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ESD-TDR-64-394

ESPOD OPERATING INSTRUCTIONS AND CARD FORMATS

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-394

JUNE 24, 1964

496L Systems Program Office
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

PROJECT ES-3-496L-3627

Prepared under Contract AF 19(628)-594

STL NO. 8497-6066-RU-000

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FOREWORD

This document is one of three reports which describe ESPOD, a general satellite orbit determination program prepared for the Air Force Electronic Systems Division for use in the SPACETRACK/SPADATS Center at Ent Air Force Base, Colorado Springs, Colorado.

This report is

ESD-TDR-64-394	ESPOD Operating Instructions and Card Formats (STL No. 8497-6066-RU000)

The companion reports are

ESD-TDR-64-393	ESPOD Functional Description (STL No. 8497-6067-RU000)
ESD-TDR-64-395	ESPOD Mathematical and Subroutine Description (STL No. 8497-6065-RU000)

The ESPOD Program was prepared by TRW Space Technology Laboratories under Air Force Contract Number AF 19(628)-594.

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ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

TABLES

1. INTRODUCTION

This report provides operating instructions and other aids pertinent to the ESPOD program. The sections are arranged in the order that they will be used to set up and run the ESPOD program.

a) Input Control Card Descriptions and Deck Setup
b) Operational Instructions
c) Output Descriptions
d) Program Constants

The operator or analyst, making frequent use of this report, will find the following features useful.

a) Card formats are exact full scale size with unused or blank areas cross hatched.

b) A separate listing of titles for preliminary data cards.

c) Tables providing diagnostic assistance in card usage and program options.

For an abridged technical description of the ESPOD Program, ESD-TDR-64-393, "ESPOD Functional Description," may be consulted.

The mathematical and computer processes for the ESPOD Program are described in ESD-TDR-64-395, "ESPOD Mathematical and Subroutine Description."

2. INPUT INSTRUCTIONS AND CARD FORMAT

This section is concerned with the detailed description of the ESPOD input quantities. The first part of the section describes the card format, content, and groupings of the B2 systems cards, the ESPOD program control cards, and the program option cards. The standard SPADATS system observations cards and sensor cards which ESPOD uses are also described.

The second part of this section is concerned with the input sequence. Sample ESPOD load sheets with the corresponding input decks are described. The various categories of the input cards are functionally grouped and tabulated as to input mode to aid the analyst in preparing an ESPOD run. There is also a complete tabulation of the program response to omitted or included cards, or both.

