of the time printout and on the line following. The time is given both in hours (0 through 24) and minutes of the day as identified at the top of the output page, as well as in minutes from start (i.e., minutes from epoch). In the case of the particular output shown, time from start corresponds to the time of day because the epoch chosen for the run happened to be midnight.
10. Maximum elevation point. The time when the elevation angle reaches its maximum is obtained by interpolation and printed along with the corresponding values for the elevation and azimuth angles in the manner shown.
11. Set message. When the time at which the elevation angle reaches the specified minimum from above is obtained by interpolation, the print shown at this position occurs.
12. Duration message. After each pass, a message is printed giving the time in minutes during which the elevation angle was above the input minimum value and the range was below the input maximum value.

4.3 Orbit Determination Sample Output

This section contains the output from the orbit determination test case. Here also, only that output which has not been previously described is considered, although all of the output is shown in Figures 25 through 31.

1. The station location card quantities, refraction indicator, sigma set, latitude, longitude, and altitude.
2. Each line is the printout of one observation card. Given are the date, station ID, both the type and set number for these measurements, and the three measurements. In this case Line 1 has a Range Rate measurement only.
3. This line contains a Range measurement only.
4. Indicates those parameters chosen in input to be estimated.
5. In this case, the spherical set of initial conditions, drag coefficient, GM, J_2 and J_3 are to be estimated.
6. The number of iterations after which the program stops. In this case, one only.
7. A count of the parameters to be estimated.
8. A count of the number of observation cards read.
9. A total obtained by assuming three observations per cards.
10. A count of all the sites entered on station location cards.
11. The number of locations that all the data has been packed into and then stored on scratch tape.
12. The number of flocks (TF and TR cards) read.
13. Segment transfer messages.
14. Differential correction bounds. This sequence corresponds to the previously described sequence of the parameter indications.
15. Weighting sigmas. The observation type number and the value of the weighting value are shown.
16. Definition of current orbit. For each iteration the current values for the parameters are used to compute the quantities shown
17. Node print. Each time the integrated trajectory crosses the equator (as determined by interpolation between integration steps) the date, time in minutes from midnight of epoch, and the rectangular elements (x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$,) in units

of earth radii and earth radii per minute are printed. The numerical integration interval for each satellite begins at epoch and ends at the time of the latest observation for that satellite. A message is printed each time any of the events of equator crossing, start of thrusting, end of thrusting, or orbit adjust are detected during the integration interval.

18. Station identification and system time of residuals. These are to be associated with all residuals which appear on the same line. It should be noted that system time is defined as seconds from midnight of the current day.

19. Residuals. These are unnormalized differences between the input observations (as modified by bias or refraction corrections) and corresponding values for the same observation types computed from the integrated trajectory position at the observation times. Up to six residuals for the same time are printed on one line. The observation type is indicated in parentheses immediately following the residual value in each case. Note that residuals appear for the unweighted as well as for the weighted observations.

    Identification of the foregoing observation-type indicators with observation descriptions or symbols defined elsewhere in this report is in accordance with the following:

Indicator	Description or Symbol	Unit
R	Range	ft
A	Azimuth	deg
E	Elevation	deg
TR	Topocentric right ascension	deg
TD	Topocentric declination	deg
HA	Topocentric hour angle	deg
GR	Geocentric right ascension	deg
GD	Geocentric declination	deg
U	Horizon scanner in-plane angle	deg
V	Horizon scanner cross-plane angle	deg
H	Altitude (h)	ft

Indicator	Description or Symbol	Unit
X	$\hat{x}$	ft
Y	$\hat{y}$	ft
Z	$\hat{z}$	ft
R	Range	ft
P	Range difference	ft
Q	Range difference	ft
RD	Range rate	ft/sec
PD	Range-rate difference	ft/sec
QD	Range-rate difference	ft/sec

20. Observation time. The time identified in Item 2 in terms of seconds from midnight is given in alternate form, wherein the day of the month and the hour and minute of the day are given as integers and seconds are given to two decimal places.

21. RMS summary of residuals. The root-mean-square of the residuals for each type of observation from each station is computed by the residuals editor and the result is printed at this location. Included are the station identification, number of residuals included in the RMS (i.e., the total number for that station and type minus the number deleted by the editor on this iteration), RMS, and the RMS divided by input weighting sigma. The observation-type indicators are the same as those used in the residuals print output. Units are feet, degrees and seconds. Interpretation of the range-rate summary for station MH is that 206 range rate measurements were used to compute the rms which equals 1.61216 feet per second. RMS over sigma is equal to 26.6209 feet per second.

22. Iteration number. TRACE-D performs the tracking, or orbit determination function, by computing series of differential corrections to the parameters selected by the user. The iteration number is advanced each time the process of computing a set is repeated. The number may be interpreted as an indication of the number of times the trajectory-integration/least-squares process has been performed.

23. Observation count. The number of individual observations included in the current least-squares computation is indicated.

24. Convergence indicator. If the weighted RMS for all residuals for the current iteration is less than that for any previous iteration, then the fitting process is converging and the message shown is printed. If the RMS obtained on the current iteration is greater than the smallest RMS obtained on previous iterations, the message

CURRENT ITERATION IS NOT GOOD

(RMS = 0.xxxxxxxx xx)

is printed in this position.

25. Current solution. If the iteration is successful (i.e., the overall RMS has been lowered), indicated values are the parameter values used in the trajectory, partial derivative, and residuals computations which have just been completed. In the case of Iteration No. 1, they are the input values of the parameters.

If the iteration is bad, the words

GO BACK TO

are printed, and the values of the parameters which so far have produced the lowest RMS are recovered from memory and printed at this point. Parameter names are generally self-explanatory, with the possible exceptions of the multiple-vehicle elements. The satellite number is printed before the element name for Satellites 2 through 6.

26. Current solution in octal digits and machine units. These numbers corresponding to those described in Item 30 are given both in the octal mode and in the units used for internal computations. Use of these quantities permits bypassing units and number-system conversions during input and output.

27. RMS. This is the quantity which is to be minimized in the tracking or orbit determination process and is the root-mean-square of the normalized residuals included in the least-squares calculations on the current iteration.

28. Corrections. The result of solving the system of normal equations associated with the parameter which occupies the corresponding position in the current solution block. Units are feet, degrees, and seconds.

29. Bounds. Current values of the numbers used to limit the size of corrections. In general, these bounds are

automatically increased on a good iteration and automatically decreased on a bad one.

30. Bounding indicator. This message will be either

    HITTING BOUNDS

    or

    NOT HITTING BOUNDS

    The first message indicates that the magnitudes of the corrections have been controlled by solving the system in such a way that the constraint implied by the bounds is satisfied, and the latter that the normal equations have been solved without applying the bounds.

31. Next solution. Each value is the sum of the parameter value given in the corresponding position under "current solution" and the associated correction. These are the parameter values which will be used for the next solution.

32. Next solution in octal mode and units of earth radii, radians, and minutes.

33. Predicted RMS. If the fitting process is converging in a completely linear fashion, this will be the RMS on the next iteration. The comparison of this number with the current RMS (see Item 32) may be used to measure the degree to which the process has already converged.

34. Sigma of parameters divided by sigma of the normalized observations. The numbers given are the square roots of the diagonal elements of the inverse normal matrix. If certain assumptions are made about the characteristics of the observation set, the numbers may then be taken as the variances on the parameter solutions.

35. Correlation matrix, correlation coefficients for the parameter set. These values are computed directly from the covariance matrix (i.e., the inverse normal matrix). Rows and columns are in the same sequence as the Item 34 data.

36. This is the upper half of the normal matrix.

37. This is the lower half of the inverse normal matrix.

Figure 16. Trajectory Prediction Output Listing of Input

```
GINTEG     TRACE-D STANDARD INTEGRATION CONSTANTS                            BASIC INPUT CARD    1
I1    1             I2    2              I3    0                             BASIC INPUT CARD    2
 4    1              5    1              11    1.00002516                    BASIC INPUT CARD    3
 23   .1           -9                                                        BASIC INPUT CARD    4
 26   1                                                                      BASIC INPUT CARD    5
 30   1              31   .015625        32    64            33   1      -7  BASIC INPUT CARD    6
I34   4             I35   1              37    .0001         38   0.         BASIC INPUT CARD    7
 40   2820.18012    I41   1                                                  BASIC INPUT CARD    8
GC          TRACE-D STANDARD PHYSICAL CONSTANTS    10/ 1/65                  BASIC INPUT CARD    9
 1    .437526904-2 2      .5530370   -2 6      .5                            BASIC INPUT CARD   1C
 8    .437526904-2 9      1.             10    10                     (1)    BASIC INPUT CARD   11
 13   3280.8399     14    57.2957795     15    20925738                      BASIC INPUT CARD   12
 16   332951.3      17    .01229853      18    .814979                       BASIC INPUT CARD   13
 19   .107821       20    317.887        21    95.129                        BASIC INPUT CARD   14
 22   23454.865     23    3443.93355     24    20925738                      BASIC INPUT CARD   15
 25   348762.3      26    32.174         30    348762.3                      BASIC INPUT CARD   16
 31   1.5           32    1.0471976      33    3.14159265                    BASIC INPUT CARD   17
 34   298.3         35    300000.        36    82505.922                     BASIC INPUT CARD   18
 NUMB               42    3443.9336                                          BASIC INPUT CARD   19
IIFLAG             I28    0                                                  BASIC INPUT CARD   2C
I108  14            I2    15             I3    14            I4   15         BASIC INPUT CARD   21
 OBJZ                                                                        BASIC INPUT CARD   22
 2    1082.645  -6 3    -2.546    -6 4    -1.649    -6                       BASIC INPUT CARD   23
 5    -.210     -6                                                           BASIC INPUT CARD   24
 6    .646      -6                                                           BASIC INPUT CARD   25
 7    -.333     -6 8    -.270     -6                                         BASIC INPUT CARD   26
 9    -.053     -6                                                           BASIC INPUT CARD   27
 10   -.054     -6 11   .302      -6 12   -.357     -6 13   -.114     -6     BASIC INPUT CARD   28
 14   .179      -6                                                           BASIC INPUT CARD   29
 OBJT                                                                        BASIC INPUT CARD   3C
 2    .1765980  -5 3    .2110765  -5 4    .3108429  -6 5    .2390598  -6     BASIC INPUT CARD   31
```

```
6    .7017339  -6 7    .1652      -6 8    .5210912  -7 9    .4986992  -8          BASIC INPUT CARD   32
10   .1111605  -6 11   .1088012   -6 12   .1717943  -7 13   .2122685  -8          BASIC INPUT CARD   33
14   .1507404  -8 15   .4264694   -7 16   .4633369  -7 17   .1291007  -8          BASIC INPUT CARD   34
18   .1967936  -8 19   .4477079   -9 20   .3729502  J0 21   .1839230  -6          BASIC INPUT CARD   35
22   .3972437  -7 23   .35430592  -8 24   .3887152  -9 25   .3299649  J0          BASIC INPUT CARD   36
26   .1515140  J0 27   .2052417   J1 28   .6820109  -7 29   .3849809  -8          BASIC INPUT CARD   37
30   .3762496  -9 31   .2771455   -9 32   .2341330  J0 33   .8894014  J1          BASIC INPUT CARD   38
34   .1641761  J2 35   .3416347   J2 36   .7642382  -7 37   .2440136  -8          BASIC INPUT CARD   39
44   .8609215  J4 45   .1013471   -6 46   .6724120  -8 47   .4173952  -9          BASIC INPUT CARD   4C
48   .7857074  J0 55   .3251625   -7 66   .1006553  -6 67   .4704701  -8          BASIC INPUT CARD   41
77   .2783799  J8                                                                 BASIC INPUT CARD   42
89   .1717906  J8 90   .3549629   J9 91   .8360589  -8                            BASIC INPUT CARD   43
101  .1059143  K0                                                                 BASIC INPUT CARD   44
                                                                       (2)
102  .1326684  J9 104  .1974783   K1                                              BASIC INPUT CARD   45
113  .5398041  J8 116  .1393759   J9 117  .1492896  K0 118  .5702221  K2          BASIC INPUT CARD   46
OBLT                                                                              BASIC INPUT CARD   47
2    165.2042     3    7.623267     4    161.8799     5    23.63307               BASIC INPUT CARD   48
6    219.3494     7    31.73482     8    115.8047     9    25.74411               BASIC INPUT CARD   49
10   232.5121     11   169.9065     12   59.74292     13   41.60563               BASIC INPUT CARD   5C
14   56.95252     15   209.876      16   140.3382     17   50.04699               BASIC INPUT CARD   51
18   66.28621     19   47.13021     20   42.58828     21   38.37493               BASIC INPUT CARD   52
22   12.06147     23   1.37273      24   53.46592     25   7.078959               BASIC INPUT CARD   53
26   27.20422     27   8.598698     28   139.0856     29   28.15497               BASIC INPUT CARD   54
30   57.94327     31   45.80993     32   22.83747     33   15.51001               BASIC INPUT CARD   55
34   15.09665     35   19.70539     36   5.856014     37   48.25990               BASIC INPUT CARD   56
44   13.95194     45   309.8056     46   100.9007     47   68.25838               BASIC INPUT CARD   57
48   59.07748     55   164.1975     66   203.5371     67   91.41733               BASIC INPUT CARD   58
77   14.87681                                                                     BASIC INPUT CARD   59
89   11.44440     90   9.804658     91   160.5400                                 BASIC INPUT CARD   6C
101  30.31227     102  23.00277     104  13.72105     113  27.04833               BASIC INPUT CARD   61
116  15.65423                                                                     BASIC INPUT CARD   62
117  16.80139     118  20.10848                                                   BASIC INPUT CARD   63
DITIN 3                                                                           BASIC INPUT CARD   64
```

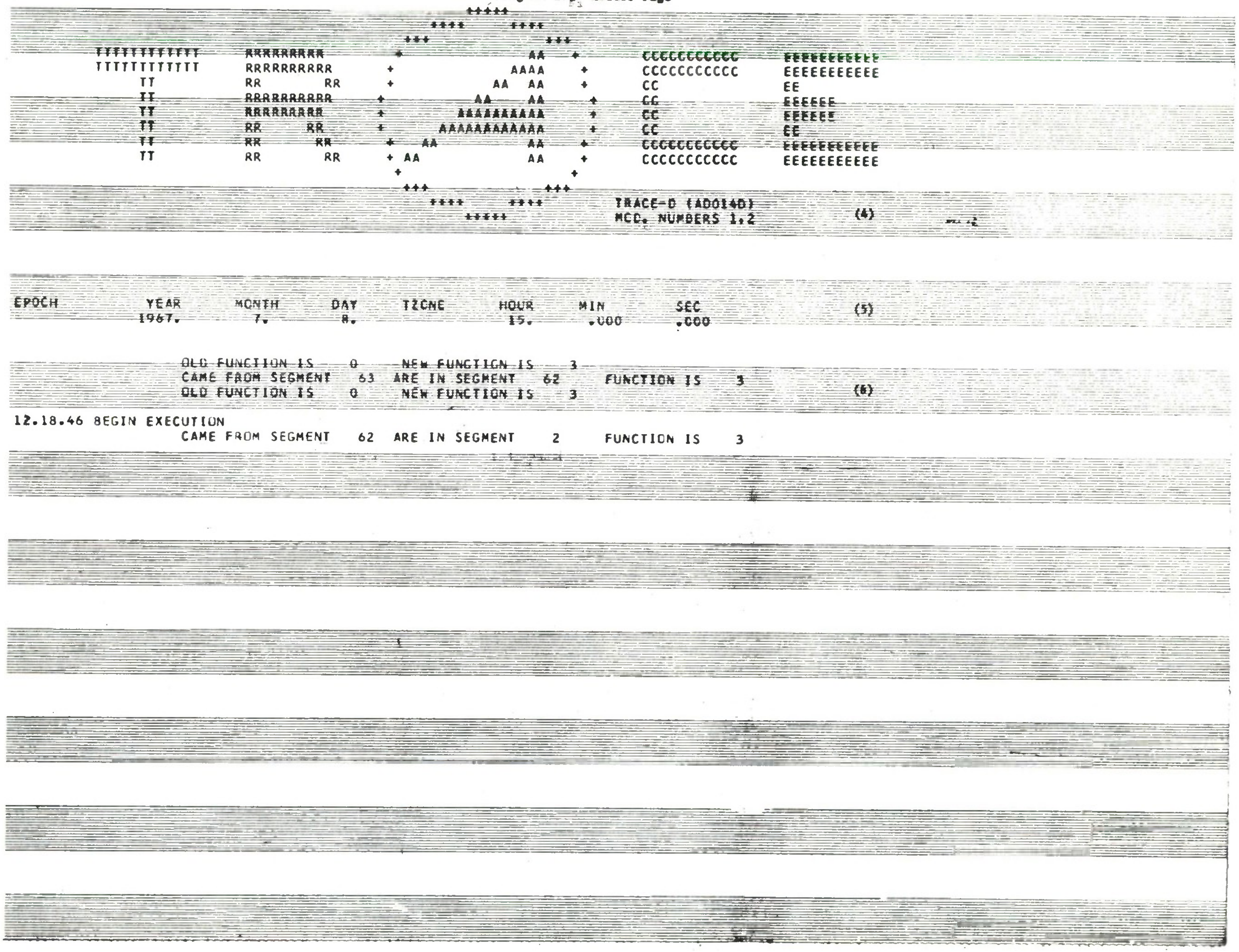
Figure 16 (cont.)

```
IICTYP2                                                                                BASIC INPUT CARD   65
 IG   358.2                                                                            BASIC INPUT CARD   66
 2    -25.5                                                                            BASIC INPUT CARD   67
 3    90.35                                                                            BASIC INPUT CARD   68
 4    47.18                                                                            BASIC INPUT CARD   69
 5    22999226.                                                                        BASIC INPUT CARD   70
 6    24797.530                                                                        BASIC INPUT CARD   71
IPRTIMO                                                                                BASIC INPUT CARD   72
I2    1              3    0.           4    5.                                         BASIC INPUT CARD   73
 5    60.                                                                              BASIC INPUT CARD   74
 6    30.            7    90.                                                          BASIC INPUT CARD   75
 DRAG .008                                                                             BASIC INPUT CARD   76
I2    1                                                                                BASIC INPUT CARD   77
 3    6.83           4    -15.684                                                      BASIC INPUT CARD   78
IYEAR 1967          IMNTH 7                                                            BASIC INPUT CARD   79
IDAY  8              TZNE 0.                                                           BASIC INPUT CARD   80
 HR   15.            MIN  0.              SEC  0.                                      BASIC INPUT CARD   81
DPRGDEX   X                                                                            BASIC INPUT CARD   82
IPTAPE4                                                                                BASIC INPUT CARD   83
END                                                                                    BASIC INPUT CARD   84
```

(3)

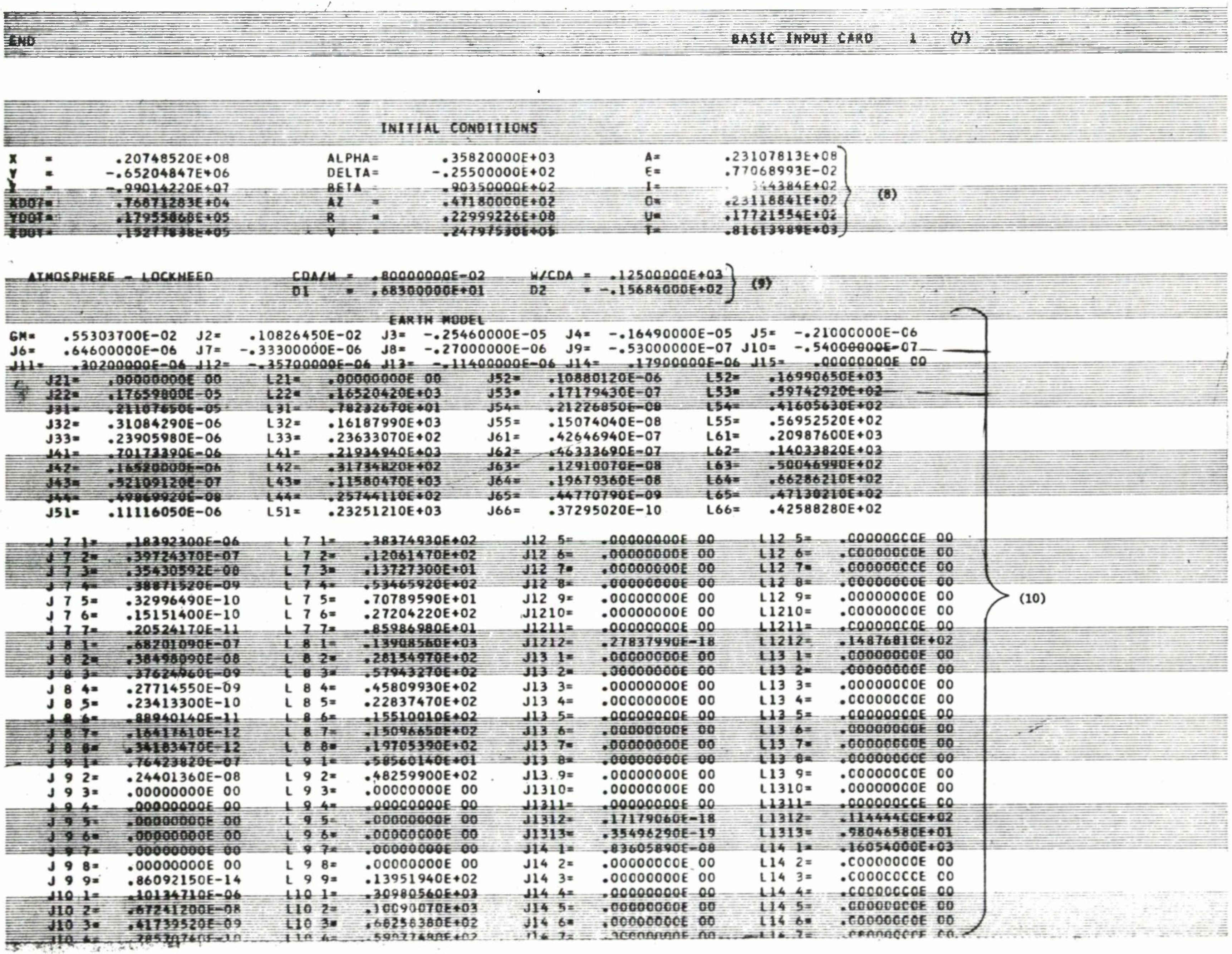
Figure 16 (cont.)