2.1 INPUT CONTROL CARD DESCRIPTION

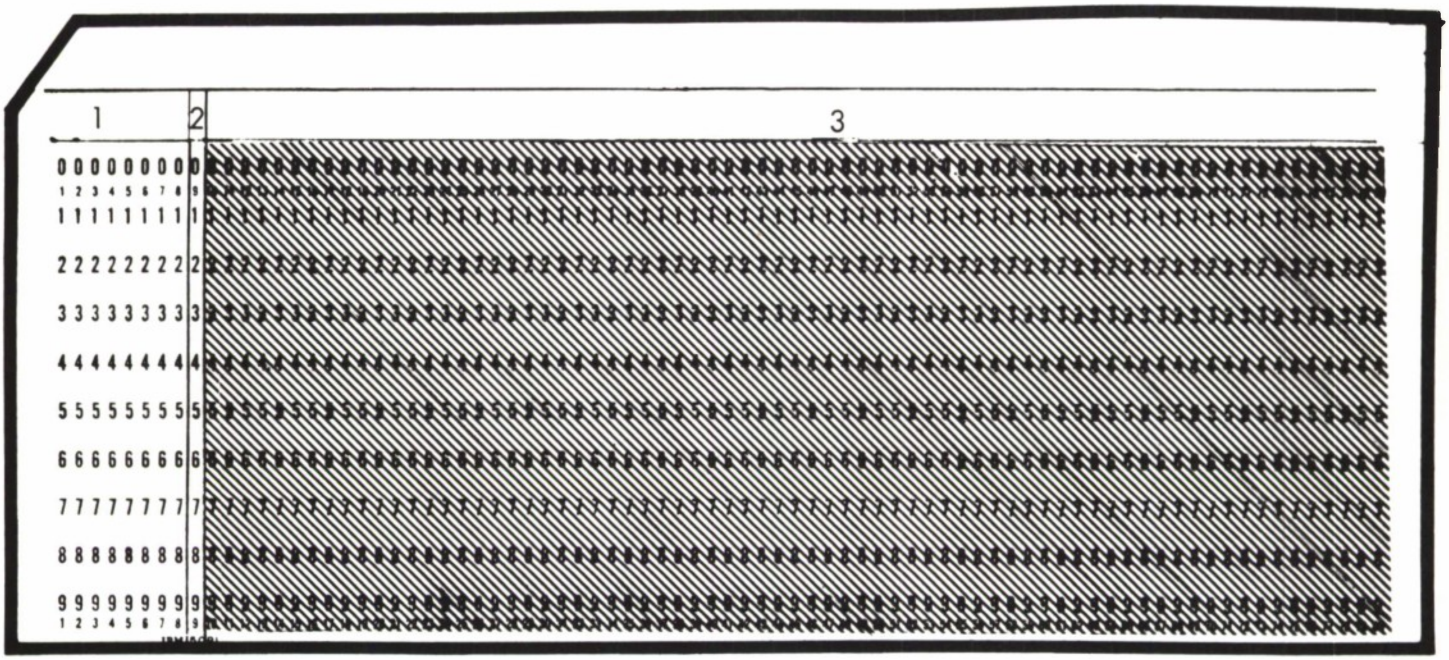
Cards for input to ESPOD fall into six classes and are listed below in their normal input sequence:

1) B2 System Job Start Cards
2) Job Description Card, JDC
3) Preliminary Data
4) Observation Cards
5) Sensor Cards
6) B2 System Job Finish Cards

All classes are not necessarily needed for a particular run. This will be discussed at length in Section 2.2.