Figure 17. Header Page



```
                                                     +++++
                                                 ++++     ++++
                                              +++              +++
          TTTTTTTTTTTT     RRRRRRRRR         +               AA   +       CCCCCCCCCCC      EEEEEEEEEEE
          TTTTTTTTTTTT     RRRRRRRRRR       +             AAAA     +      CCCCCCCCCCC      EEEEEEEEEEE
               TT          RR        RR     +           AA   AA    +      CC               EE
               TT          RRRRRRRRRR      +          AA     AA     +     CC               EEEEEE
               TT          RRRRRRRRR       +        AAAAAAAAAA      +     CC               EEEEEE
               TT          RR     RR       +      AAAAAAAAAAAA      +     CC               EE
               TT          RR      RR       +   AA           AA    +      CCCCCCCCCCC      EEEEEEEEEEE
               TT          RR        RR     + AA             AA    +      CCCCCCCCCCC      EEEEEEEEEEE
                                             +                    +
                                              +++              +++
                                                 ++++     ++++         TRACE-D (ADO14D)
                                                     +++++             MCC. NUMBERS 1,2            (4)

EPOCH           YEAR      MONTH      DAY      TZONE      HOUR     MIN         SEC                  (5)
               1967.        7.         8.                 15.      .000       .000

                    OLD FUNCTION IS     0     NEW FUNCTION IS    3
                    CAME FROM SEGMENT  63    ARE IN SEGMENT   62      FUNCTION IS    3
                    OLD FUNCTION IS     0     NEW FUNCTION IS    3                                 (6)
12.18.46 BEGIN EXECUTION
                    CAME FROM SEGMENT   62   ARE IN SEGMENT    2      FUNCTION IS    3
```

Figure 18. Initial Information



```
END                                                               BASIC INPUT CARD     1    (7)


                                   INITIAL CONDITIONS
X     =        .20748520E+08       ALPHA=        .35820000E+03         A=        .23107813E+08 )
Y     =      -.65204847E+06        DELTA=       -.25500000E+02         E=        .77068993E-02 |
Z     =      -.99014220E+07        BETA  =       .90350000E+02         I=          544384E+02  } (8)
XDOT=          .76871283E+04       AZ    =       .47180000E+02         O=        .23118841E+02 |
YDOT=          .17955868E+05       R     =       .22999226E+08         U=        .17721554E+02 |
ZDOT=          .15277838E+05       V     =       .24797530E+05         T=        .81613989E+03 )


  ATMOSPHERE - LOCKHEED         CDA/M  =  .80000000E-02    W/CDA  =  .12500000E+03 )
                                D1     =  .68300000E+01    D2     = -.15684000E+02 ) (9)

                                   EARTH MODEL
GM=    .55303700E-02  J2=    .10826450E-02  J3=  -.25460000E-05  J4=  -.16490000E-05  J5=  -.21000000E-06
J6=    .64600000E-06  J7=   -.33300000E-06  J8=  -.27000000E-06  J9=  -.53000000E-07 J10=  -.54000000E-07
J11=    .30200000E-06 J12=  -.35700000E-06 J13=  -.11400000E-06 J14=   .17900000E-06 J15=    .00000000E 00
    J21=   .00000000E 00       L21=   .00000000E 00       J52=   .10880120E-06     L52=   .16990650E+03
    J22=   .17659800E-05       L22=   .16520420E+03       J53=   .17179430E-07     L53=   .59742920E+02
    J31=   .21107650E-05       L31=   .78232670E+01       J54=   .21226850E-08     L54=   .41605630E+02
    J32=   .31084290E-06       L32=   .16187990E+03       J55=   .15074040E-08     L55=   .56952520E+02
    J33=   .23905980E-06       L33=   .23633070E+02       J61=   .42646940E-07     L61=   .20987600E+03
    J41=   .70173390E-06       L41=   .21934940E+03       J62=   .46333690E-07     L62=   .14033820E+03
    J42=   .16520000E-06       L42=   .31734820E+02       J63=   .12910070E-08     L63=   .50046990E+02
    J43=   .52109120E-07       L43=   .11580470E+03       J64=   .19679360E-08     L64=   .66286210E+02
    J44=   .49869920E-08       L44=   .25744110E+02       J65=   .44770790E-09     L65=   .47130210E+02
    J51=   .11116050E-06       L51=   .23251210E+03       J66=   .37295020E-10     L66=   .42588280E+02

    J 7 1=   .18392300E-06        L 7 1=   .38374930E+02        J12 5=   .00000000E 00      L12 5=   .C00000CCE 00
    J 7 2=   .39724370E-07        L 7 2=   .12061470E+02        J12 6=   .00000000E 00      L12 6=   .C000000CE 00
    J 7 3=   .35430592E-08        L 7 3=   .13727300E+01        J12 7=   .00000000E 00      L12 7=   .000000CCE 00
    J 7 4=   .38871520E-09        L 7 4=   .53465920E+02        J12 8=   .00000000E 00      L12 8=   .00000000E 00
    J 7 5=   .32996490E-10        L 7 5=   .70789590E+01        J12 9=   .00000000E 00      L12 9=   .00000000E 00
    J 7 6=   .15151400E-10        L 7 6=   .27204220E+02        J1210=   .00000000E 00      L1210=   .C0000000E 00
    J 7 7=   .20524170E-11        L 7 7=   .85986980E+01        J1211=   .00000000E 00      L1211=   .C00000C0E 00
    J 8 1=   .68201090E-07        L 8 1=   .13908560E+03        J1212=   .27837990E-18      L1212=   .14876810E+02
    J 8 2=   .38498090E-08        L 8 2=   .28154970E+02        J13 1=   .00000000E 00      L13 1=   .00000000E 00
    J 8 3=   .37624960E-09        L 8 3=   .57943270E+02        J13 2=   .00000000E 00      L13 2=   .00000000E 00
    J 8 4=   .27714550E-09        L 8 4=   .45809930E+02        J13 3=   .00000000E 00      L13 3=   .00000000E 00
    J 8 5=   .23413300E-10        L 8 5=   .22837470E+02        J13 4=   .00000000E 00      L13 4=   .C00000C0E 00
    J 8 6=   .88940140E-11        L 8 6=   .15510010E+02        J13 5=   .00000000E 00      L13 5=   .C0000000E 00
    J 8 7=   .16417610E-12        L 8 7=   .15096650E+02        J13 6=   .00000000E 00      L13 6=   .00000000E 00
    J 8 8=   .34183470E-12        L 8 8=   .19705390E+02        J13 7=   .00000000E 00      L13 7=   .00000000E 00
    J 9 1=   .76423820E-07        L 9 1=   .58560140E+01        J13 8=   .00000000E 00      L13 8=   .00000000E 00
    J 9 2=   .24401360E-08        L 9 2=   .48259900E+02        J13 9=   .00000000E 00      L13 9=   .C00000C0E 00
    J 9 3=   .00000000E 00        L 9 3=   .00000000E 00        J1310=   .00000000E 00      L1310=   .00000000E 00
    J 9 4=   .00000000E 00        L 9 4=   .00000000E 00        J1311=   .00000000E 00      L1311=   .000000CCE C0
    J 9 5=   .00000000E 00        L 9 5=   .00000000E 00        J1312=   .17179060E-18      L1312=   .114444CCE+02
    J 9 6=   .00000000E 00        L 9 6=   .00000000E 00        J1313=   .35496290E-19      L1313=   .98046580E+01
    J 9 7=   .00000000E 00        L 9 7=   .00000000E 00        J14 1=   .83605890E-08      L14 1=   .16054000E+03
    J 9 8=   .00000000E 00        L 9 8=   .00000000E 00        J14 2=   .00000000E 00      L14 2=   .C0000000E 00
    J 9 9=   .86092150E-14        L 9 9=   .13951940E+02        J14 3=   .00000000E 00      L14 3=   .C000CCCCE C0
    J10 1=   .10134710E-06        L10 1=   .30980560E+03        J14 4=   .00000000E 00      L14 4=   .C0000CC0E 00
    J10 2=   .67241200E-08        L10 2=   .10090070E+03        J14 5=   .00000000E 00      L14 5=   .000000C0E 00
    J10 3=   .41739520E-09        L10 3=   .68258380E+02        J14 6=   .00000000E 00      L14 6=   .C0000000E 00
    J10 4=   .78530760E-10        L10 4=   .59027480E+02        J14 7=   .00000000E 00      L14 7=   .C0000CCCE C0
                                                                                                              (10)
```

```
    J10 5=   .00000000E 00     L10 5=   .00000000E 00     J14 8=   .00000000E 00     L14 8=   .00000000E 00
    J10 6=   .00000000E 00     L10 6=   .00000000E 00     J14 9=   .00000000E 00     L14 9=   .00000000E 00
    J10 7=   .00000000E 00     L10 7=   .00000000E 00     J1410=   .00000000E 00     L1410=   .00000000E 00
    J10 8=   .00000000E 00     L10 8=   .00000000E 00     J1411=   .10591430E-[illegible]  L1411=   .2[illegible]312270E+02
    J10 9=   .00000000E 00     L10 9=   .00000000E 00     J1412=   .1326[illegible]  L1412=   .22002770E+02
    J1010=   .00000000E 00     L1010=   .00000000E 00     J1413=   .00000000E 00     L1413=   .50[illegible]00000E 00
    J11 1=   .32516250E-07     L11 1=   .16419750E+03     J1414=   .19747830E-21     L1414=   .13721050E+02
    J11 2=   .00000000E 00     L11 2=   .00000000E 00     J15 1=   .00000000E 00     L15 1=   .00000000E 00
    J11 3=   .00000000E 00     L11 3=   .00000000E 00     J15 2=   .00000000E 00     L15 2=   .00000000E 00
    J11 4=   .00000000E 00     L11 4=   .00000000E 00     J15 3=   .00000000E 00     L15 3=   .00000000E 00
    J11 5=   .00000000E 00     L11 5=   .00000000E 00     J15 4=   .00000000E 00     L15 4=   .00000000E 00
    J11 6=   .00000000E 00     L11 6=   .00000000E 00     J15 5=   .00000000E 00     L15 5=   .00000000E 00
    J11 7=   .00000000E 00     L11 7=   .00000000E 00     J15 6=   .00000000E 00     L15 6=   .00000000E 00
    J11 8=   .00000000E 00     L11 8=   .00000000E 00     J15 7=   .00000000E 00     L15 7=   .00000000E 00   (10)
    J11 9=   .00000000E 00     L11 9=   .00000000E 00     J15 8=   .00000000E 00     L15 8=   .00000000E 00
    J1110=   .00000000E 00     L1110=   .00000000E 00     J15 9=   .53980410E-18     L15 9=   .270[illegible]330E+02
    J1111=   .00000000E 00     L1111=   .00000000E 00     J1510=   .00000000E 00     L1510=   .00000000E 00
    J12 1=   .10065530E-06     L12 1=   .20353710E+03     J1511=   .00000000E 00     L1511=   .00000000E 00
    J12 2=   .47047010E-08     L12 2=   .91417330E+02     J1512=   .13937590E-19     L1512=   .15654230E+02
    J12 3=   .00000000E 00     L12 3=   .00000000E 00     J1513=   .14928960E-20     L1513=   .16801390E+02
    J12 4=   .00000000E 00     L      =   .00000000E 00     J1514=   .57022210E-22     L1514=   .20108480E+02
                                                          J1515=   .00000000E 00     L1515=   .00000000E 00

THE FOLLOWING BODIES ARE USED FOR PLANETARY PERTURBATIONS  (11)

NONE

FORMULATION
            COWELL (EQS.OF MOTION)

DIFFERENTIAL EQUATION SUBROUTINE
            GAUSS-JACKSON          E BAR=    .1000E-09      A= 1.000    RATIO OF COWELL STEP TO RUNGE KUTTA   4   (12)
STEP SIZE -      INITIAL=      .1000E+01    MINIMUM=      .1562E-01      MAXIMUM=      .6400E+02
 DO NOT RECOMPUTE PERTURBATIONS FOR CORRECTOR

EQUATIONS OF MOTION   USE N1 =14 N2=15   (13)

                                                  CONSTANTS
                                DECIMAL          OCTAL                                      DECIMAL          OCTAL
OMEGA E                     .43752690E-02   325340203260    GM                          .55303700E-02    66221635100
ALPHA G                     .49787546E+01   752211125620
FT/KM                       .32808399E+04   340355733740    EARTH RADIUS - FT           .20925738E+08   452000000000
E.R./A.U.                   .23454865E+05   565605075320    N.M./E.R.                   .34439335E+04   737510377420
I-O, DISTANCE               .20925738E+08   452000000000    I-O, VELOCITY               .34876230E+06   223146314620   (14)
G                           .32174000E+02   132071260100    FT/SEC//E.R./MIN.           .34876230E+06   223146314620
DEG/SEC//RAD/MIN            .10471976E+01   444250714340    1/EPS.                      .290[illegible]00E+03   314631463140
RELATIVE MASS(SUN)          .33295130E+06   723146314620    (MOON)                      .1229[illegible]0E-01   614043432460
(VENUS)                     .81497900E+00   355337552020    (MARS)                      .10782100E-00   203232233700
(JUPITER)                   .31788700E+03   422335136140    (SATURN)                    .95129000E+02    30446722720

                     CAME FROM SEGMENT    2  ARE IN SEGMENT   62     FUNCTION IS    3
                     OLD FUNCTION IS    3     NEW FUNCTION IS    3

12.18.49 BEGIN EXECUTION
                     CAME FROM SEGMENT   62  ARE IN SEGMENT    1     FUNCTION IS    3
                     OLD FUNCTION IS    3     NEW FUNCTION IS    3

12.18.52 BEGIN EXECUTION
                     CAME FROM SEGMENT    1  ARE IN SEGMENT   12     FUNCTION IS    3
                     CAME FROM SEGMENT   12  ARE IN SEGMENT    1     FUNCTION IS    3
                     OLD FUNCTION IS    3     NEW FUNCTION IS    3
                     CAME FROM SEGMENT    1  ARE IN SEGMENT   62     FUNCTION IS    3
                     OLD FUNCTION IS    3     NEW FUNCTION IS    3
```

Figure 18 (cont.)

```
     7/ 8/67  15 HRS.  35 MIN.      -.00000 SEC.  (15)
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    35.00000      -.78647439E+07    -.22155572E+05        48.44481      120.83651095              1.26426
   935.00000 (16)  .13174136E+08 (17)-.10895596E+05 (18) 321.18493 (19)  48.25372594 (20)          .00000 (21)
 56100.00000       .17192791E+08    -.15414935E+04       354.98433       89.57732323              .00000
     2.00000       .23043526E+08     .24737811E+05        48.42694       95.84605663              .0C000

     7/ 8/67  15 HRS.  40 MIN.      -.00000 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    40.00000      -.13996194E+08    -.18373776E+05        43.54303      146.43077687              1.31540
   940.00000       .92882160E+07    -.14783492E+05       345.52577       43.35092053              .0C000
 56400.00000       .15857608E+08    -.72765022E+04       363.35710       89.55149561              .0C000
     2.00000       .23100393E+08     .24679845E+05        43.52467      114.38479712              .0C000

     7/ 8/67  15 HRS.  45 MIN.      -.00000 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    45.00000      -.18704571E+08    -.12753361E+05        34.04550      166.59726815              1.36628
   945.00000       .44569999E+07    -.17147176E+05         4.43884       33.86722360              .00000
 56700.00000       .12904892E+08    -.12234554E+05       370.87110       89.57441311              .0C000
     2.00000       .23157333E+08     .24624341E+05        34.02811      127.11199948              .00000

     7/ 8/67  15 HRS.  50 MIN.      -.00000 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPDK,NREG
    50.00000      -.21522524E+08    -.58797845E+04        22.00012      182.19590890              1.41695
   950.00000      -.82527309E+06    -.17768552E+05        18.78406       21.86679475              .CCQ00
 57000.00000       .86438611E+07    -.15927250E+05       377.23886       89.6445C786              .CC000
     2.00000       .23208111E+08     .24575813E+05        21.98690      134.49388396              .00000

     7/ 8/67  15 HRS.  55 MIN.      -.00000 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    55.00000      -.22176610E+08     .15507212E+04         8.74437      195.19936864              1.46742
   955.00000      -.60249895E+07    -.16604303E+05        30.53409        8.68673381              .0C000
 57300.00000       .35110626E+07    -.18000179E+05       382.32037       89.75379172              .0C000
     2.00000       .23247153E+08     .24538013E+05         8.73857      137.96525192              .00000

     7/ 8/67  15 HRS.  58 MIN.     12.34578 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    58.20576      -.21422141E+08     .62654795E+04        -.00000      202.95255504              1.5C000
   958.20576      -.90722318E+07    -.14971745E+05        37.48365       -.00000299              .0C000
 57492.34578      -.12134505E+01    -.18380968E+05       384.82785       89.83857563              .0C000
     2.00000       .23263996E+08     .24520795E+05        -.00000      138.55663441              .00000

     7/ 8/67  16 HRS.   0 MIN.      -.00000 SEC.
ME,MM,ST,DT          X,R              XDOT,V       LAT,LONG,H,SBV  ALPHA,DELTA,BETA,A    REV,NPD,NPCK,NREG
    60.00000      -.20610321E+08     .87998393E+04       -4.90010      207.26480397              1.51805
   960.00000      -.10621752E+08    -.13784272E+05        41.34611       -4.86745637              .00000
 57600.00000      -.19745058E+07    -.18261616E+05       385.94442       89.88918664              .0C000
     2.00000       .23270273E+08     .24513873E+05       -4.89679      138.37283634              .0C000
              CAME FROM SEGMENT   31  ARE IN SEGMENT   13      FUNCTION IS    0
              OLD FUNCTION IS    0     NEW FUNCTION IS    0
              CAME FROM SEGMENT   13  ARE IN SEGMENT   62      FUNCTION IS    0
              OLD FUNCTION IS    3     NEW FUNCTION IS    0
              CAME FROM SEGMENT   62  ARE IN SEGMENT   63      FUNCTION IS    0
```