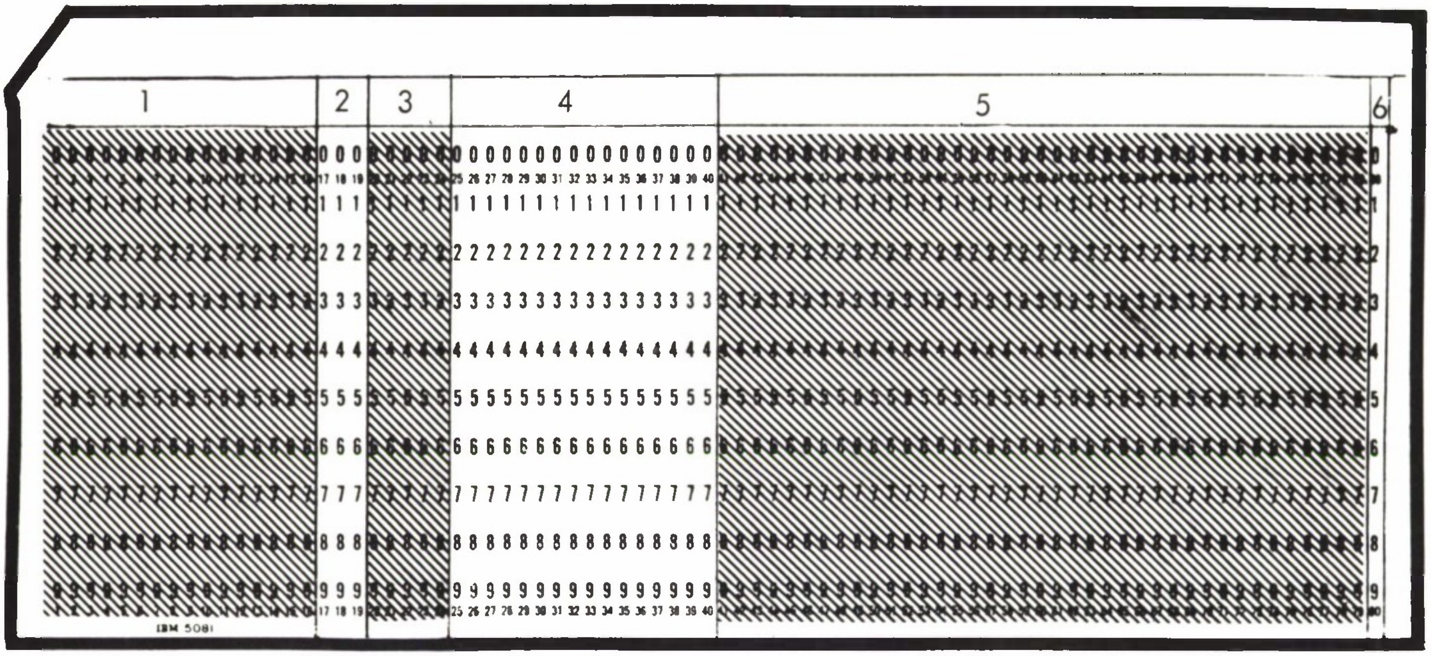
2.1.1 B2 System Inputs

There are two types of input cards which must be used with ESPOD inputs when running in the scheduled mode. The Job Start and Job Finish input cards are described on the following pages.



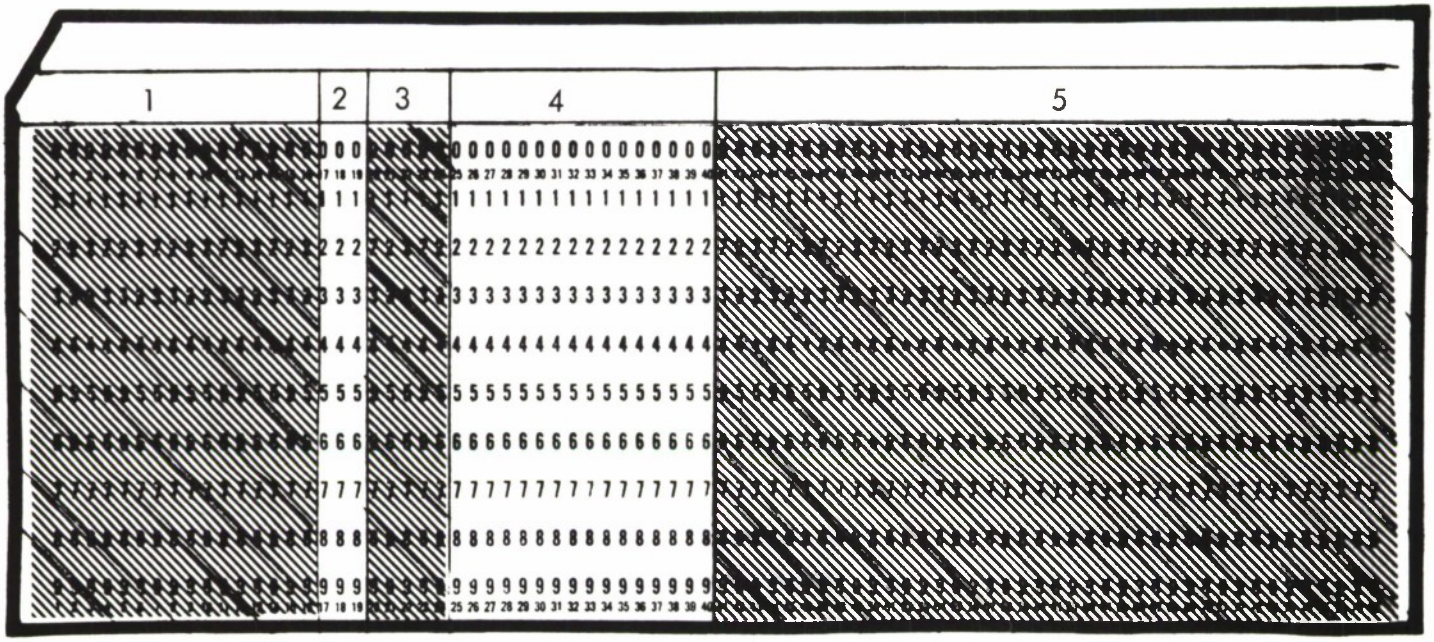
Field	Column	Content	Description
1	1-8	70 ΔSCHTP	
2	9	11-8-2	11-8-2 multipunch
3	10-80		Not used

Figure 2-1. 70 SCHTP Card Format



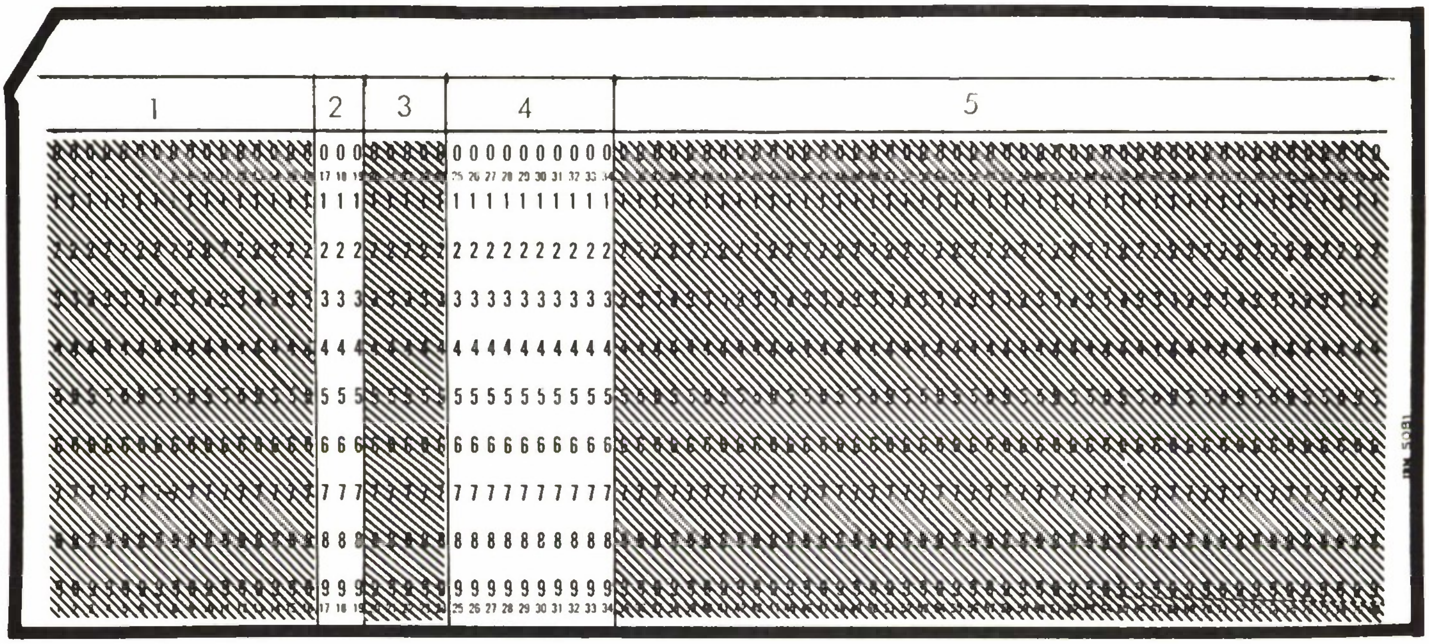
Field	Column	Content	Description
1	1-16		Not used
2	17-19	JOB	
3	20-24		Not used
4	25-40	NNNN	Job number
5	41-79		Not used
6	80	J	