Figure 19. Ephemeris Output (Last 25 minutes of output)

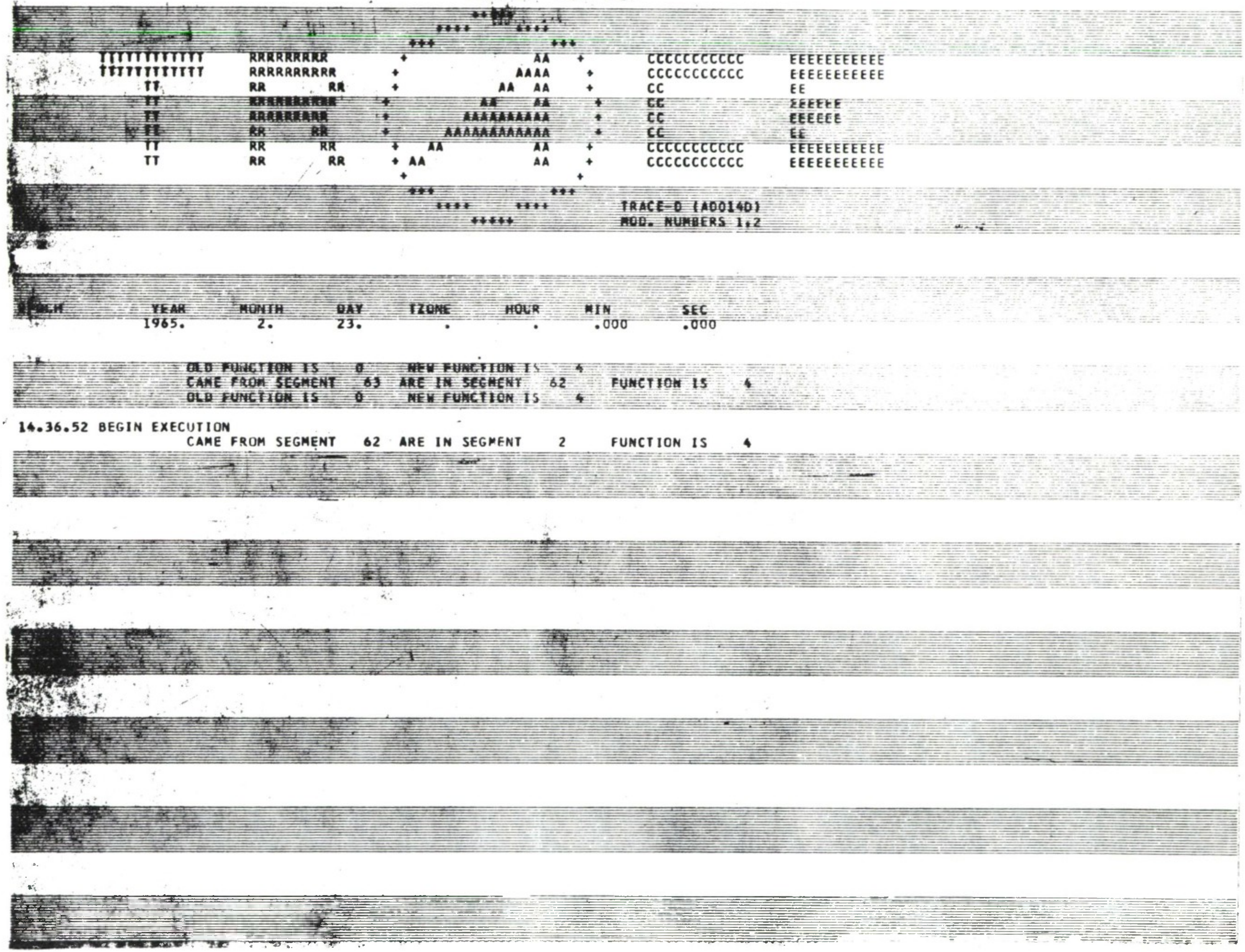
Figure 20. Observation Generation Output Listing of Input

```
BINTEG    TRACK-0 STANDARD INTEGRATION CONSTANTS                         BASIC INPUT CARD    1
I1    1             I2   2             I3   0                            BASIC INPUT CARD    2
4     1             5    1             11   1.00002516                   BASIC INPUT CARD    3
23     .1         -9 26  1             30   1                            BASIC INPUT CARD    4
 31   .015625       32   64            33   1                            BASIC INPUT CARD    5
I34   4             I35  1             37   .001                         BASIC INPUT CARD    6
38    0.            40   2820.1763     I41  1                            BASIC INPUT CARD    7
GC                                                                       BASIC INPUT CARD    8
1     .437526904-2 2     .5530370  -2 6     .5                           BASIC INPUT CARD    9
6     .5            8    .43752695 -2                                    BASIC INPUT CARD   10
 9    1.            10   10                                              BASIC INPUT CARD   11
13    3280.8399     14   57.2957795    15   20923738                     BASIC INPUT CARD   12
16    332951.3      17   .0122999      18   .814979                      BASIC INPUT CARD   13
 19   .107821       20   317.887       21   95.129                       BASIC INPUT CARD   14
I22   23454.865     23   3443.9336     24   20925738                     BASIC INPUT CARD   15
25    348762.3      26   32.174        30   348762.3                     BASIC INPUT CARD   16
 31    1.5          32   1.0471976     33   3.14159265                   BASIC INPUT CARD   17
34    298.3         35   300000.       36   82505.922                    BASIC INPUT CARD   18
ITMATX4                                                                  BASIC INPUT CARD   19
 DRAG .01          I2    1             3    6.83                         BASIC INPUT CARD   20
4     -15.684                                                            BASIC INPUT CARD   21
RREFG1.                                                                  BASIC INPUT CARD   22
GC    STANDARD DECK FOR GUIERS 6,TH ORDER EARTH MODEL      10/15/65      BASIC INPUT CARD   23
1     .043752695-1 2     .55304505 -2 15    20925741.                    BASIC INPUT CARD   24
24    20925741.    OBJI              2      1.723      -6                BASIC INPUT CARD   25
3     1.856        -6 4  .4482       -6 5   .1643      -6                BASIC INPUT CARD   26
6     .7278        -6 7  .1536       -6 8   .05719     -6                BASIC INPUT CARD   27
9     .004781      -6 10 .1509       -6 11  .05329     -6                BASIC INPUT CARD   28
12    .005842      -6 13 .004093     -6 14  .0008462   -6                BASIC INPUT CARD   29
15    .06611       -6 16 .03746      -6 17  .01166     -6                BASIC INPUT CARD   30
18    .002256      -6 19 .0003328    -6 20  .00005153  -6                BASIC INPUT CARD   31
```

Figure 20. (Cont.)

```
OBLT             2   -13.18      3   5.31                    BASIC INPUT CARD   32
 4   -13.33      5   16.00       6   -136.68                 BASIC INPUT CARD   33
 7   27.47       8   -1.10       9   36.01                   BASIC INPUT CARD   34
 10  -81.86      11  -2.60       12  -3.45                   BASIC INPUT CARD   35
 13  58.25       14  -15.32      15  157.21                  BASIC INPUT CARD   36
 16  113.15      17  -1.75       18  60.74                   BASIC INPUT CARD   37
 19  -17.75      20. -14.34      DBJZ                         SIC INPUT CARD   38
 2   1082.76  -6 3   -2.693   -6 4   -1.56    -6             BASIC INPUT CARD   39
 5   -.006    -6 6   .39      -6 7   -.633    -6             BASIC INPUT CARD   40
 B   0.          9   .210     -6IIOB 9                       BASIC INPUT CARD   41
 I2  6           I3  9           I4  6                       BASIC INPUT CARD   42
BEGIN 4          IYEAR 1965      IMNTH 2                     BASIC INPUT CARD   43
IDAY  23                                                     BASIC INPUT CARD   44
IICTYP4                                                      BASIC INPUT CARD   45
 IC  -60.                                                    BASIC INPUT CARD   46
 2   0.          3   90.                                     BASIC INPUT CARD   47
 4   25.                                                     BASIC INPUT CARD   48
 5   -607612.    6   -1.                                     BASIC INPUT CARD   49
IPTAPE4                                                      BASIC INPUT CARD   50
BNOISE1          IISIG 1         I2  2                       BASIC INPUT CARD   51
I3   3           I4  4           I5  5                       BASIC INPUT CARD   52
I6   6           I7  7           IB  B                       BASIC INPUT CARD   53
I9   13          I10 14          I11 15                      BASIC INPUT CARD   54
I12  19          SIGMA100.       2   .1                      BASIC INPUT CARD   55
 3   .1          4   .05         5   .05      6   .05        BASIC INPUT CARD   56
 7   .05         8   .05         9   1000.                   BASIC INPUT CARD   57
 10  1000.       11  1000.       12  .1                      BASIC INPUT CARD   58
END                                                          BASIC INPUT CARD   59
```

Figure 21: Header Page



```
                                                      +++++
                                                  ++++     ++++
                                              +++              +++
          TTTTTTTTTTTT      RRRRRRRRR         +              AA   +       CCCCCCCCCCC      EEEEEEEEEEE
          TTTTTTTTTTTT      RRRRRRRRRR      +              AAAA    +      CCCCCCCCCCC      EEEEEEEEEEE
                TT          RR       RR    +             AA  AA    +      CC               EE
                TT          RRRRRRRRRR     +           AA    AA     +     CC               EEEEEE
                TT          RRRRRRRRR      +         AAAAAAAAAA     +     CC               EEEEEE
                TT          RR     RR      +      AAAAAAAAAAAA      +     CC               EE
                TT          RR      RR      +   AA           AA    +      CCCCCCCCCCC      EEEEEEEEEEE
                TT          RR       RR     + AA             AA    +      CCCCCCCCCCC      EEEEEEEEEEE
                                              +                   +
                                              +++              +++
                                                  ++++     ++++        TRACE-D (A0014D)
                                                     +++++             MOD. NUMBERS 1,2


EPOCH           YEAR      MONTH       DAY     TZONE      HOUR      MIN        SEC
              1965.          2.       23.         .          .      .000      .000

                    OLD FUNCTION IS     0     NEW FUNCTION IS     4
                    CAME FROM SEGMENT  63    ARE IN SEGMENT   62      FUNCTION IS    4
                    OLD FUNCTION IS     0     NEW FUNCTION IS     4
14.36.52 BEGIN EXECUTION
                    CAME FROM SEGMENT  62    ARE IN SEGMENT     2     FUNCTION IS    4
```

Figure 22. Initial Information

```
MRAPAR05,99                                                                       BASIC INPUT CARD    1
                           )
D01,0188  RBIAS     03,011000, } (1)                                              BASIC INPUT CARD    2
                           )
END                                                                               BASIC INPUT CARD    3



                                SIGMA TABLE
 1    .1000000E+03  2    .1000000E-00  3    .1000000E-00  4    .5000000E-01  5    .5000000E-01  6    .5000000E-01 )
                                                                                                                    } (2)
 7    .5000000E-01  8    .5000000E-01 13    .1000000E+04 14    .1000000E+04 15    .1000000E+04 19    .1000000E-00 )


                                        INITIAL CONDITIONS

X    =      -.10056004E+07         ALPHA=        .92676667E+02         A=        .21533353E+08
Y    =       .21509860E+08         DELTA=        .00000000E 00         E=        .35865344E-09
Z    =       .00000000E 00         BETA =        .90000000E+02         I=        .65000000E+02
XDOT=       -.10793656E+05         AZ   =        .25000000E+02         C=        .92676667E+02
YDOT=       -.50461068E+03         R    =        .21533353E+08         U=        .90005515E+02
ZDOT=        .23172351E+05         V    =        .25567860E+05         T=       -.66145701E+02


  ATMOSPHERE - LOCKHEED          CDA/W  =  .10000000E-01     W/CDA  =  .10000000E+03
                                 D1     =  .68300000E+01     D2     = -.15684000E+02

                                         EARTH MODEL
GM=    .55304505E-02  J2=    .10827600E-02  J3=  -.26930000E-05  J4=  -.15600000E-05  J5=  -.60000000E-08
J6=    .39000000E-06  J7=   -.63300000E-06  J8=   .00000000E 00  J9=   .21000000E-06 J10=   .00000000E 00
    J21=   .00000000E 00      L21=   .00000000E 00       J52=    .53290000E-07      L52=  -.26000000E+01
    J22=   .17230000E-05      L22=  -.13180000E+02       J53=    .58420000E-08      L53=  -.34500000E+01
    J31=   .18560000E-05      L31=   .53100000E+01       J54=    .40930000E-08      L54=   .58250000E+02
    J32=   .44820000E-06      L32=  -.13330000E+02       J55=    .84620000E-09      L55=  -.15320000E+02
    J33=   .16430000E-06      L33=   .16000000E+02       J61=    .66110000E-07      L61=   .15721000E+03
    J41=   .72780000E-06      L41=  -.13668000E+03       J62=    .37460000E-07      L62=   .11315000E+03
    J42=   .15360000E-06      L42=   .27470000E+02       J63=    .11660000E-07      L63=  -.17500000E+01
    J43=   .57190000E-07      L43=  -.11000000E+01       J64=    .22560000E-08      L64=   .60740000E+02
    J44=   .47810000E-08      L44=   .36010000E+02       J65=    .33280000E-09      L65=  -.17750000E+02
    J51=   .15090000E-06      L51=  -.81860000E+02       J66=    .51530000E-10      L66=  -.14340000E+02
THE FOLLOWING BODIES ARE USED FOR PLANETARY PERTURBATIONS

NONE

FORMULATION
          COWELL (EQS.OF MOTION)

DIFFERENTIAL EQUATION SUBROUTINE
          GAUSS-JACKSON         E BAR=   .1000E-09      A= 1.000    RATIO OF COWELL STEP TO RUNGE KUTTA  4
STEP SIZE =      INITIAL=      .1000E+01      MINIMUM=      .1562E-01      MAXIMUM=      .6400E+02
 DO NOT RECOMPUTE PERTURBATIONS FOR CORRECTOR

EQUATIONS OF MOTION   USE N1 = 9 N2= 6

                                         CONSTANTS
                         DECIMAL           OCTAL                                          DECIMAL           OCTAL
OMEGA E                 .43752695E-02   327323635240    GM                              .55304505E-02   620017133540
ALPHA G                 .26647105E+01   474077224600
```

```
FT/KM                        .32808399E+04   340353733740   EARTH RADIUS - FT        .20925741E+C8   4550000CC00C
E.R./A.U.                    .23454865E+05   565605075320   N.M./E.R.                .34439336E+04   740032155600
I-O, DISTANCE                .20925741E+08   455C00000000   I-O, VELOCITY            .34876230E+C6   22314631462C
G                            .32174000E+02   132071260100   FT/SEC//E.R./MIN.        .34876230E+06   22314631462C
DEG/SEC//RAD/MIN             .10471976E+01   444250714340   1/EPS.                   .29830000E+03   314631463140
RELATIVE MASS(SUN)           .33295130E+06   723146314620   (MOON)                   .12299900E-01   41207636660C
(VENUS)                      .81497900E+00   355337552020   (MARS)                   .10782100E-00   20323222370C
(JUPITER)                    .31788700E+03   422335136140   (SATURN)                 .95129000E+02    30446722720

                         CAME FROM SEGMENT     2  ARE IN SEGMENT    62     FUNCTION IS     4
                         OLD FUNCTION IS    4     NEW FUNCTION IS     4

14.36.56 BEGIN EXECUTION
                         CAME FROM SEGMENT    62  ARE IN SEGMENT     1     FUNCTION IS     4
                         OLD FUNCTION IS    4     NEW FUNCTION IS     4

14.36.58 BEGIN EXECUTION
                         CAME FROM SEGMENT     1  ARE IN SEGMENT    12     FUNCTION IS     4
```

Figure 22 (cont.)

Figure 23. Data Specifications

```
STATIONS
    SIG  REF       LATITUDE         LONGITUDE          HEIGHT

AA   .    .      75.00000000      300.00000000      1000.0000
BB   .    .      45.00000000      240.00000000       100.0000
CC   .    .        .00000000      315.00000000       500.0000
DD   .    .        .00000000       15.00000000       200.0000   (3)
EE   .    .     -15.00000000      135.00000000       100.0000
FF   .    .     -65.00000000       75.00000000      5000.0000

DATA
    INTERVAL  MIN.EL  MAX.EL  MAX.RANGE   MDT        START          STOP
      SEC.     DEG.    DEG.      N.M      MIN.    DA  HR  MN    DA  HR  MN
AA  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .
BB  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .
CC  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .
DD  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .   (4)
EE  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .
FF  15.0000    .00     .00        .        .0      .   .  70.    .  24.   .
PARAMETERS TO BE CORRECTED

BB
 RBIAS (5)

DATA TYPES
 S   RANGE  AZMTH  ELEV.  R.DOT  P.DOT  Q.DOT   P      Q     AZ.DT  E.DOT  R.DDT  MU.VIS  LAT.  LONG.
 T
 A   SUR.R  HIGHT  DOPLR  LOOK   VARI.  KAPPA  ASPCT  ATTEN  X,Y,Z  T-R,C  G-R,D  HR.ANG.  U,V
 T

 AA   X      X      X      X
             Y                                                Y      Y      Y      Y       Y

 BB   X      X      X      X
                                                              Y      Y      Y      Y       Y

 CC   X      X      X      X
      Y                                                       Y      Y      Y      Y       Y

 DD   X      X      X      X                                                                    (6)
                                                              Y      Y      Y      Y       Y

 EE   X      X      X      X
                                         Y      Y             Y      Y      Y      Y       Y

 FF   X      X      X      X
                                                              Y      Y      Y      Y       Y

            CAME FROM SEGMENT    12   ARE IN SEGMENT     1     FUNCTION IS    4
            OLD FUNCTION IS     4     NEW FUNCTION IS    4                          (7)
            CAME FROM SEGMENT    1   ARE IN SEGMENT    62     FUNCTION IS    4
            OLD FUNCTION IS     4     NEW FUNCTION IS    4
```

Figure 24. Generated Data

```
                              FEBRUARY  23,  1965

ST HR   MINS    T-ST       RANGE     AZIMUTH  ELEVATION RANGE RATE    HEIGHT          X           Y           Z
                        QM'Y YARDS   DEGREES   DEGREES     FT/SEC  QM'Y YARDS  QM'Y YARDS KILO YARDS KILC YARDS

                       TOP RT.ASC TOP DECLIN GEO RT.ASC GEO DECLIN TOP HR.ANG          U           V
                          DEGREES    DEGREES    DEGREES    DEGREES    CEGREES    DEGREES    DEGREES

AA    RISE (     .00 DEGREES ELEV.)        3. HOURS  14.57 MINUTES    AZIMUTH 162.149 DEGREES  (8)

AA  3. 14.75  194.7[illegible](9)  845.973    159.154       .835  -7043.454    105.410   1088.808  -1286.868   3112.074
                          162.791    -13.836    151.780     61.490    338.501     76.039     64.300
AA  3. 15.00  195.00      830.615    155.308      1.089  -5391.169    105.431   1113.590  -1232.336   3125.509
                          167.047    -13.140    153.647     62.007    334.506     77.061     64.395
AA  3. 15.25  195.25      819.452    151.007      1.340  -3656.130    105.447   1138.030  -1177.339   3137.836
                          171.310    -12.468    155.679     62.467    330.236     78.083     64.483
AA  3. 15.50  195.50      812.601    146.640      1.315  -1861.900    105.458   1162.830  -1122.054   3148.852
                          175.780    -11.783    157.684     62.758    325.904     79.104     64.563
AA  3. 15.75  195.75      810.253    142.366      1.218    -36.293    105.465   1186.511  -1066.625   3159.401
                          180.152    -10.969    159.857     63.285    321.512     80.126     64.635
AA  MAX EL (   1.73 DEGREES ELEV.)         3. HOURS  15.76 MINUTES    AZIMUTH 142.251 DEGREES  (10)
AA  3. 16.00  196.00      812.477    137.939      1.426   1790.209    105.467   1210.878  -1010.412   3168.371
                          184.587    -10.380    161.906     63.560    317.202     81.148     64.700
AA  3. 16.25  196.25      819.105    133.852      1.129   3586.645    105.463   1234.504   -954.212   3176.608
                          188.951     -9.690    164.143     63.817    312.920     82.170     64.758
AA  3. 16.50  196.50      830.117    129.605       .998   5325.267    105.455   1257.468   -898.441   3184.295
                          193.316     -9.039    166.445     64.068    308.742     83.192     64.808
AA  3. 16.75  196.75      845.334    125.807       .955   6981.888    105.442   1280.617   -841.573   3190.240
                          197.394     -8.465    168.705     64.271    304.604     84.214     64.851

AA     SET  (    .00 DEGREES ELEV.)        3. HOURS  16.93 MINUTES    AZIMUTH 122.587 DEGREES   (11)
 ELAPSED VISIBLE TIME =     2.37 MINUTES  (12)


AA    RISE (     .00 DEGREES ELEV.)        4. HOURS  42.80 MINUTES    AZIMUTH 204.539 DEGREES

AA  4. 43.00  283.00      827.557    201.704      1.144 -15084.728    105.313    552.279  -1572.426   3122.351
                          141.179    -13.467    152.983     61.947     22.507     76.822     64.376
AA  4. 43.25  283.25      791.759    198.381      1.359 -13902.781    105.330    595.668  -1531.189   3134.880
                          144.814    -13.154    155.006     62.371     18.798     77.844     64.465
AA  4. 43.50  283.50      759.095    194.527      1.920 -12552.291    105.342    639.448  -1489.138   3146.351
                          148.770    -12.736    156.935     62.628     15.016     78.866     64.547
AA  4. 43.75  283.75      729.978    190.348      2.580 -11022.434    105.349    682.631  -1446.793   3156.854
                          153.160    -12.442    159.140     63.053     10.661     79.888     64.621
AA  4. 44.00  284.00      704.815    185.950      3.001  -9308.496    105.351    725.865  -1404.008   3166.334
                          157.743    -12.057    161.202     63.546      6.171     80.910     64.688
AA  4. 44.25  284.25      684.137    181.183      3.420  -7416.445    105.348    769.404  -1361.406   3174.670
                          162.702    -11.740    163.388     63.790      1.302     81.932     64.747
AA  4. 44.50  284.50      668.364    176.239      3.759  -5364.263    105.340    812.380  -1318.244   3182.736
                          167.824    -11.395    165.646     64.027    356.136     82.954     64.799
AA  4. 44.75  284.75      657.782    170.775      4.035  -3185.517    105.327    855.121  -1274.715   3188.946
                          173.208    -11.009    167.849     64.277    350.827     83.976     64.844
AA  4. 45.00  285.00      652.696    165.697      3.968   -926.626    105.309    898.104  -1230.643   3194.411
                          178.739    -10.463    170.214     64.542    345.424     84.998     64.882
AA  MAX EL (   4.25 DEGREES ELEV.)         4. HOURS  45.10 MINUTES    AZIMUTH 163.452 DEGREES
AA  4. 45.25  285.25      653.199    160.142      4.007   1356.185    105.287    940.288  -1186.490   3198.845
                          184.303    -10.190    172.564     64.754    339.943     86.020     64.913
AA  4. 45.50  285.50      659.353    155.064      3.867   3604.314    105.259    982.733  -1142.031   3202.239
                          189.811     -9.755    174.948     64.874    334.541     87.042     64.936
```

Figure 24 (cont.)

```
                                 FEBRUARY  23,  1965

ST HR   MINS    T-ST       RANGE       AZIMUTH  ELEVATION RANGE RATE         X            Y            Z  TOP RT.ASC
                        QM'Y YARDS     DEGREES   DEGREES     FT/SEC  QM'Y YARDS KILO YARDS KILO YARDS    DEGREES

                       TOP DECLIN GEO RT.ASC GEO DECLIN TOP HR.ANG         U            V            V
                          DEGREES    DEGREES    DEGREES    DEGREES   DEGREES      DEGREES      DEGREES

BB     RISE (     .00 DEGREES ELEV.I         4. HOURS  33.11 MINUTES    AZIMUTH 149.915 DEGREES

BB  4. 33.25  273.25       824.583     146.101       .947 -14120.608  -1090.503  -2761.350   1931.005    142.384
                           -36.695     109.545     32.957    318.752     36.990      2.207
BB  4. 33.50  273.50       791.225     144.488      1.382 -12858.371  -1052.616  -2744.016   1976.559    146.073
                           -34.273     110.342     33.831    315.185     38.011     52.849
BB  4. 33.75  273.75       761.258     140.606      1.847 -11430.015  -1014.499  -2725.958   2020.881    149.823
                           -31.768     110.856     34.761    311.506     39.032     53.463
BB  4. 34.00  274.00       734.923     136.292      2.426  -9830.536   -976.125  -2706.477   2064.999    153.686
                           -29.094     111.499     35.634    307.717     40.053     54.052
BB  4. 34.25  274.25       712.835     131.735      2.560  -8061.687   -937.243  -2686.516   2108.533    157.456
                           -26.147     112.253     36.483    303.912     41.074     54.617
BB  4. 34.50  274.50       695.282     127.075      3.069  -6136.014   -897.994  -2666.067   2151.478    161.617
                           -22.968     112.830     37.453    299.906     42.095     55.157
BB  4. 34.75  274.75       682.671     121.944      3.273  -4078.574   -858.816  -2644.261   2193.127    165.633
                           -19.566     113.480     38.209    295.850     43.116     55.675
BB  4. 35.00  275.00       675.241     116.710      3.554  -1927.175   -818.891  -2621.992   2234.590    169.611
                           -16.110     114.217     39.090    291.897     44.137     56.172
BB  MAX EL (    3.63 DEGREES ELEV.)        4. HOURS  35.24 MINUTES    AZIMUTH 111.684 DEGREES
BB  4. 35.25  275.25       673.200     111.575      3.539    271.158   -778.823  -2599.453   2275.219    173.764
                           -12.624     114.980     40.061    287.876     45.158     56.648
BB  4. 35.50  275.50       676.570     106.379      3.310   2462.983   -738.242  -2575.600   2315.230    177.842
                            -9.039     115.767     40.858    283.914     46.179     57.103
BB  4. 35.75  275.75       685.318     101.208      3.412   4596.676   -697.821  -2551.261   2354.177    181.731
                            -5.685     116.557     41.678    280.135     47.200     57.54C
BB  4. 36.00  276.00       699.155      96.345      2.951   6626.616   -657.093  -2526.583   2392.713    185.522
                            -2.469     117.317     42.491    276.378     48.221     57.959
BB  4. 36.25  276.25       717.894      91.502      2.695   8518.012   -615.847  -2500.517   2430.301    189.163
                              .525     118.176     43.330    272.712     49.242     58.360
BB  4. 36.50  276.50       741.082      87.009      2.224  10248.754   -574.153  -2473.836   2467.506    192.671
                             3.582     118.931     44.102    269.398     50.263     58.744
BB  4. 36.75  276.75       768.327      82.804      1.852  11808.934   -532.641  -2446.770   2503.773    196.169
                             6.008     119.796     44.983    265.928     51.285     59.111
BB  4. 37.00  277.00       799.223      79.017      1.125  13198.797   -490.672  -2418.845   2538.768    199.309
                             8.378     120.652     45.792    262.762     52.306     59.464
BB  4. 37.25  277.25       833.377      75.579      1.038  14425.412   -448.228  -2390.327   2573.149    202.32C
                            10.429     121.607     46.588    259.860     53.327     59.801

BB     SET (      .00 DEGREES ELEV.)        4. HOURS  37.38 MINUTES    AZIMUTH  73.682 DEGREES
 ELAPSED VISIBLE TIME =    4.27 MINUTES

BB     RISE (     .00 DEGREES ELEV.)        6. HOURS   1.85 MINUTES    AZIMUTH 228.700 CEGREES

BB  6.  2.00  362.00       808.339     229.231      1.304 -23616.336  -1939.243  -2134.200   2055.880     65.177
                           -26.924     111.217     35.496     58.250     39.835     53.932
BB  6.  2.25  362.25       750.146     230.414      1.911 -23518.703  -1896.105  -2130.351   2099.512     65.049
                           -25.454     111.879     36.375     58.453     40.856     54.501
BB  6.  2.50  362.50       692.273     231.523      3.312 -23387.981  -1852.034  -2126.213   2142.083     64.774
                           -23.949     112.497     37.206     58.698     41.877     55.047
BB  6.  2.75  362.75       634.744     233.061      4.435 -23212.145  -1807.965  -2122.050   2184.493     64.550
                           -22.047     113.209     38.127     59.115     42.898     55.570
```

Figure 25. Orbit Determination Output Listing of Input

```
GINTEG       TRACE-D STANDARD INTEGRATION CONSTANTS                              BASIC INPUT CARD    1
I1    1              I2    2               I3    0                               BASIC INPUT CARD    2
 4    1               5    1               11    1.DDD02516                      BASIC INPUT CARD    3
 23   .1       -9                                                                BASIC INPUT CARD    4
 26   1                                                                           BASIC INPUT CARD    5
 30   1               31   .015625         32    64                33   1        -7    BASIC INPUT CARD    6
I34   4              I35   1               37    .0001             38   0.       BASIC INPUT CARD    7
 40   2820.18012     I41   1                                                      BASIC INPUT CARD    8
GC           TRACE-D STANDARD PHYSICAL CONSTANTS    1C/ 1/65                     BASIC INPUT CARD    9
 1    .437526904-2 2      .55304203 -2 6    .5                                    BASIC INPUT CARD   1C
 8    .437526904-2 9      1.           10    10                                   BASIC INPUT CARD   11
 13   3280.8399      14   57.2957795   15    20925738                             BASIC INPUT CARD   12
 16   332951.3       17   .01229853    18    .814979                              BASIC INPUT CARD   13
 19   .107821        20   317.887      21    95.129                               BASIC INPUT CARD   14
 22   23454.865      23   3443.93355   24    20925738                             BASIC INPUT CARD   15
 25   348762.3       26   32.174       30    348762.3                             BASIC INPUT CARD   16
 31   1.5            32   1.0471976    33    3.14159265                           BASIC INPUT CARD   17
 34   298.3          35   300000.      36    82505.922                            BASIC INPUT CARD   1E
 NUMB                42   3443.9336                                               BASIC INPUT CARD   19
DITIN 12                                                                          BASIC INPUT CARD   2C
DPRCDE X X                                                                        BASIC INPUT CARD   21
IICTYP2                                                                           BASIC INPUT CARD   22
 IC   23.11454                                                                    BASIC INPUT CARD   23
 2    26.51516                                                                    BASIC INPUT CARD   24
 3    89.88977                                                                    BASIC INPUT CARD   25
 4    45.73312                                                                    BASIC INPUT CARD   26
 5    24780836.7                                                                  BASIC INPUT CARD   27
 6    23765.259                                                                   BASIC INPUT CARD   28
IMAXIT1                                                                           BASIC INPUT CARD   29
IYEAR 1967                                                                        BASIC INPUT CARO   3C
IMNTH 7                                                                           BASIC INPUT CARD   31
IDAY  8                                                                           BASIC INPUT CARD   32
```

Figure 25 (cont.)

```
TZNE 0                                                          BASIC INPUT CARD   33
HR   14.                                                        BASIC INPUT CARD   34
MIN  45.                                                        BASIC INPUT CARD   35
DRAG .2849          I2    1                                     BASIC INPUT CARD   36
3    6.83            4    -15.684                               BASIC INPUT CARD   37
IIOB 10             I2    6              I3    10               BASIC INPUT CARD   38
I4   6                                                          BASIC INPUT CARD   39
OBJZ                                                              SIC INPUT CARD   40
2    .1082645 -2                                                BASIC INPUT CARD   41
3    -.2546000 -5                                               BASIC INPUT CARD   42
4    -1.649     -6                                              BASIC INPUT CARD   43
5    -.210      -6 6   .646      -6 7    -.333     -6           BASIC INPUT CARD   44
8    -.270      -6 9   -.053     -6 10   -.054     -6           BASIC INPUT CARD   45
OBJT             2     1.5664    -6 3    1.7287    -6           BASIC INPUT CARD   46
4    .3025      -6 5   .1966     -6 6    .5234     -6           BASIC INPUT CARD   47
7    .1372      -6 8   .04166    -6 9    .009378   -6           BASIC INPUT CARD   48
10   .1247      -6 11  .05846    -6 12   .02219    -6           BASIC INPUT CARD   49
13   .001605    -6 14  .001029   -6 15   .09572    -6           BASIC INPUT CARD   50
16   .02928     -6 17  .001037   -6 18   .001500   -6           BASIC INPUT CARD   51
19   .000381    -6 20  .000140   -6                             BASIC INPUT CARD   52
OBLT             2     -15.50       3    -1.43                  BASIC INPUT CARD   53
4    -32.30      5     32.31        6    -133.53                BASIC INPUT CARD   54
7    35.75       8     -2.75        9    26.09                  BASIC INPUT CARD   55
10   -164.13     11    -24.19       12   58.58                  BASIC INPUT CARD   56
13   32.27       14    -15.79       15   99.46                  BASIC INPUT CARD   57
16   -38.87      17    0.0          18   -19.96                 BASIC INPUT CARD   58
19   -25.28      20    -16.92                                   BASIC INPUT CARD   59
SIGMA22.96                                                      BASIC INPUT CARD   60
2    .06056                                                     BASIC INPUT CARD   61
3    22.96                                                      BASIC INPUT CARD   62
4    .06056                                                     BASIC INPUT CARD   63
```

Figure 25 (cont.)

```
 5    22.96                                          BASIC INPUT CARD   64
 6    .06056                                         BASIC INPUT CARD   65
IPTAPE4                                              BASIC INPUT CARD   66
IISIG 101                                            BASIC INPUT CARD   67
I2    119                                            BASIC INPUT CARD   68
I3    201                                            BASIC INPUT CARD   69
I4    219                                            BASIC INPUT CARD   70
I5    301                                            BASIC INPUT CARD   71
I6    319                                            BASIC INPUT CARD   72
DCPRAM2XXXXXX                                        BASIC INPUT CARD   73
DDPRAMXXXX                                           BASIC INPUT CARD   74
 BNDS 1.5                                            BASIC INPUT CARD   75
 2    1.5                                            BASIC INPUT CARD   76
 3    .3                                             BASIC INPUT CARD   77
 4    .75                                            BASIC INPUT CARD   78
 5    4920.                                          BASIC INPUT CARD   79
 6    492.                                           BASIC INPUT CARD   80
 7    .15                                            BASIC INPUT CARD   81
 8    .1          -7                                 BASIC INPUT CARD   82
 9    .1          -7                                 BASIC INPUT CARD   83
 10   .1          -7                                 BASIC INPUT CARD   84
END                                                  BASIC INPUT CARD   85
```

Figure 26. Header and Observations

```
                                                   +++++
                                               ++++     ++++
                                            +++             +++
         TTTTTTTTTTTT     RRRRRRRRR        +              AA    +       CCCCCCCCCCC     EEEEEEEEEEE
         TTTTTTTTTTTT     RRRRRRRRRR      +             AAAA     +      CCCCCCCCCCC     EEEEEEEEEEE
              TT          RR        RR    +           AA  AA     +      CC              EE
              TT          RRRRRRRRRR     +          AA    AA      +     CC              EEEEEE
              TT          RRRRRRRRR      +        AAAAAAAAAA      +     CC              EEEEEE
              TT          RR      RR     +      AAAAAAAAAAAA      +     CC              EE
              TT          RR       RR     +   AA          AA     +      CCCCCCCCCCC     EEEEEEEEEEE
              TT          RR        RR    + AA            AA     +      CCCCCCCCCCC     EEEEEEEEEEE
                                           +                   +
                                            +++             +++
                                               ++++     ++++        TRACE-D (AD014D)
                                                   +++++            MOD. NUMBERS 1,2


EPOCH          YEAR      MONTH      DAY     TZONE      HOUR     MIN         SEC
      .       1967.        7.        8.        .        14.    45.000       .000


                   OLD FUNCTION IS     0     NEW FUNCTICN IS     1
                   CAME FROM SEGMENT   63   ARE IN SEGMENT   62      FUNCTION IS      1
                   OLD FUNCTION IS     0     NEW FUNCTION IS     1
14.08.50 BEGIN EXECUTION
                   CAME FROM SEGMENT   62   ARE IN SEGMENT    1      FUNCTION IS      1
                   OLD FUNCTION IS     1     NEW FUNCTICN IS     1

14.08.55 BEGIN EXECUTION
                   CAME FROM SEGMENT    1   ARE IN SEGMENT   11      FUNCTION IS      1
PERMANENT STATIONS
     SIG    REF      LATITUDE          LONGITUDE          HEIGHT

MH      1.    .      .42617373E+02     .28850853E+03     .22309700E+03
BD      2.    .      .42505961E+02     .28876481E+03    -.91864000E+02   (1)
BH      3.    .      .42645973E+02     .28890644E+03     .15419900E+03

OBSERVATIONS
 MO DY HR MN   SEC        STA  TYP
  7  8 14 53 16.7706      MH   70     -.17007600E+05    .00000000E 00   .00000000E 00  (2)
  7  8 14 53 21.2185      MH   70     -.16953515E+05    .00000000E 00   .00000000E 00
  7  8 14 53 25.5664      MH   70     -.16898818E+05    .00000000E 00   .00000000E 00
  7  8 14 53 29.9604      MH   70     -.16841865E+05    .00000000E 00   .00000000E 00
  7  8 14 53 34.4423      MH   70     -.16781987E+05    .00000000E 00   .00000000E 00
  7  8 14 53 38.7262      MH   70     -.16723026E+05    .00000000E 00   .00000000E 00
  7  8 14 53 42.5562      MH   70     -.16668817E+05    .00000000E 00   .00000000E 00
  7  8 14 53 43.5395      MH   10      .84946710E+07    .00000000E 00   .00000000E 00
  7  8 14 53 46.4341      MH   70     -.16612447E+05    .00000000E 00   .00000000E 00  (3)
  7  8 14 53 50.2880      MH   70     -.16554963E+05    .00000000E 00   .00000000E 00
  7  8 14 53 54.0480      MH   70     -.16497402E+05    .00000000E 00   .00000000E 00
  7  8 14 53 57.9419      MH   70     -.16436200E+05    .00000000E 00   .00000000E 00
  7  8 14 53 58.5792      MH   10      .82458846E+07    .00000000E 00   .00000000E 00
  7  8 14 54  1.7558      MH   70     -.16374666E+05    .00000000E 00   .00000000E 00
  7  8 14 54  5.5158      MH   70     -.16312415E+05    .00000000E 00   .00000000E 00
  7  8 14 54  9.2757      MH   70     -.16248541E+05    .00000000E 00   .00000000E 00
  7  8 14 54 10.9870      MH   10      .80433210E+07    .00000000E 00   .00000000E 00
```