Figure 2-2. SPADATS Job Card Format



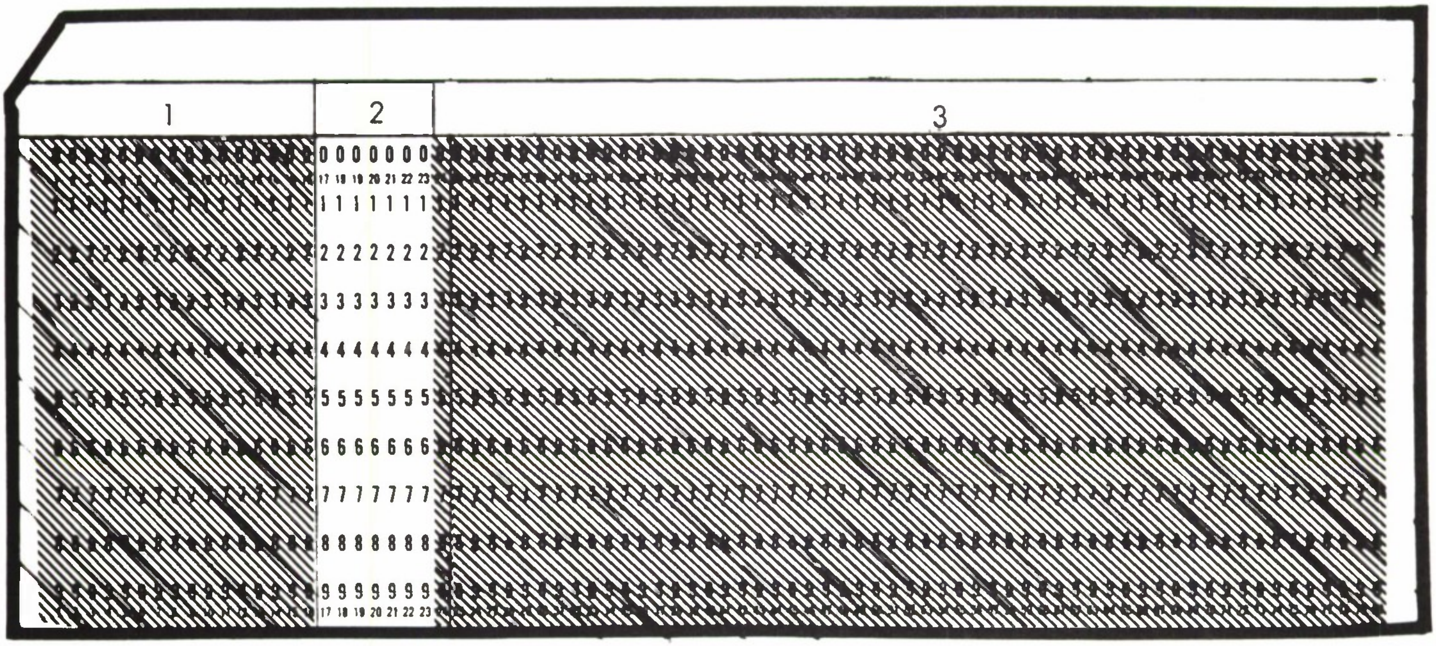
Field	Column	Content	Description
1	1-16		Not used
2	17-19	REM	
3	20-24		Not used
4	25-40	XXXX	Arbitrary remark
5	41-80		Not used