Figure 26 (cont.)

```
 7  8 14 54 13.0356    MH  70      -.16183004E+05  .00000000E 00   .00000000E 00
 7  8 14 54 16.7956    MH  70      -.16115794E+05  .00000000E 00   .00000000E 00
 7  8 14 54 20.5955    MH  70      -.16046088E+05  .00000000E 00   .00000000E 00
 7  8 14 54 22.4540    MH  10       .78584983E+07  .00000000E 00   .00000000E 00
 7  8 14 54 24.3555    MH  70      -.15975297E+05  .00000000E 00   .00000000E 00
 7  8 14 54 28.1154    MH  70      -.15902687E+05  .00000000E 00   .00000000E 00
 7  8 14 54 31.8753    MH  70      -.15828202E+05  .00000000E 00   .00000000E 00
 7  8 14 54 34.1106    MH  10       .76731863E+07  .00000000E 00   .00000000E 00
 7  8 14 54 35.6353    MH  70      -.15751775E+05  .00000000E 00   .00000000E 00
 7  8 14 54 39.3952    MH  70      -.15673354E+05  .00000000E 00   .00000000E 00
 7  8 14 54 43.1552    MH  70      -.15592932E+05  .00000000E 00   .00000000E 00
 7  8 14 54 45.5784    MH  10       .74935796E+07  .00000000E 00   .00000000E 00
 7  8 14 54 46.9151    MH  70      -.15510398E+05  .00000000E 00   .00000000E 00
 7  8 14 54 50.6750    MH  70      -.15425733E+05  .00000000E 00   .00000000E 00
 7  8 14 54 54.4350    MH  70      -.15338886E+05  .00000000E 00   .00000000E 00
 7  8 14 54 56.8583    MH  10       .73197144E+07  .00000000E 00   .00000000E 00
 7  8 14 54 58.1949    MH  70      -.15250051E+05  .00000000E 00   .00000000E 00
 7  8 14 55  1.9549    MH  70      -.15158382E+05  .00000000E 00   .00000000E 00
 7  8 14 55  5.7148    MH  70      -.15064618E+05  .00000000E 00   .00000000E 00
 7  8 14 55  8.1361    MH  10       .71489053E+07  .00000000E 00   .00000000E 00
 7  8 14 55  9.4747    MH  70      -.14968426E+05  .00000000E 00   .00000000E 00
 7  8 14 55 13.2347    MH  70      -.14869750E+05  .00000000E 00   .00000000E 00
 7  8 14 55 16.9946    MH  70      -.14768548E+05  .00000000E 00   .00000000E 00
 7  8 14 55 19.4179    MH  10       .69813415E+07  .00000000E 00   .00000000E 00
 7  8 14 55 20.7546    MH  70      -.14664727E+05  .00000000E 00   .00000000E 00
 7  8 14 55 24.5145    MH  70      -.14558237E+05  .00000000E 00   .00000000E 00
 7  8 14 55 28.2745    MH  70      -.14449018E+05  .00000000E 00   .00000000E 00
 7  8 14 55 30.8858    MH  10       .68146050E+07  .00000000E 00   .00000000E 00
 7  8 14 55 32.0344    MH  70      -.14336992E+05  .00000000E 00   .00000000E 00
 7  8 14 55 35.7943    MH  70      -.14222113E+05  .00000000E 00   .00000000E 00
 7  8 14 55 39.5543    MH  70      -.14104283E+05  .00000000E 00   .00000000E 00
 7  8 14 55 42.3536    MH  10       .66518137E+07  .00000000E 00   .00000000E 00
 7  8 14 55 43.3142    MH  70      -.13983450E+05  .00000000E 00   .00000000E 00
 7  8 14 55 47.0742    MH  70      -.13859568E+05  .00000000E 00   .00000000E 00
 7  8 14 55 50.8341    MH  70      -.13732534E+05  .00000000E 00   .00000000E 00
 7  8 14 55 53.6334    MH  10       .64958471E+07  .00000000E 00   .00000000E 00
 7  8 14 55 54.5941    MH  70      -.13602290E+05  .00000000E 00   .00000000E 00
 7  8 14 55 58.3540    MH  70      -.13468764E+05  .00000000E 00   .00000000E 00
 7  8 14 56  2.1140    MH  70      -.13331885E+05  .00000000E 00   .00000000E 00
 7  8 14 56  4.9133    MH  10       .63443140E+07  .00000000E 00   .00000000E 00
 7  8 14 56  5.8739    MH  70      -.13191593E+05  .00000000E 00   .00000000E 00
 7  8 14 56  9.6339    MH  70      -.13047800E+05  .00000000E 00   .00000000E 00
 7  8 14 56 13.3938    MH  70      -.12900445E+05  .00000000E 00   .00000000E 00
 7  8 14 56 16.1931    MH  10       .61975452E+07  .00000000E 00   .00000000E 00
 7  8 14 56 17.1538    MH  70      -.12749447E+05  .00000000E 00   .00000000E 00
 7  8 14 56 20.9137    MH  70      -.12594759E+05  .00000000E 00   .00000000E 00
 7  8 14 56 24.6737    MH  70      -.12436287E+05  .00000000E 00   .00000000E 00
 7  8 14 56 27.4730    MH  10       .60559275E+07  .00000000E 00   .00000000E 00
 7  8 14 56 28.4336    MH  70      -.12273993E+05  .00000000E 00   .00000000E 00
 7  8 14 56 31.8176    MH  70      -.12124570E+05  .00000000E 00   .00000000E 00
 7  8 14 56 56.8006    MH  10       .57145904E+07  .00000000E 00   .00000000E 00
 7  8 14 56 57.4793    MH  70      -.10883785E+05  .00000000E 00   .00000000E 00
 7  8 14 56 57.4793    BH  70      -.11177129E+05  .00000000E 00   .00000000E 00
 7  8 14 57  1.2393    MH  70      -.10685357E+05  .00000000E 00   .00000000E 00
 7  8 14 57  1.2393    BH  70      -.10985441E+05  .00000000E 00   .00000000E 00
 7  8 14 57  4.9992    MH  70      -.10482536E+05  .00000000E 00   .00000000E 00
 7  8 14 57  4.9992    BH  70      -.10789370E+05  .00000000E 00   .00000000E 00
 7  8 14 57  8.7592    MH  70      -.10275272E+05  .00000000E 00   .00000000E 00
 7  8 14 57  8.7592    BO  70      -.10406459E+05  .00000000E 00   .00000000E 00
 7  8 14 57  8.7592    BH  70      -.10588926E+05  .00000000E 00   .00000000E 00
 7  8 14 57 11.0885    MH  10       .55640412E+07  .00000000E 00   .00000000E 00
 7  8 14 57 12.5191    MH  70      -.10063541E+05  .00000000E 00   .00000000E 00
 7  8 14 57 12.5191    BH  70      -.10384057E+05  .00000000E 00   .00000000E 00
 7  8 14 57 16.2791    MH  70      -.98473123E+04  .00000000E 00   .00000000E 00
 7  8 14 57 16.2791    BO  70      -.99874485E+04  .00000000E 00   .00000000E 00
```

Figure 26 (cont.)

```
  7  8 16 49 16.3007     MH  70       -.15920201E+05  .00000000E 00  .00000000E 00
  7  8 16 49 19.6847     MH  70       -.15844733E+05  .00000000E 00  .00000000E 00
  7  8 16 49 19.6847     BD  70       -.15919783E+05  .00000000E 00  .00000000E 00
  7  8 16 49 23.4446     MH  70       -.15758649E+05  .00000000E 00  .00000000E 00
  7  8 16 49 23.4446     BD  70       -.15835988E+05  .00000000E 00  .00000000E 00
  7  8 16 49 27.2046     MH  70       -.15670155E+05  .00000000E 00  .00000000E 00
  7  8 16 49 27.2046     BD  70       -.15749923E+05  .00000000E 00  .00000000E 00
  7  8 16 49 27.5679     MH  10        .69524426E+07  .00000000E 00  .00000000E 00
  7  8 16 49 30.9645     MH  70       -.15579191E+05  .00000000E 00  .00000000E 00
  7  8 16 49 30.9645     BD  70       -.15661681E+05  .00000000E 00  .00000000E 00
  7  8 16 49 30.9645     BH  70       -.15745267E+05  .00000000E 00  .00000000E 00
  7  8 16 49 34.7245     MH  70       -.15485680E+05  .00000000E 00  .00000000E 00
  7  8 16 49 34.7245     BD  70       -.15570657E+05  .00000000E 00  .00000000E 00
  7  8 16 49 34.7245     BH  70       -.15655694E+05  .00000000E 00  .00000000E 00
  7  8 16 49 37.9204     MH  70       -.15404131E+05  .00000000E 00  .00000000E 00
  7  8 16 49 37.9204     BH  70       -.15577519E+05  .00000000E 00  .00000000E
  7  8 16 49 38.8477     MH  10        .67773553E+07  .00000000E 00  .00000000E
  7  8 16 49 42.5963     MH  70       -.15281319E+05  .00000000E 00  .00000000E 00
  7  8 16 49 42.5963     BD  70       -.15372063E+05  .00000000E 00  .00000000E 00
  7  8 16 49 42.5963     BH  70       -.15459887E+05  .00000000E 00  .00000000E 00
  7  8 16 49 47.0783     MH  70       -.15159574E+05  .00000000E 00  .00000000E 00
  7  8 16 49 47.0783     BD  70       -.15254576E+05  .00000000E 00  .00000000E 00
  7  8 16 49 49.4822     MH  70       -.15092622E+05  .00000000E 00  .00000000E 00
  7  8 16 49 49.4822     BD  70       -.15188788E+05  .00000000E 00  .00000000E 00
  7  8 16 49 50.1275     MH  10        .66055733E+07  .00000000E 00  .00000000E 00
  7  8 16 49 53.8062     MH  70       -.14969175E+05  .00000000E 00  .00000000E 00
  7  8 16 49 53.8062     BD  70       -.15068604E+05  .00000000E 00  .00000000E 00
  7  8 16 49 53.8062     BH  70       -.15160727E+05  .00000000E 00  .00000000E 00
  7  8 16 49 57.2841     MH  70       -.14866995E+05  .00000000E 00  .00000000E 00
  7  8 16 49 57.2841     BD  70       -.14969642E+05  .00000000E 00  .00000000E 00
  7  8 16 49 57.2841     BH  70       -.15062846E+05  .00000000E 00  .00000000E 00
  7  8 16 50   .8960     MH  70       -.14758099E+05  .00000000E 00  .00000000E 00
  7  8 16 50   .8960     BD  70       -.14863678E+05  .00000000E 00  .00000000E 00
  7  8 16 50   .8960     BH  70       -.14958410E+05  .00000000E 00  .00000000E 00
  7  8 16 50  1.4074     MH  10        .64373838E+07  .00000000E 00  .00000000E 00
  7  8 16 50  4.8040     MH  70       -.14636991E+05  .00000000E 00  .00000000E 00

PARAMETERS TO BE CORRECTED (4)

 ALPHA DELTA BETA  A      R      V      CDA/W GM     J2     J3  (5)

   1 ITERATIONS (MAXIMUM), (6)10 PARAMETERS (7)

(8)556 OBSERVATION TIMES, 1668 OBSERVATIONS, (9) 3 STATIONS, 3336 CELLS IN COMPACTED DATA LIST (11)
   4 FLOCKS (IF BCD INPUT)(12)                              (10)
                    OLD FUNCTION IS     1     NEW FUNCTION IS     2
                    CAME FROM SEGMENT   11  ARE IN SEGMENT    1     FUNCTION IS    2 )
                    OLD FUNCTION IS     1     NEW FUNCTION IS     2                  |
                    CAME FROM SEGMENT    1  ARE IN SEGMENT   62     FUNCTION IS    2 |
                    OLD FUNCTION IS     1     NEW FUNCTION IS     2                  } (13)
                                                                                     |
14.09.48 BEGIN EXECUTION                                                             |
                    CAME FROM SEGMENT   62  ARE IN SEGMENT    2     FUNCTION IS    2 )
```

Figure 27. Initial Information

```
END                                                                                          BASIC INPUT CARD    1


BOUNDS
 .150000E+01  .150000E+01  .300000E-00  .750000E+00  .492000E+04  .492000E+03  .150000E-00  .100000E-07  .100000E-07   (14)
 .100000F-07

                           SIGMA TABLE
101    .2296000E+02119    .6056000E-01201    .2296000E+02219    .6056000E-01301    .2296000E+02319    .6056000E-01        (15)

                                                INITIAL CONDITIONS

X    =         .20394186E+08          ALPHA=        .23114540E+02         A=         .24639581E+08
Y    =         .87049750E+07          DELTA=        .26515160E+02         E=         .60470640E-02
Z    =         .11063023E+08          BETA =        .89889770E+02         I=         .50150392E+02
XDOT=         -.13454234E+05          AZ   =        .45733120E+02         C=         .35850639E+03
YDOT=          .12760866E+05          R    =        .24780837E+08         U=         .23399700E+03
ZDOT=          .14863762E+05          V    =        .23765259E+05         T=         .83661994E+03

  ATMOSPHERE - LOCKHEED         CDA/W =  .28490000E-00     W/CDA =  .35100035E+01
                                D1    =  .68300000E+01     D2    = -.15684000E+02

                                                EARTH MODEL
GM=    .55304203E-02  J2=    .10826450E-02  J3=  -.25460000E-05  J4=  -.16490000E-05  J5=  -.21000000E-06
J6=    .64600000E-06  J7=  -.33300000E-06  J8=  -.27000000E-06  J9=  -.53000000E-07 J10=  -.54000000E-07
     J21=   .00000000E 00      L21=   .00000000E 00      J52=   .58460000E-07      L52=  -.24190000E+02
     J22=   .15664000E-05      L22=  -.15500000E+02      J53=   .22190000E-07      L53=   .58580000E+02
     J31=   .17287000E-05      L31=  -.14300000E+01      J54=   .16050000E-08      L54=   .32270000E+02
     J32=   .30250000E-06      L32=  -.32300000E+02      J55=   .10290000E-08      L55=  -.15790000E+02
     J33=   .19660000E-06      L33=   .32310000E+02      J61=   .95720000E-07      L61=   .99460000E+02
     J41=   .52340000E-06      L41=  -.13353000E+03      J62=   .29280000E-07      L62=  -.38870000E+02
     J42=   .13720000E-06      L42=   .35750000E+02      J63=   .10370000E-08      L63=   .00000000E 00
     J43=   .41660000E-07      L43=  -.27500000E+01      J64=   .15000000E-08      L64=  -.15960000E+02
     J44=   .93780000E-08      L44=   .26090000E+02      J65=   .38100000E-09      L65=  -.25280000E+02
     J51=   .12470000E-06      L51=  -.16413000E+03      J66=   .14000000E-09      L66=  -.16920000E+02

THE FOLLOWING BODIES ARE USED FOR PLANETARY PERTURBATICNS

NONE

FORMULATION
          COWELL (EQS.OF MOTION)

DIFFERENTIAL EQUATION SUBROUTINE
          GAUSS-JACKSON          E BAR=   .1000E-09      A= 1.000    RATIO OF COWELL STEP TO RUNGE KUTTA  4
STEP SIZE -      INITIAL=      .1000E+01    MINIMUM=      .1562E-01      MAXIMUM=     .6400E+02
 DO NOT RECOMPUTE PERTURBATIONS FOR CORRECTOR

EQUATIONS OF MOTION    USE N1 =10 N2= 6

VARIATIONAL EQUATIONS USE N1 =10 N2= 6 FOR V MATRIX
    NO T MATRIX

                                                CONSTANTS
                     DECIMAL            OCTAL                                      DECIMAL            OCTAL
OMEGA E             .43752690E-02   325340203260    GM                            .55304203E-02   416244532400
ALPHA G             .49787546E+01   752211125620
FT/KM               .33808399E+06   360353733760    EARTH RADIUS - FT             .209257 [illegible]
```

```
E.R./A.U.              .23454865E+05   565605075320   N.M./E.R.              .34439335E+04   737510377420
I-O, DISTANCE          .20925738E+08   452000000000   I-O, VELOCITY          .34876230E+06   223146314620
G                      .32174000E+02   132071260100   FT/SEC//E.R./MIN.      .34876230E+06   223146314620
DEG/SEC//RAD/MIN       .10471976E+01   444250714340   1/EPS.                 .29830000E+03   314631463140
RELATIVE MASS(SUN)     .33295130E+06   723146314620   (MOON)                 .12298530E-01   614043432460
(VENUS)                .81497900E+00   355337552020   (MARS)                 .10782100E-00   203232233700
(JUPITER)              .31788700E+03   422335136140   (SATURN)               .95129000E+02    30446722720


                CAME FROM SEGMENT    2  ARE IN SEGMENT   62     FUNCTION IS    2
                OLD FUNCTION IS    2     NEW FUNCTION IS    2

14,09.51 BEGIN EXECUTION
                CAME FROM SEGMENT   62  ARE IN SEGMENT    1     FUNCTION IS
                OLD FUNCTION IS    2     NEW FUNCTION IS    2

14.09.54 BEGIN EXECUTION
                CAME FROM SEGMENT    1  ARE IN SEGMENT   12     FUNCTION IS    2
```

Figure 27 (cont.)

```
COMPUTED VALUES FOR ITERATION    1    7/ 8/67    885.000   MIN.
 A,E,I,O,U,T          MEAN ANM= 161.33899          APOGEE= 4079.67530
 .24639581E+08        TRUE ANM= 161.55913              HT  =  640.21816
 .60470640E-02            ODOT=  -3.60450         PERIGEE= 4030.63175
 .50150392E+02            UDOT=   2.96157              HT  =  591.17461   (16)
 .35850639E+03                                   PERIOD(K)=  107.95173
 .23399700E+03                                   PERIOD(A)=  107.90175
 .83661994E+03                                   PERIOD(N)=  107.83470
                    CAME FROM SEGMENT   12  ARE IN SEGMENT    1     FUNCTION IS    2
                    OLD FUNCTION IS    2     NEW FUNCTION IS    2
                    CAME FROM SEGMENT    1  ARE IN SEGMENT   62     FUNCTION IS    2
                    OLD FUNCTION IS    2     NEW FUNCTION IS    2

14.09.58 BEGIN EXECUTION
14.10.02 BEGIN EXECUTION
                    CAME FROM SEGMENT   62  ARE IN SEGMENT   13     FUNCTION IS    2

14.10.03 BEGIN EXECUTION
                    CAME FROM SEGMENT   13  ARE IN SEGMENT   21     FUNCTION IS    2

ECI COORDINATES OF POSITION AND VELOCITY AT ALL NODAL CROSSINGS WITHIN THE DATA SPAN IN EARTH RADII UNITS

7/ 8/67  928.51826 MM
   -.11723811230828E+01  .33186605308784E-01 -.44360801643162E-07 -.88733583935479E-03 -.44075741531771E-01 -.52843125292297E-01
                                                                                                                                  (17)
7/ 8/67  982.07495 MM
    .11809264324098E+01 -.36221085592795E-01  .26694674803984E-07  .17022679758151E-02  .43732551948509E-01  .52457384687182E-01
                    CAME FROM SEGMENT   21  ARE IN SEGMENT   13     FUNCTION IS    2
                    OLD FUNCTION IS    0     NEW FUNCTION IS    2
                    CAME FROM SEGMENT   13  ARE IN SEGMENT   62     FUNCTION IS    2
                    OLD FUNCTION IS    2     NEW FUNCTION IS    2
14.11.38 BEGIN EXECUTION

14.11.40 BEGIN EXECUTION
                    CAME FROM SEGMENT   62  ARE IN SEGMENT   15     FUNCTION IS    2
```

Figure 28. Computed Values

```
RESIDUALS
         (18)                                                  (19)                                                                     (20)
MH    53596.7706   .3891E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145316.77
MH    53601.2185   .3951E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145321.22
MH    53605.5664   .4120E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145325.57
MH    53609.9604   .4274E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145329.96
MH    53614.4423   .4371E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145334.44
MH    53618.7262   .4348E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145338.73
MH    53622.5562   .4496E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145342.56
MH    53623.5395  -.5794E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145343.54
MH    53626.4341   .4828E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145346.43
MH    53630.2880   .4819E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145350.29
MH    53634.0480   .4846E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145354.05
MH    53637.9419   .5010E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145357.94
MH    53638.5792  -.5673E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145358.58
MH    53641.7558   .5114E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81454 1.76
MH    53645.5158   .5239E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81454 5.52
MH    53649.2757   .5442E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81454 9.28
MH    53650.9870  -.5803E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145410.99
MH    53653.0356   .5702E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145413.04
MH    53656.7956   .5701E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145416.80
MH    53660.5955   .5792E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145420.60
MH    53662.4548  -.5758E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145422.45
MH    53664.3555   .6088E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145424.36
MH    53668.1154   .6218E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145428.12
MH    53671.8753   .6270E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145431.88
MH    53674.1106  -.5688E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145434.11
MH    53675.6353   .6441E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145435.64
MH    53679.3952   .6740E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145439.40
MH    53683.1552   .6735E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145443.16
MH    53685.5784  -.5467E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145445.58
MH    53686.9151   .7016E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145446.92
MH    53690.6750   .7231E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145450.68
MH    53694.4350   .7363E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145454.43
MH    53696.8583  -.5535E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145456.86
MH    53698.1949   .4910E-00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145458.19
MH    53701.9549   .7748E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81455 1.95
MH    53705.7148   .7923E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81455 5.71
MH    53708.1381  -.5311E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     81455 8.14
MH    53709.4747   .8181E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81455 9.47
MH    53713.2347   .8452E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145513.23
MH    53716.9946   .8565E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145516.99
MH    53719.4179  -.5311E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145519.42
MH    53720.7546   .8807E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145520.75
MH    53724.5145   .9055E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145524.51
MH    53728.2745   .9252E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145528.27
MH    53730.8858  -.5280E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145530.89
MH    53732.0344   .9530E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145532.03
MH    53735.7943   .9685E+00(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145535.79
MH    53739.5543   .1002E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145539.55
MH    53742.3536  -.5180E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145542.35
MH    53743.3142   .1036E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145543.31
MH    53747.0742   .1051E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145547.07
MH    53750.8341   .1076E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145550.83
MH    53753.6334  -.4995E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145553.63
MH    53754.5941   .1102E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145554.59
MH    53758.3540   .1131E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145558.35
MH    53762.1140   .1160E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81456 2.11
MH    53764.9133  -.4823E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     81456 4.91
MH    53765.8739   .1183E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81456 5.87
MH    53769.6339   .1214E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     81456 9.63
MH    53773.3938   .1243E+01(RD)   .0000E 00(PD)   .0000E 00(CD)   .0000E 00     .0000E 00     .0000E 00     8145613.39
MH    53776.1931  -.4780E+03(R)    .0000E 00(A)    .0000E 00(E)    .0000E 00     .0000E 00     .0000E 00     8145616.19
```

Figure 29. Residual Output

```
STAT   N       RMS         TYPE      N        RMS         TYPE      N        RMS         TYPE
             RMS/SIG                        RMS/SIG                        RMS/SIG

MH    206   .161216E+01   (RD)      63    .393518E+03   (R)  ⎫
            .266209E+02                   .171393E+02        ⎪
                                                             ⎪
BD    116   .196791E+01   (RC)      26    .268186E+03   (R)  ⎬  (21)
            .324953E+02                   .116806E+02        ⎪
                                                             ⎪
BH    119   .202287E+01   (RD)      26    .268868E+03   (R)  ⎪
            .334027E+02                   .117103E+02        ⎭
```

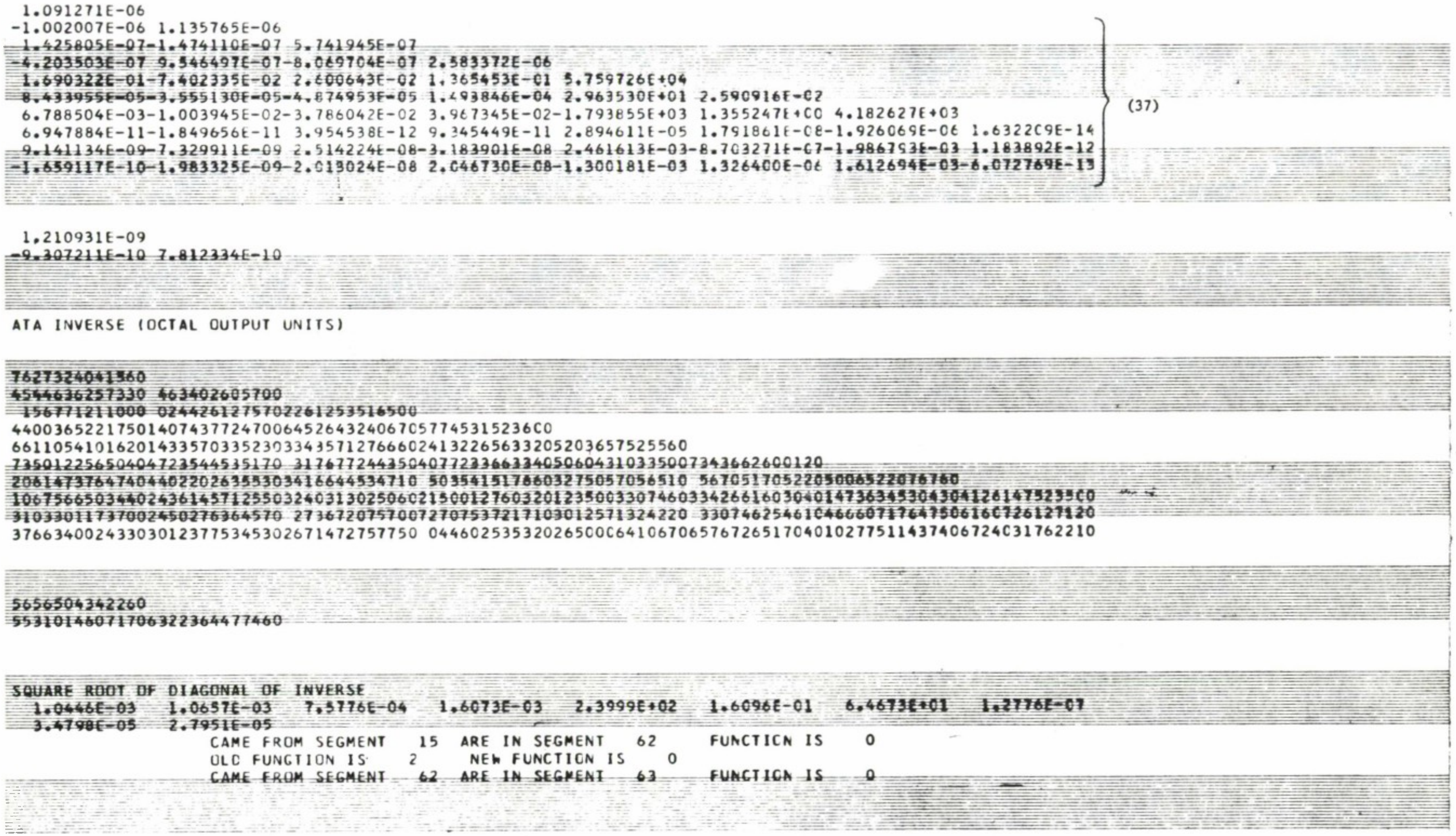
Figure 30. RMS Summary

Figure 31. Results of Iterations

```
ITERATION      1   (22)
  556 DATA POINTS WERE USED IN THE SOLUTION - (23)
CURRENT SOLUTION IS BEST SO FAR  (24)

CURRENT SOLUTION IS

      ALPHA               DELTA               BETA                A                   R                   V
     .23114540E+02       .26515160E+02       .89889770E+02       .45733120E+02       .24780837E+08       .23765259E+05
(25)
      CDA/W               GM                  J2                  J3
     .28490000E-00       .55304203E-02       .10826450E-02      -.25460000E-05


CURRENT SOLUTION (OCTAL MACHINE UNITS)
          747215545733221420            766361054213543440            544320637766672260
          146126322171017100            513624612320204100           1705615702466762520
(26)      710736323265026060           3732470416244532400           4706747423362016360
        11325333744653222010

****  RMS=      .27708293E+02  FOR THIS SOLUTION  (27)
CORRECTIONS
     .25207767E-02      -.48463704E-04      -.85928347E-04       .49035265E-03       .60568054E+02       .21986359E-01  (28)
    -.99368143E-01       .66223787E-08      -.47399442E-09      -.47709546E-09

BOUNDS
     .15000000E+01       .15000000E+01       .30000000E-00       .75000000E+00       .49200000E+04       .49200000E+03  (29)
     .15000000E-00       .10000000E-07       .10000000E-07       .10000000E-07

HITTING BOUNDS    (30)

NEXT SOLUTION IS
     .23117061E+02       .26515112E+02       .89889684E+02       .45733610E+02       .24780897E+08       .23765281E+05  (31)
     .18993186E-00       .55304269E-02       .10826445E-02      -.25464771E-05


NEXT SOLUTION (OCTAL MACHINE UNITS)
          747223356341216200            766360763404357700            544320606644204560
          146126761316752460            513624672757153540           1705615723417225540
         1336774040257223140           3732470452607342040           4706747413250565300  (32)
        11325344111322167510

****  PREDICTED RMS=      .80560426E+00  FOR NEXT SOLUTION   (33)
SIGMA(PARAMETERS)/SIGMA(NORMALIZED DATA)

          1                   2                   3                   4                   5                   6
      ALPHA               DELTA               BETA                A                   R                   V
     .10446393E-02       .10657229E-02       .75775623E-03       .16072872E-02       .23999429E+03       .16096322E-00
                                                                                                                         (34)
          7                   8                   9                   10
      CDA/W               GM                  J2                  J3
     .64677230E+02       .12775792E-06       .24798432E-04       .27950557E-04

CORRELATION MATRIX
```

```
                1          2          3          4          5          6          7          8          9          10
   1          1.000
   2          -.900      1.000
   3           .180      -.183      1.000
   4          -.250       .557      -.663      1.000
   5           .574      -.289       .143       .354      1.000
   6           .502      -.207      -.400       .577       .767      1.000                                                       }
   7           .100      -.146      -.773       .382      -.116       .130      1.000                                            }
   8           .521      -.136       .041       .455       .944       .871      -.233      1.000                                 } (35)
   9           .251      -.198       .953      -.569       .295      -.155      -.883       .266      1.000                      }
  10          -.006      -.067      -.950       .456      -.194       .295       .892      -.170      -.957      1.000           }

 SCATTER COEFFICIENT = .49796E-25

ATA AT         .10100801E+04  MIN.

    ALPHA         DELTA          BETA            A             R             V           CDA/W          GM
8.739871E+10 7.162304E+10 6.797189E+10-9.163661E+C9-4.445279E+05 9.811838E+06 3.489418E+C5 6.385007E+14 }
             6.462455E+10 3.844057E+10-1.553297E+10-3.116567E+05 2.937087E+C7 2.957622E+05 4.599958E+14 }
                          1.214932E+11 1.969401E+10-4.184874E+05 5.819339E+07 2.266678E+04 3.933732E+14 }
                                       1.293515E+10-9.916563E+03-1.011060E+07-8.899696E+04-3.780274E+13 }
                                                    1.226783E+01 1.008336E+04-2.119903E+01-3.226412E+10 }      (36)
                                                                 1.049446E+C7-2.035551E+C4-2.988893E+13 }
                                                                              4.149645E+01 6.077923E+10 }
                                                                                           9.037485E+19 }

     J2           J3
-1.047626E+12-3.663519E+10
-1.012544E+12-4.510847E+11
-6.702075E+11 1.391875E+12
 3.210844E+11 6.647128E+11
-3.448647E+07-3.051625E+07
-4.084022E+10-2.906415E+10
 7.430841E+07 5.313188E+07
 1.081604E+17 8.312186E+16
 1.788363E+14 1.272090E+14
              1.223409E+14

ATA (OCTAL OUTPUT UNITS)


2747006111000 4162623172207030603046360445731320365057725406313107374217524620156073001766055C4264625260
              6613720304520362210423734054560762140105055102517010476640251246022126202515006437550545640
                             434704660346032550534502006731556621130536506566142054376467704202527657522760
                                           7525102256400220147135005064106244347102365711721225066424765601210
                                                                 1014651031540535010642016074715516152702734374443210
                                                                              17742345522007015613410170 364742744250
                                                                                                42740605373003454C43405120
                                                                                                             63764541547C0
3311763252310202250150703O
 25267640331053723533016l0
3365301322630106643236342O
4177210553140376171421374O
6142520046310203344672051O
4213614735230336320544101O
3315653304120646604656712O
1521341542740734365431170O
6444443626600423364303550O
              1331061516240

ATA INVERSE
```

Figure 31 (cont.)



```
 1.091271E-06
-1.002007E-06 1.135765E-06
 1.425805E-07-1.474110E-07 5.741945E-07
-4.203503E-07 9.546497E-07-8.069704E-07 2.583372E-06
 1.690322E-01-7.402335E-02 2.600643E-02 1.365453E-01 5.759726E+04
 8.433955E-05-3.555130E-05-4.874953E-05 1.493846E-04 2.963530E+01 2.590916E-02
 6.788504E-03-1.003945E-02-3.786042E-02 3.967345E-02-1.793855E+03 1.355247E+00 4.182627E+03      (37)
 6.947884E-11-1.849656E-11 3.954538E-12 9.345449E-11 2.894611E-05 1.791861E-08-1.926069E-06 1.632209E-14
 9.141134E-09-7.329911E-09 2.514224E-08-3.183901E-08 2.461613E-03-8.703271E-07-1.986793E-03 1.183892E-12
-1.659117E-10-1.983325E-09-2.013024E-08 2.046730E-08-1.300181E-03 1.326400E-06 1.612694E-03-6.072769E-13


 1.210931E-09
-9.307211E-10 7.812334E-10

ATA INVERSE (OCTAL OUTPUT UNITS)


7627324041360
4544636257330 463402605700
 156771211000 0244261275702261253516500
44003652217501407437724700645264324067057745315236C0
66110541016201433570335230334357127666024132265633205203657525560
73501225650404723544535170 317677244350407723366334050604310335007343662600120
206147376474044022026355303416644534710 5035415178603275057056510 56705170522050006522076760
106756650344024361457125503240313025060215001276032012350033074603342661603040147363453043041261475235C0
31033011737002450276364570 27367207570072707537217103012571324220 3307462546104666071764750616C726127120
3766340024330301237753453026714727577 50 04460253532026500C6410670657672651704010277511437406724C31762210


5656504342260
553101460717063223644774 60


SQUARE ROOT OF DIAGONAL OF INVERSE
  1.0446E-03   1.0657E-03   7.5776E-04   1.6073E-03   2.3999E+02   1.6096E-01   6.4673E+01   1.2776E-07
  3.4798E-05   2.7951E-05
                    CAME FROM SEGMENT   15  ARE IN SEGMENT   62     FUNCTICN IS    0
                    OLD FUNCTION IS    2     NEW FUNCTION IS    0
                    CAME FROM SEGMENT   62  ARE IN SEGMENT   63     FUNCTICN IS    0
```

Figure 31 (cont.)

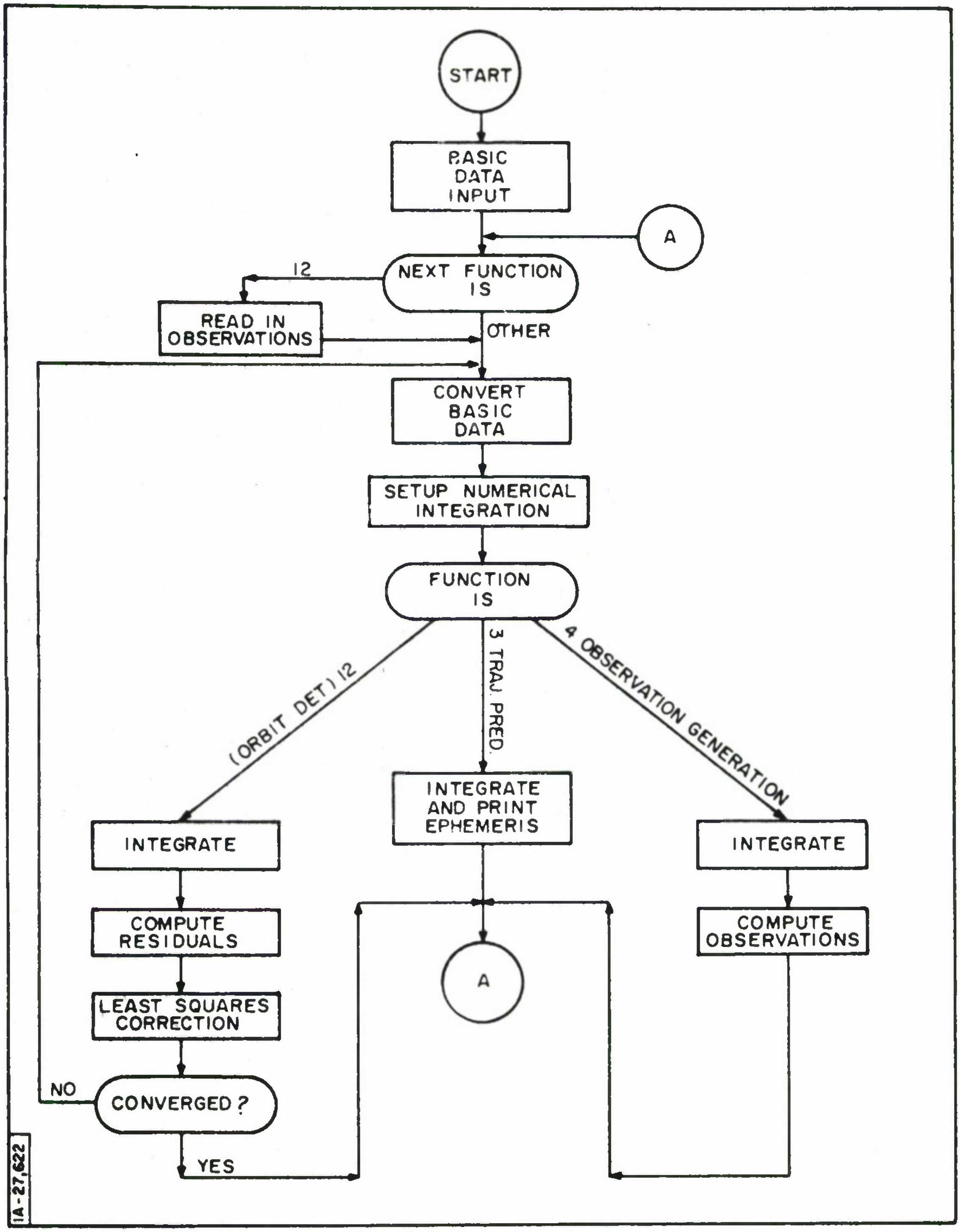


Figure 32. General TRACE-D Flow Chart

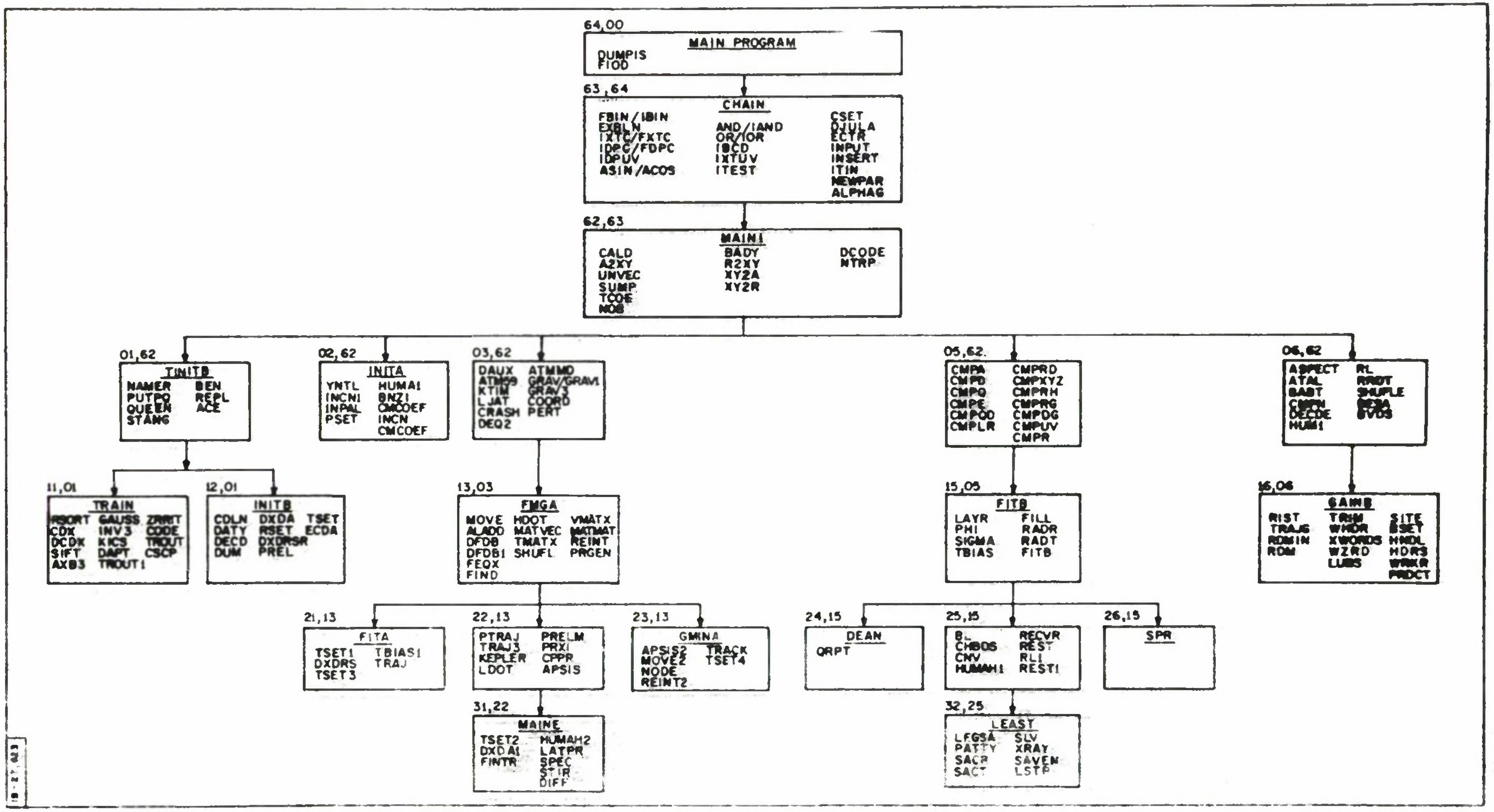


Figure 33. TRACE-D Segmentation Flow Chart

Section 5.