Figure 2-3. SPADATS Remarks Card Format



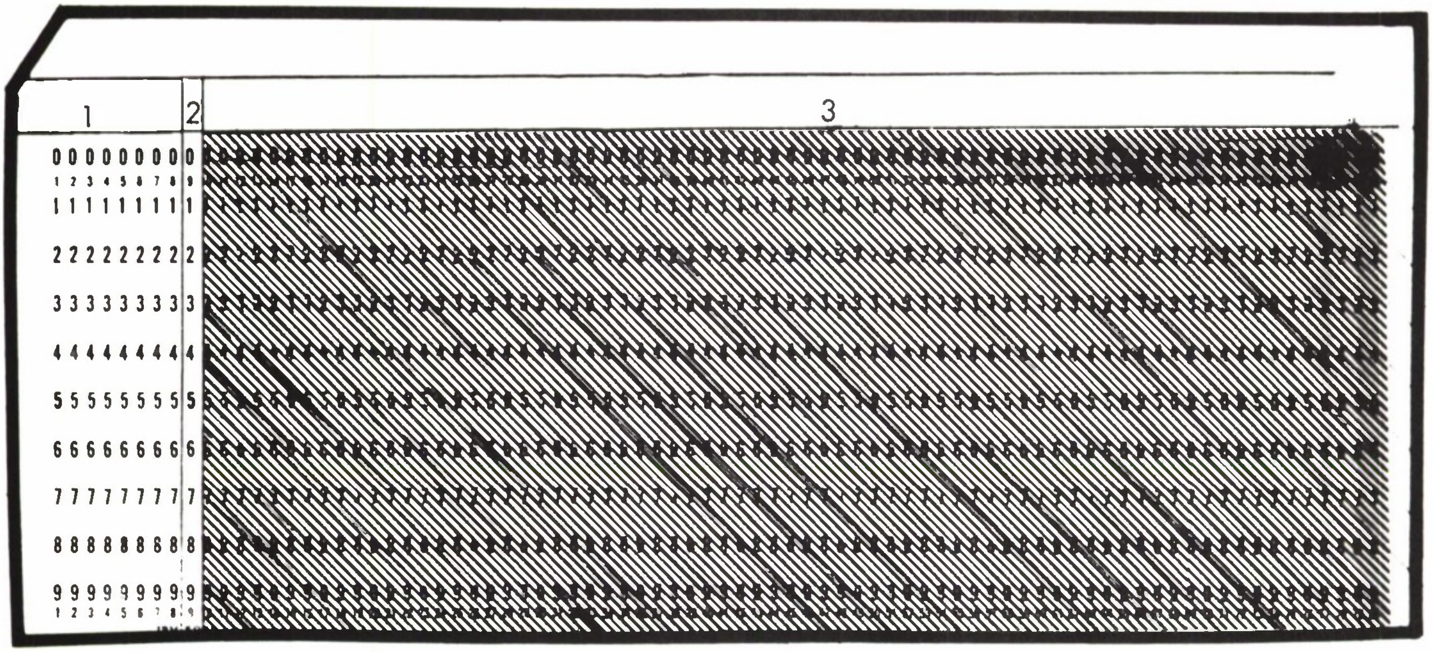
Field	Column	Content	Description
1	1-16		Not used
2	17-19	RUN	
3	20-24		Not used
4	25-34	ESPOD, DATA	
5	35-80		Not used