Programming Information

5.1 Structures and Flowcharts

Figures 32 and 33 are both flowcharts of the TRACE-D program; however, each is geared to a different level of description. Figure 32 depicts program paths determined by the function to be performed with only basic operations considered, while Figure 33 presents pertinent programming details also.

Since the TRACE-D program is extremely large (approximately 22,000 source language cards) and can not be fully contained in core, the segmentation mode of operation is employed whereby the program becomes several coreloads. Figure 33 shows the levels of segmentation employed and the makeup of each and every segment. The fact that only the segments along a single vertical path are in core at any one point in time solves the storage program.

The number appearing outside each segment block in Figure 33 serves to identify its level and position in the structure. Those subroutine names underlined are the control programs, which among other things, transfer control to the proper segments for each major function.

5.2 Tape Usage

The TRACE-D program employs many tapes to handle input-output data as well as intermediate calculations. The tape requirements for each option consists of a basic set common to all functions (listed in Table 11) plus a unique option-dependent set. All of the possible option-dependent tapes are listed in Tables 12, 13, 14 and those that are mandatory are appropriately marked. Please note that no more than five tapes from Table 14 may be used in one run (in addition to the basic set, of course).

The above description has been included for completeness; however, as previously mentioned, the user may obtain a running deck for any option he wishes to choose which will set up all appropriate tapes for him.

Table 11.

Basic Set of Tapes

TAPE NUMBER	NAME	FUNCTION
	LIB1	Program tape #1
	LIB2	Program tape #2
2		System Input Tape
3		System Output Tape
4	PTAPE*	Necessary Scratch Tape
3		Necessary Scratch Tape

* This is a necessary input quantity for all runs.

Table 12.

Trajectory Prediction Tapes

TAPE NUMBER	NAME	FUNCTION
7	CTAPE	Planetary Coordinate Tape
17	NTAPE	Binary trajectory tape (nominal) for trajectory differencing (program generated).
19	DTAPE	Binary difference tape for trajectory differencing.
15		A binary trajectory tape generated by the program and saved.

Table 13.

Observation Generation Tapes

TAPE NUMBER	NAME	FUNCTION
11	ETAPE	BCD tape of observations program generated.
7	CTAPE	Planetary tape
10	IFLAG(16)*	Scratch tape (for trajectory)

* Necessary tape for this option.

Table 14.

Orbit Determination Tapes

TAPE NUMBER	NAME	FUNCTION
11	IBCDI	BCD tape of observations
12	IBINI	Binary tape of compacted observations
7	CTAPE	Planetary coordinate tape
9*		Scratch tape (for normal matrix)
5*		Necessary scratch tape
10*		Scratch tape (trajectory)

* Necessary tapes for this option

5.3 Subroutines

This section is devoted to a complete listing of every subroutine in TRACE-D with a functional description and other pertinent facts also given. In some cases two or more routines are identical in function and differ only slightly in name. This is due to the segmentation rule that the same routine name cannot appear in more than one logical path (i.e., one complete coreload). Therefore, since some routines were needed in more than one path only the names were changed not the content. The routines are listed alphabetically in Table 15 and the information given is self-explanatory.

Table 15.

Subroutine Listing

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
A2XY	62	x	x	x	INCN, INCN1, KICS, ISET	BADY	Converts orbital elements to cartesian coordinates	312
ACE	01	x			TRAIN DUM	QUEEN	Sets up the code lists for all radar parameters	1212
ALADD	13	x	x	x	TRACK, TRAJ, TRAJ3,		Adds longitude independent terms to the variational equations for alpha	141
ALPHAG	63	x	x	x			Computes right ascension at Greenwich at 0 hours of given Julian date	133
AND	63	x	x	x			Logical "AND" function for two variables	14
APSIS	22	x	x		TRAJ, TRAJ3	CALD, NTRP, SHUFL	Interpolates for and prints latitude, longitude and altitude when BETA = 90°	503

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	USED IN TRAJPRE	USED IN DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
APSIS2	23			x	TRACK	NTRP	Same as APSIS	422
ASIN/ ACOS	63		x		PTRAJ		Computes arcsine and arccosine	141
ASPECT	05			x	SITE	XY2R	Computes aspect angles	471
ATAL	05			x	BABT		Finds I, J elements of matrix	116
ATM59	03	x	x	x	ATMMD, LJAT		Computes atmospheric density	543
ATMMD	03	x	x	x	PERT	ATM59, LJAT	Channels density evaluation to appropriate routine	115
AXB3	11	x			INV3		Solves the system AX=B using Cramer's Rule	205
BABT	06				SITE		Computes BABT where B and A appropriate matrices	241
BADY	62				A2XY		Computes solution of two-body problem	1000
BEN	01	x			NAMER		Performs data coding	401
BL	25	x			REST, REST1		Finds I, J element of matrix in special format	111

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
BNZI	02	x			INCN		Converts and prints bounds and sigmas	251
BSET	16			x	HNDL		Sets up headings and labels	341
BVDS	06			x	HNDL	IDPC, AND	Builds variable data formats	203
CALD	62				INITB, HNDL, PTRAJ, ORPT, RADT, TRAJ, WZRD		Computes complete date from Julian date	216
CDLN	12	x	x	x	DUM	IXTUV, ITIN	Computes data location from BCD name	210
CDX	11	x			RSORT	IDPUV	Packs data into one word	100
CHAIN	63	x	x	x	MAIN1	INPUT, CSET, DJULA, ALPHAG NEWPAR, ITIN	Control program for segment 63	607
CHBDS	25	x			LEAST		Modifies bounds for orbit determination	120
CMCOEF	02	x			INITA		Computes coefficients for dynamic station location constraints	1031

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPREN	DATAGEN				
CMPA	05	x			RADR	PHI	Computes azimuth partials and residual	456
CMPA	05	x			RADR		Computes topocentric declination partials and residual	623
CMPDG	05	x			RADR		Computes geocentric declination partials and residuals	364
CMPE	05	x			RADR	PHI, CMPR	Computes elevation partials and residuals	626
CMPLR	05	x			RADR		Computes little residuals and partials	451
CMPN	06			x	SITE		Computes noise	136
CMPQ	05	x			SITE	CMPR, FILL	Computes P and O partials and residuals	476
CMPQD	05	x			SITE	CMPRD, FILL	Computes $\dot{P}$ and $\dot{O}$ partials and residuals	500
CMPR	05	x			SITE		Computes range partials and residuals	530

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTIONS	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
CMPRD	05	x			SITE	PHI	Computes range rate partials and residuals	734
CMPRG	05	x			SITE		Computes right ascension partials and residuals	340
CMPRH	05	x			SITE		Computes topocentric RA, HA partials and residuals	636
CMPUV	05	x			SITE		Computes U, V partials and residuals	606
CMPXYZ	05	x			SITE		Computes X, Y, Z partials and residuals	514
CNV	25	x			LEAST		Checks for convergence in orbit determination mode	144
CODE	11	x			CSCP	IDPUV	Packs data into one word	142
COORD	03	x	x	x	PERT		Reads JPL tape and performs interpolation	606
CPPR	22		x		TRAJ3	DIFF, PRXI, PRELM, PTRAJ	Controls output during trajectory prediction	143

Table 15 (cont.)

NAME	SEGMENT NU NUMBER	USED IN ORBDET	USED IN TRAJPRE	USED IN DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTIONS	ROUTINE SIZE
CRASH	03	x	x	x	TRACK, TRAJ, TRAJ3	NTRP, HDOT	Tests for vehicle below critical altitude	447
CSCP	11	x			TRAIN	TCDE, DCDX, REPL, IDPC	Compacts and codes data	1174
CSET	63	x	x	x	CHAIN, TSET		Sets up some constants	135
DAPT	11	x			SIFT	TCDE	Prints deleted observations	217
DATY	12	x	x	x	DUM	DECD	Prints data types used in partial generation	276
DAUX	03	x	x	x		MOVE, PERT, MATVEC, GRAV2	Computes derivatives for equations of motion and variational equations	270
DCDX	11				CSCP, RSORT, TROUT	IXTUV	Decodes a data word coded by CDX	107
DCODE	62	x	x	x	KICS, SUMP	IXTUV	Decodes words coded by CODE	141
DECDE	06			x	DATY	IXTUV	Decodes packed data word	133

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	USED IN TRAJPRE	USED IN DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTIONS	ROUTINE SIZE
DECD	12	x	x	x	SITE, HDRS	IXTUV	Same as DECDE	133
DESA	06			x	GAINB	PRDCT	Keeps simulation list current	273
DEQ2	03	x	x	x	TRAJ, TSET	DAUX	Performs integration	1472
DFDB	13	x	x		PERT	NOB, DFDB1 MATVEC	Computes non-homogeneous terms for variational equations	376
DFDB1	13	x	x		DFDB		Same as DFDB	723
DIFF	31	x	x		CPPR	HUMAH2		750
DJULA	63	x	x	x	TROUT, CHAIN, INCN, INCN1		Computes Julian date	177
DUM	12	x	x	x	INITB	ACE, DATY, ITEST, REPL, CDLN, ECDA, PUTPQ	Reads station data and stores it	1045
DXDA1	31		x		TRAJ3		Computes partials of pos and vel wrt orbital elements	355
DXDA	12	x	x		TSET		Same as DXDA1	355
DXDRSR	12	x			TSET		Computes partials of pos and vel wrt spherical coordinates	342

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
DXDRS	21	x			TSET3		Same as DXDRSR	342
ECDA	12	x	x	x	DUM	IDPU, IXTC	Codes an array	155
ECTR	63	x	x	x	CHAIN, INCN1	ITEST	Codes an array	253
EXBLN	63	x	x	x	INPUT		Extract routine	123
FBIN	63	x	x	x	INPUT		Conversion routine	305
FDPC	63	x	x	x	INPUT		Deposit routine	35
FEQX	13	x					Generates a matrix	183
FILL	15	x			RADR, CMPQ CMPQD	IXTUV, UTRD	Fills a list for partials computation	533
FIND	13	x	x	x	PERT		Performs linear interpolation	242
FINTR	31		x		MAINE		Used to end a trajectory run	360
FIOD	64	x	x	x			Sets up appropriate magnetic tapes	14000
FITA	21	x			FMGA	ISET1, ITIN TSET3, TRAJ TBIAS1	Control routine for segment 21	1472
FITB	15	x			MAIN1	NTRP, LEAST	Control routine for segment 15	663
FMGA	13	x	x	x	MAIN1	FITA, GAINA MAINE	Control routine for segment 13	202

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAPRE	DATAGEN				
FXTC	63	x	x	x	INPUT		Extract character routine	35
GAINA	23			x	FMGA	TRACK	Control routine for segment 23	1266
GAINB	06			x	MAIN1	RIST, SITE, TRAJG, HNDL, WZRP, DESA, ITIN	Control routine for segment 06	320
GAUSS	11	x			KICS		Determines elliptic elements given 2 points	652
GRAV GRAV1 GRAV3	13	x	x	x	DAUX, PERT, TSET2, TSET4		Computes acceleration components due to geopotential	470
HDOT	13	x	x	x	CRASH, SITR		Computes $\dot{H}$ and $\ddot{H}$ for minimum and maximum altitude interpolation	301
HDRS	16			x	HNDL	DECDE	Sets up page headers for observations	410
HNDL	16			x	GAING, TRAJG	BSET, BVDS, CALD, HDRS, WHDR	Controls observation output	1351

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPREE	DATAGEN				
HUM1	06			x	SITE		Input-output conversion	474
HUMA1	02	x	x	x	BNZI		Input-output conversion	474
HUMAH1	25	x			XRAY, LSTP		Input-output conversion	474
HUMAH2	31		x		DIFF, PRXI		Input-output conversion	327
1AND	63	x	x	x	INPUT		Logical and function	
1BCD	63	x	x	x	INPUT		Conversion routine	
IBIN	63	x	x	x	INPUT		Conversion routine	
1DPC	63	x	x	x	INPUT		Conversion routine	
1DPUV	63	x	x	x	INPUT		Deposit routines	
INCN	02	x	x	x	INITA	BNZI, R2XY, XY2R, NOB, INPUT, A2XY, ALPHAG	Initializes input	766
INCN1	02	x	x	x	INCN	NEWPAR, NOB, ECTR, INPAL, XY2R, YNTL, DJULA	Initializes input	1245

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	 TRAJPREE	 DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
INITA	02	x	x	x	MAIN1	INCN	Control routine for segment 02	525
INITB	12	x	x	x	INITB	DUM, TCDE, CALD, PREL, REST, NAMER	Control routine for segment 12	360
INPAL	02	x	x	x	INITA		Checks for incorrect input	261
INPUT	63	x	x	x	CHAIN	IXTC, IBIN, FBIN	Reads in and stores all input	1662
INSERT	63	x	x	x	INPUT	INPUV	Inserts character information words	102
INV3	11	x	x	x	TROUT1	AXB3	Computes noise	108
IOR	63	x	x	x	INPUT		Logical function	
ITEST	63	x	x	x	INPUT		Tests for certain character configurations	117
ITIN	63	x	x	x	CHAIN		Checks the next function code in list and sets indicator	106
IXTC	63	x	x	x	INPUT		Extract routine for characters	
IXTUV	63	x	x	x	INPUT		Extract routine	
KEPLER	22		x		TRAJ3		Solves Keplers equation	160

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	 TRAJPRE	 FATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
KICS	11	x			TRAIN	SUMP, A2XY, DCODE, GAUSS, STRANG	Computes initial conditions from 2 R, A, E sets	505
KTIM	03	x	x	x	TRACK, TRAJ TRAJ3		Tests for orbit adjusts times	
LATPR	31		x		STIR	NTRP, LDOT	Latitude print routine	
LAYR	15	x			RADR		Accumulates ATA matrix and residuals	
LDOT	22		x		LATPR		Computes longitude and rate of longitude	163
LEAST	32	x			FITB	SAVEN, SLV, LSTP. RECVR, TCDE, ITIN, SIGMA, SACR, SACT, PATTY, CNV	Control routine for segment 32	578
LEGSA	32	x			SLV		Solves AX=B in least squares sense	1355
LJAT	03	x	x	x	ATMMD	ATM59	Compute density for Lockheed Jacchia	564

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPREE	DATAGEN				
LSTP	32	x			LEAST	HUMAH1	Controls output for least squares	1125
LUBS	16			x	SITE		Checks data generation indicators	155
MAIN1	62	x	x	x	MAIN Prog	INITA,FITB, TINITB, FMGA, GAINB	Control routine for segment 62	516
MAINE	31		x		FMGA	ITIN, FINTR SPEC, TSET2 TRAJ3	Control routine for segment 32	1322
MATMAT	13	x	x	x	DAUX, DFDB DFDB1		Computes AB+C	114
MATVEC	13	x	x	x	REINT, REINT2		Computes matrix times vector product	111
MOVE	13	x	x	x	DAUX, TRAJ TRAJ3, TSET2		Moves data from one array to another	267
MOVE2	23			x	TRACK, TSET4		Same as MOVE	236
NAMER	01	x	x	x	TRAIN, INITB,		Finds list of names for output	230
NEWPAR	63	x	x	x	CHAIN, INCN1	INSERT	Decodes parameter list	561

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	USED IN TRAJPRE	USED IN DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
NOB	62	x	x	x	DFDB, INCN, INCN1, SACT		Finds correct geopotential coefficient	141
NODE	23			x	TRACK	NTRP	Interpolates for nodal crossings	252
NTRP	62	x	x	x	CRASH, FILL, FITB, TRAJ, TRAJ3, TRAJG		Interpolation routine	371
OR	63	x	x	x	INPUT		Logical or function	
PATTY	32	x			LEAST	XRAY	Prints ATA and inverse	1231
PERT	03	x	x	x	DAUX	ATMMD, COORD, DFDB. FEQX, GRAV, TMATX VMATX	Computes perturbative accelerations	641
PHI	15	x			CMPA, CMPE CMPRD		Computes station coordinate quantities	126
PRDCT	16			x	DESA	TRAJG, XY2A, IXTUV	Predicts rise and set times	571
PREL	12	x	x	x	INITB	XY2A	Computes and prints elements	427
PRELM	22		x		CPPR		Generates print times	345
PRGEN	13	x	x	x	TRAJ, TRAJ3 TSET2			

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
PRXI	22		x		CPPR	HUMAH2	Prints partial derivatives	262
PSET	03	x	x	x	INITA		Dummy routine	50
PTRAT	22		x		CPPR	CALD, SPEC, XY2R, ITEST	Prints trajectory	1216
PUTPQ	01	x			TRAIN, DUM		Sets up station codes	115
QUEEN	01	x			ACE		Sets up code list for parameters	140
R2XY	62	x	x	x	INCN, TSET TSET3		Converts spherical to cartesian coordinates	257
RADR	15	x			FITB	SUMP, CMPA, CMPRG, TCDE FILL, CMPE, CMPQ, SIGMA	Controls partial and residual computation	1233
RADT	15	x			RADR	CALD, ITEST	Residual output routine	741
RDM	16			x	GAINB		Random number generators	10
RDMIN	16			x	RDM			10
RECVR	25	x			LEAST		Recovers old matrix from tape	135
REINT	13	x	x		TRAJ TRAJ3	MATVEC	Reinitializes for thrusts and kicks	456

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
REINT2	23			x	TRACK		Same as REINT	540
REPL	01	x			CSCP, DUM TRAIN		Replaces word by an integer	153
REST	25	x			SLV		Prepares bounds and ATA for constraints	153
REST1	25	x			SLV		Modifies solution for constraints	250
RIST	16			x	GAINB	NTRP, WRKK, IXTUV	Checks for vehicle visibility	630
RLI	25	x			REST1		Finds I, J element of inverse matrix	103
RL	06			x	BABT		Same as RL1	103
RKDT	06			x	SITE		Computes range and range rate for station N	224
RSET	12	x	x	x	INITB	STANG	Computes stored quantities for RADR	125
RSORT	11	x			TRAIN	CDX, BCDX	Sorts data	317
SACR	32	x			LEAST	TCDE	Corrects radar parameters	244
SACT	32	x			LEAST	NOB	Corrects trajectory parameters	233

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
SAVEN	32	x			LEAST		Saves old matrix on tape	135
SHUFLE	06			x	TRAJG		Shuffles two data list	116
SHUFL	13	x	x		TRAJ3, TSET2			117
SIFT	11	x			TRAIN	IXTUV, DAPT	Second difference editing routine	522
SIGMA	15	x			A2XY, BADY, ASPECT		Finds correct sigma for station L	157
SITE	16			x	GAINB	BABT, LUBS, RRDT, WZRD, CMPN, HUM1, ASPECT, DECDE, WRKR REST1, REST LEGSA	Decodes parameter words for data generation	2443
SLV	32	x			LEAST		Solves normal equations	204
SPEC	31				MAINE, CPPR		Write special trajectory tape	340
STANG	01	x			KICS, PSET, TRAIN		Computes station data	137
STIR	31		x		TRAJ3		Interpolates for special trajectory print times	266
SUMP	62	x	x	x	KICS, RADR	DCODE	Codes data words	237
TBIAS	15	x			FITB	SUMP, IXTUV	Computes time bias for each station	217

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
TBIAS1	21	x			FITA	SUMP, IXTUV	Same as TBIAS	217
TCDE	62	x	x	x	FILL, NAMER		Decodes date	101
TINITB	01	x			MAIN1	INITB, TRAIN	Control routine for segment 01	227
TMATX	13	x	x		PERT		Calculates T matrix for variational equations	236
TRAIN	11	x			TINTB	KICS, SIFT, ACE, PUTPQ, REPL, TROUT RSORT, INPUT, STANG, ZRRIT	Control routine for segment 11	1330
TRACK	23	x			GAINA		Generates trajectory tape for data generation	453
TRAJ3	31		x		MAINE	MOVE, NTRP, APSIS, KTIM, CPPR, SHUFL, STIR, DEQ2, PRGEN, CRASH, TSET2 DXDA1	Controls integration in trajectory prediction mode	1010

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN ORBDET	USED IN TRAJPRE	USED IN DATAGEN	CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
TRAJ	21	x			FITA	NTRP, MOVE CALL, REINT KTIM, TSET1 CRASH, ALADD, PRGEN,	Controls integration in orbit determination mode	1033
TRAJG	16			x	GAINB, PRDCT	TRIM, NTRP, SHUFLE	Reads trajectory from tape for data generation	267
TRIM	16			x	TRAJG		Computes yaw, roll and pitch corrections	152
TROUT	11	x			TRAIN	TCDE, EXIT, DCDX, IXTUV TROUT1, DJULA, ALPHAG, INV3	Tracking data output routine	1047
TROUT1	11	x			TROUT		Tracking covariance matrix setup and output routine	313
TSET	12	x	x	x	INITB	CSET, DXDA, A2XY, XY2A, DXDRSR, R2XY	Initializes integration	514

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPREE	DATAGEN				
TSET1	21	x			FITA, TRAJ	DAUX, DEQ2, GRAV1, MOVE, PRGEN, SHUFL	Initializes integration for orbit determination	403
TSET2	31		x		MAINE, TRAJ3	DAUX, DEQ2, MOVE, GRAV1 SHUFL	Initializes integration for trajectory prediction	344
TSET3	21	x			FITA	R2XY, DXDRS	Initializes integration for multiple vehicles	262
TSET4	23			x	TRACK	DAUX, DEQ2, GRAV1, MOVE2	Initializes integration for data generation	331
UNVEC	62	x	x	x	TRAJ, RADT		Computes unit vector	
VMATX	03	x			PERT	MATMAT	Calculates matrix for variational equations	263
WHDR	16			x	HNDL		Writes header page	255
WRKR	16			x	RIST, SITE		Controlled output routine	172
WZRD	16			x	GAINB, TRAJG, SITE	CALD, IXTUV	Data generation routine	
XRAY	32	x			PATTY	HUMAH1	Converts units of ATA	172

Table 15 (cont.)

NAME	SEGMENT NUMBER	USED IN			CALLED BY SUBROUTINES	CALLS SUBROUTINES	FUNCTION	ROUTINE SIZE
		ORBDET	TRAJPRE	DATAGEN				
XY2A	62	x	x	x	DIFF, INCN, PRDCT		Converts rectangular coordinates to elliptical	412
XY2R	62	x	x	x	DIFF, INCN,		Converts rectangular coordinates to spherical	225
YNTL	02	x	x	x	INCN1		Output initial conditions and constants	3713
ZRRIT	11	x			TRAIN	SUMP	Sets up sigmas for zero residuals	240

5.4 Variable Lists

In this section are listed several variable arrays used in the TRACE-D program. These particular variables were chosen because they are the most important and critical storage areas of TRACE-D. They contain all of the indicators and input that dictate the logical program flow.

Table 16. NUMB ARRAY

NUMB	NUMBER OF	SET IN	INPUT NAME
1	RADAR STATIONS	TRAIN	
2	OBSERVATION TIMES	TRAIN	
	OR STATIONS REQUIRING SIGHTING EPHEMERIS DATA	DUM	
	OR STATIONS REQUIRING SIMULATION DATA	DUM	
3	WORDS IN COMPACTED RADAR OBSERVATION LIST - TOTAL	TRAIN	
4	WORDS OF COMPACTED RADAR OBSERVATIONS IN CORE NOW	TRAIN	
5	DIFFERENTIAL EQUATION PARAMETERS TO BE SOLVED FOR	CHAIN	
6	INITIAL CONDITION PARAMETERS TO BE SOLVED FOR	CHAIN	
7	RADAR STATION PARAMETERS TO BE SOLVED FOR	KING	
8	RADAR OBSERVATION PARAMETERS TO BE SOLVED FOR	KING	
9	PROGRAM TAPE UNIT	CHAIN	- PTAPE
10	MAXIMUM ITERATIONS ALLOWED	CHAIN	- MAXIT
11	TOTAL PARAMETERS (SUM OF 5,6,7 AND 8)	TRAIN	
12	TRAJECTORY PARAMETERS (SUM OF 5 AND 6)	TRAIN	
13	OBSERVATIONS (TOTAL NUMBER OF MEASUREMENTS)	TRAIN	
14	PRESENT ITERATION		
15	BASIC TYPES OF OBSERVATIONS	CHAIN	
16	SIZE OF BUFFERS IN DEAN (Q DATA) - IF = 0, SET TO 5000	DEAN	
17	TOTAL RADAR PARAMETERS (SUM OF 7 AND 8)	TRAIN	
18	TAPE UNIT FOR PLANETARY COORDINATE TAPE	CHAIN	- CTAPE
19	SECOND ORDER DIFFERENTIAL EQUATIONS BEING INTEGRATED (3*(1+NUMB(12)*IFLAG(8)))	INCN	
20	POSSIBLE KINDS OF RADAR PARAMETERS (LAT, LONG, HEIGHT, AND BIASES)	CHAIN	
21	WORDS IN CORE FOR SIGHTING EPHEMERIS BUCKET	CHAIN	
22	POSSIBLE KINDS OF SIGHTING DATA	CHAIN	
23	DATA NOISE CONTROL (ZERO FOR NO NOISE, NON-ZERO STARTS RANDOM NUMBER GENERATORS FOR DATA NOISE)	CHAIN	- NOISE
24	POSITION IN ITIN LIST OF FUNCTION BEING EXECUTED	ITIN	
25	EFFECTIVE PARAMETERS BEING SOLVED FOR (NUMB(11)-(NO. OF CONSTRAINTS))	CHAIN	- KNST
26	TAPE UNIT FOR GENERATING BCD STATION AND OBSERVATION TAPE (IF ZERO, NO TAPE GENERATED)	CHAIN	- ETAPE

Table 16 (cont.)

27	FLOCKS OF DATA	TRAIN
28	TAPE UNIT FOR ECLIPSE COORD TAPE	CHAIN
29	CURRENT PASS THRU DUM - 0 FOR 1ST PASS, 1 FOR REST	CHAIN
30	ELEMENTS IN ATA	MAIN
31	TAPE UNIT FOR NOMINAL TRAJ. FOR DIFFERENCING RUN	INPAL - NTAPE
32	TAPE UNIT FOR DIFFERENCED TRAJ. FOR DIFFERENCING RUN (LOGICAL NO.)	INPAL - DTAPE
33	MAXUMUM NUMBER OF 2ND DIFFERENCE EDITOR ITERATIONS	
34	NUMBER OF 3 COLUMN PARAMETERS	
35	NOT USED	
36		
37		
38		
39		
40		
41		
42	CONVERSION CONSTANT FOR DISTANCES GENERATED IN GAIN. MUST BE INPUT = 3443.9336 NM/ER OR 6975.246 KYD/ER	
43	LOGICAL TAPE NUMBER FOR ANOTHER COMPACTED DATA TAPE TO BE GENERATED IN TRAIN	
44	INDICATOR FOR FIXED BASELINE STATION LOCATION CONSTRAINTS - 1 IF OPTION BEING USED	
45	NOT USED	
46	NON-ZERO INDICATES SPECIAL TRAJECTORY TAPE GENERATION	TTAPE
47-50	NOT USED	

Table 17. IFLAG ARRAY

IFLAG - OPTION INDICATORS		INPUT NAME
1	CURRENT FUNCTION BEING EXECUTED = 1, } ORBIT DETERMINATION = 2, } = 3, TRAJECTORY = 4, GAIN	
2	RESTORE (1) LAST GOOD SOLUTION OR CORRECT (0) PRESENT SOLUTION	
3	CURRENT LINK BEING EXECUTED	
4	REASON FOR EXIT FROM MAIN (1-MAXIMUM NUMBER OF ITERATIONS. 2-CONVERGED, 3-TRAJECTORY COMPLETED)	
5	CORRECTIONS ARE HITTING BOUNDS (1) OR NOT (0)	
6	= 0, COMPLETE SIGHTING EPHEMERIS PRINTED = 1, ONLY RISE, SET, MAXIMUM ELEVATION TIMES PRINTED = 2, ALL DATA, EXCEPT THAT AT RISE, SET, ETC., SAVED ON TAPE	
7	ZERO, REGULAR RESIDUAL PRINTING NEGATIVE, AT ITERATION = MAXIT, SORTED RESIDUALS ARE PRINTED AFTER THE REGULAR RESIDUAL PRINTING POSITIVE, AT ITERATION = MAXIT, ONLY SORTED RESIDUALS ARE PRINTED. NO RESIDUALS ARE PRINTED PRIOR TO THIS. USED ONLY WHEN RESIDUAL PRINTING INDICATED IN THE PRCDE. (PRCDE(2))	
8	ANALYTIC TRAJECTORY PARTIALS (0) OR VARIATIONAL EQUATIONS (1)	PARTL
9	BOUNDS PROVIDED FOR LEAST SQUARES SOLUTION (1) OR NO BOUNDS (0)	
10	NOT USED	
11	T-MATRIX OPTION IF=0, NO T-MATRIX =1, INPUT DRHODH*H/RHO, NO EARTH FLATTENING =2, INPUT DRHODH*H/RHO, USE EARTH FLATTENING =3, CALC. DRHODH*H/RHO, NO EARTH FLATTENING =4, CALC, DRHODH*H/RHO,USE EARTH FLATTENING	TMATX
12	PARAMETER SPECIFYING SEQUENCE OF FUNCTIONS TO BE	ITIN
13	PERFORMED	
14	USED IN GAIN. IF = 0, SORT OUTPUT -- NON-ZERO, DO NOT SORT USED IN SUBROUTINE FINTR IN MAIN	
15	TRAJECTORY COMPARISON OPTION IF IDIFF = 0, REGULAR TRAJECTORY = 1, WRITE PRESENT TRAJECTORY AS REFERENCE ON NTAPE = 2, 1ST COMPARISON, DIFFERENCES WRITTEN ON DTAPE	IDIFF

Table 17 (cont.)

	= 3, OTHER THAN FIRST OR LAST COMPARISON CASES = 4, FOR ONE AND ONLY COMPARISON CASE = 5, LAST COMPARISON	
16	FORTRAN LOGICAL UNIT FOR TRAJECTORY TAPE WRITTEN BY FIT A AND GAIN A.	
17	SET NON-ZERO IN TSET IF TO IS A PARAMETER	
18	NON-ZERO, ACCUMULATE ATA IN DOUBLE PRECISION (FOR ATA LESS THAN 2746)	
19	IF SET NON-ZERO SIGMA TABLE WEIGHTING VALUES WILL BE USED EVEN IF VARIANCE/COVARIANCE MATRICES ARE INCLUDED IN DATA DECK	
20	IF NON-ZERO, OPERATE IN 3 PTS./PASS MODE	
21	OPTION INDICATOR FOR 2ND DIFFERENCE EDITOR, CONTROLS EDITING OF FIRST 2 AND LAST 2 POINTS	
22 23 24	NOT USED	
25	SET IN TSET IF ALPHA PARTIALS ARE TO BE COMPUTED.	
26	AFTER COMPLETING FIT A CALL FIT B (0) OR DO NEXT FUNCTION (1).	
27	NOT USED	
28	INDICATOR FOR RESPECIFICATION OF GEOPOTENTIAL COEFFICIENTS 0 = RESPECIFICATION	
29	NUMBER OF ORBIT ADJUSTS IN SPECIAL TABLE (DELV)	IDLV

Table 18. CNDT ARRAY

CNDT - PARAMETER LIST. CODES ARE IN ITRCD

1-6	INITIAL CONDITIONS	
7	T-ZERO	
8	CDA/W	
9	GM	
10-18	J2-J10	
19-38	J21-J66	ORDERED J21, J31, J41,...,J56, J66
39-58	LAMBDA21-LAMBDA66	SAME
59	ASUBE ' EARTH RADIUS	
60	OMEGASUBA - ATMOSPHERE ROTATION RATE	
61	T1 THRUST (T1*EXPF(-T2*T)	
62	T2	
68-75	ICS, TO, AND DRAG FOR SATELLITE NO. 2	
80-87	ICS, TO, AND DRAG FOR SATELLITE NO. 3	
92-99	ICS, TO, AND DRAG FOR SATELLITE NO. 4	
104-111	ICS, TO, AND DRAG FOR SATELLITE NO. 5	
116-123	ICS, TO, AND DRAG FOR SATELLITE NO. 6	
124-129 130-135 136-153	NOT USED	
154	K-ZERO -- TELEMETRY DATA	
155	K-ONE -- TELEMETRY DATA	

Table 19. KIND ARRAY

KIND - MISCELLANEOUS FIXED POINT INPUT		INPUT NAME
1	UNIT FOR INPUT BCD RADAR DATA TAPE	IBCDI
2	UNIT FOR INPUT BINARY COMPACTED RADAR DATA TAPE	IBINI
3	USED INTERNALLY	
4	EPOCH DATE - YEAR	YEAR
5	- MONTH	MONTH
6	- DAY	DAY
7	PRCDE - OUTPUT CONTROL	PRCDE
8	PARAMETER	
9	FLOCK FLAG	

Table 20. TREG ARRAY

USE OF TREG FOR INTEGRATION (COW)

TREG CELL	CONTENTS
(K+3)	NEQ (SET IN COW AT B = 35)
(K+2)	CURRENT TIME IN MINUTES FROM MIDNIGHT OF EPOCH
(K+1)	CURRENT INTEGRATION STEP SIZE
(K)-(K-2)	X
(K-3I)-(K-3I-2)	X(PI)
(K-NEQ)-(K-NEQ-2)	X-DOT
(K-NEQ-3I)-(K-NEQ-3I-2)	X-DOT(PI)
(K-2NEQ)-(K-2NEQ-2)	X-DBL. DOT
(K-2NEQ-3I)-(K-2NEQ-3I-2)	X-DBL. DOT(PI)

WHERE --- NEQ = 3(N+1)
N = TOTAL NUMBER OF I.C. AND D. E. PARAMETERS FOR THE CURRENT RUN
K = L-3 (CURRENTLY = 5490)
L = DIMENSION OF TREG = 90(M+1)+3
M = MAXIMUM NUMBER OF I.C. AND D.E. PARAMETERS (CURRENTLY = 60)

Table 21. TEMP ARRAY

USE OF TEMP FOR INTEGRATION (DAUX AND PERT)

(1)	T	
(2)-(4)	X	
(5)-(7)	PSI(P1)	
(3K+2)-(3K+4)	PSI(PK)	
(185)	DELTA-T	
(186)-(188)	X-DOT	
(189)-(191)	PSI-DOT(P1)	
(3K+186)-(3K+188)	PSI-DOT(PK)	
(369)-(371)	X-DOUBLE DOT	
(372)-(374)	PSI-DOUBLE DOT(P1)	
(3K+369)-(3K+371)	PSI-DOUBLE DOT(PK)	
(552)		
(553)	R	
(554)	R**2	
(555)	R**3	
(556)	R**5	
(557)	R	GRAV CALLING SEQUENCE
(558)	SIN(PHI)	GRAV CALLING SEQUENCE
(559)	COS(PHI)	GRAV CALLING SEQUENCE
(560)	SIN(ALPHA(G))	GRAV CALLING SEQUENCE
(561)	COS(ALPHA(G))	GRAV CALLING SEQUENCE
(562)	SIN(ALPHA)	GRAV CALLING SEQUENCE
(563)	COS(ALPHA)	GRAV CALLING SEQUENCE
(564-566)	F(1)	GRAV CALLING SEQUENCE
(567-569)	GLH	GRAV CALLING SEQUENCE
(570-578)	ROT MATRIX	GRAV CALLING SEQUENCE
(579)	U POTENTIAL	GRAV CALLING SEQUENCE
(580-588)	A	GRAV CALLING SEQUENCE
(589-608)	B	GRAV CALLING SEQUENCE
(609-628)	C	GRAV CALLING SEQUENCE
(629-637)	D	GRAV CALLING SEQUENCE
(638-657)	E	GRAV CALLING SEQUENCE

Table 21 (cont.)

(658-677)	SIN(M(LAMBDA-LAMBDA(MN)))	GRAV CALLING SEQUENCE
(678-697)	COS(M(LAMBDA-LAMBDA(MN)))	GRAV CALLING SEQUENCE
(698-706)	DFDX(1) V-MATRIX	
(707-715)	DFDX(2) T-MATRIX	
(716-724)	DFDXD U-MATRIX	
(725-727)	DF/DX*(PSI(PK))	
(728-730)	DF/DXDOT*(PSI-DOT(PK))	
(731-910)	DF/DB	
(916)	RHO (DENSITY)	
(917)	A (VEL OF SOUND)	
(918)	H (ALTITUDE)	
(919)		
(920)	M (MACH NUMBER)	
(921-923)	X-DOT(A)	
(924)	D/V(A) = RHO/2*V(A)*CDA/W	
(925-927)	F(3)	
(928)	ABSF(X-DOT) = V(A)	
(935-937)	F(4) THRUST FORCE	
(938-943)	ABSF(X(J))**3	
(944-949)	ABSF(X-X(J))	
(950-955)	ABSF(X-X(J))**3	
(956-961)	ABSF(X-X(J))**5	
(962-964)	X-X(1)	
(965-967)	X-X(2)	
(968-970)	X-X(3)	
(971-973)	X-X(4)	
(974-976)	X-X(5)	
(977-979)	X-X(6)	
(980-982)	F(2)	
(983-1000)	INTERPOLATED VELOCITIES OF OTHER BODIES	

Table 22. STAT ARRAY

STAT--PROPERTIES RELATED TO THE LTH STATION

CELL	DESCRIPTION	UNITS
(1,L) ---	GEODETIC LATITUDE	(RADIANS)
(2,L) ---	EAST LONGITUDE	(RADIANS)
(3,1) ---	ALTITUDE	(EARTH RADII)
(4,L) ---	COS (LAT)	
(5,L) ---	SIN (LAT)	
(6,L) ---	W1	(EARTH RADII)
(7,L) ---	W3	(EARTH RADII)
(8,L) ---	SIGMA SET	
(9,L) ---	REFRACTIVITY TYPE	
(10.L) ---	STATION NAME	
	Q STATION NUMBER	
	P STATION NUMBER	
(11,L) ---	(NOT USED)	

Table 23. COMMON LAYOUT

COMMON A - BLOCKS NEEDED FOR ALL LINKS - 8722 CELLS

ALPH	1	ITEMP	45
AUS	1	ITRCD	62
C	100	KIND	10
CC	3,6	NUMB	50
CO	56	PARINT	50
C1	56	PKICK	50
CNDT	160	PRTIM	21
CPRAM	2	PUSH	200
DAVE	100	REFR	15
DPRAM	40	SIS	1
DRAG	120	SUSP	1
ELL	20	TRAJX	367
FIC	10	TRJN1	552
FLEE	100	TUMP	100
HEAD	24	XTRA	50
IDTAPE	17	TEMP	1000
IFLAG	30	TREG	5493

COMMON B - BLOCKS NEEDED FOR FIT AND DATA GENERATION LINKS - 4300 CELLS

GOK	1800	PBIAS	100
BIAS	100	RPRAM	200
DPAR	100	SIGGY	100
ICDLC	100	SIGMY	100
IPRCD	500	STAT	11,100
ISIG	100		

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13. ABSTRACT

This report describes the MITRE version of the TRACE-D program now in operation. While the primary function of TRACE-D is orbit determination, options are also available in the program for trajectory prediction and observational data generation. A functional description of these features is contained in this report along with a complete user's manual and a brief program description.

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
PROGRAMMING						
ORBIT DETERMINATION						
TRAJECTORY PREDICTION						
OBSERVATIONAL DATA GENERATION						
SATELLITE TRACKING						

Security Classification