Figure 2-4. RUN Card Format



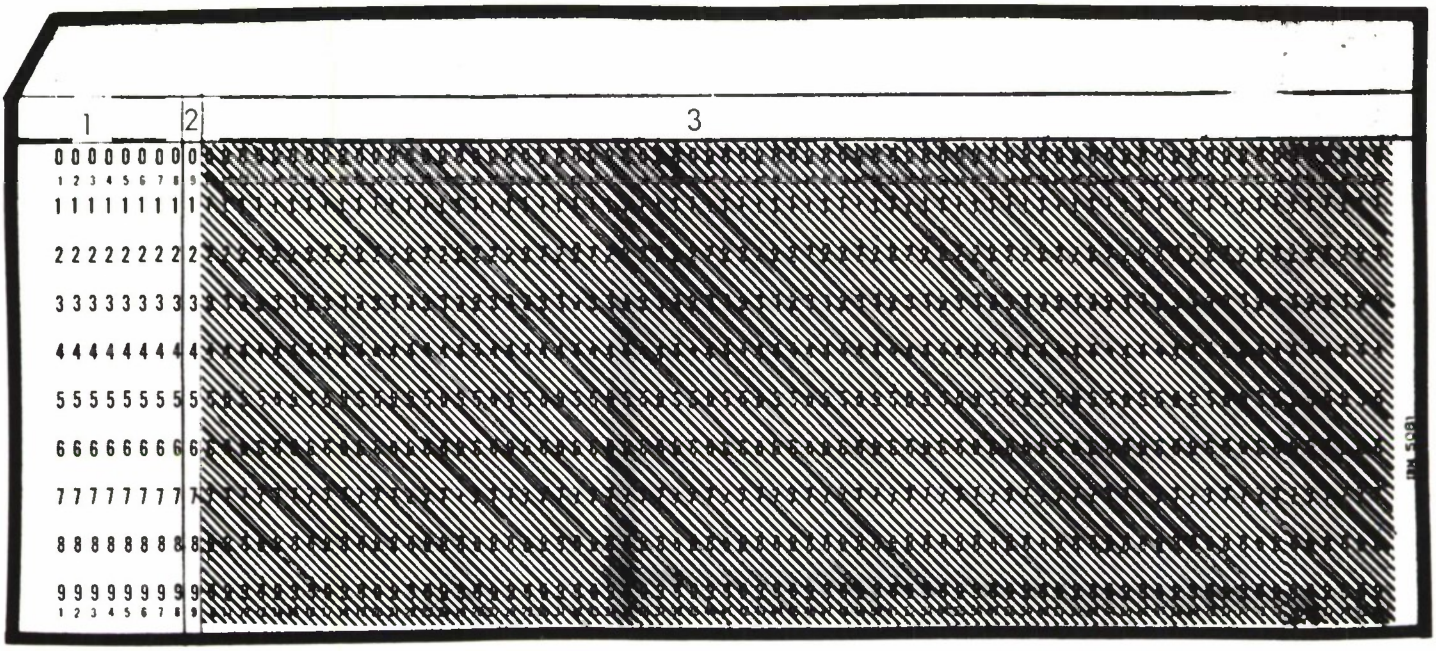
Field	Column	Content	Description
1	1-16		Not used
2	17-23	ENDDATA	
3	24-80		Not used

Figure 2-5. ENDDATA Card Format



Field	Column	Content	Description
1	1-8	ENDØFJØB	
2	9	11-8-2	11-8-2 Multipunch
3	10-80		Not used

Figure 2-6. End of Schedule Mode Card Format



Field	Columns	Content
1	1-8	ENDSCHED
2	9	11-8-2 multipunch
3	10-80	Not used

Figure 2-7. Schedule Tape END Card

2.1.2 JDC—Job Description Card

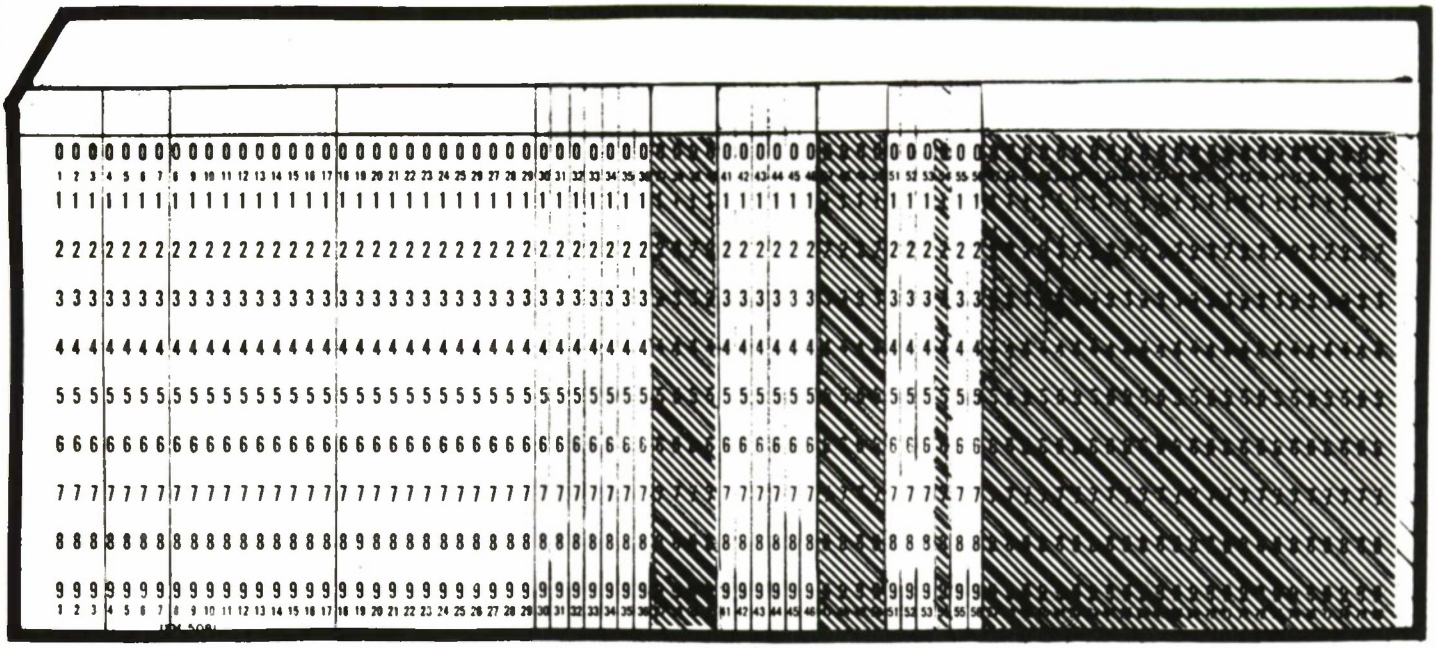
The JDC serves as a control card for the flow of information through ESPOD. This card is always the first card of an input deck. It defines the program sections to be used, and selects certain options. It identifies the vehicle number and name and permits a short arbitrary remark. Column description of the JDC card follows. A pictorial description of the JDC card appears at the top of the load sheet (see Section 2.2.3 for illustration).

2.1.3 Preliminary Data

The preliminary data input cards control the detailed options available to ESP0D and provide numerical information specific to the case. Preliminary data must be provided for all cold-start runs except for those which only sort and list the observations. An ENDPR card must follow the last of the preliminary data cards. The full set of fields required to set up the preliminary data cards is illustrated in Figure 2-9. It should be noted that they have a fixed format. An Identifier Field (I-Field) (3, 5, 7 or 9, Figure 2-9) is five columns wide. A Variable Field (V-Field) (4, 6, 8 or 10, Figure 2-9) is 14 columns wide. All Identifiers are left adjusted in the I-Field. All numerical values appearing alone in a V-Field must have a decimal point indicated somewhere and if the numerical value is expressed in floating decimal format, the exponent must be right adjusted in the V-Field. A value in a V-Field which is not preceded by a name in the associated I-Field will be considered as a value for an element in the array identified in the first I-Field-1 of the card. Subsequent values after the first are put into consecutive locations in the array. If a V-Field is left blank, the field is ignored. The following is an example of the same value entered into its V-Field in two different forms, fixed decimal and floating decimal formats.

Column number	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fixed decimal	-	1	4	5	.	3	2	6	7					
Floating decimal	-	.	1	4	5	3	2	6	7				+	3
	-	0	.	1	4	5	3	2	6	7		+	0	3
Floating decimal	-	0	1	.	4	5	3	2	6	7		+	0	2
Floating decimal	-	0	1	4	5	.	3	2	6	7		+	0	0

JDC JDC

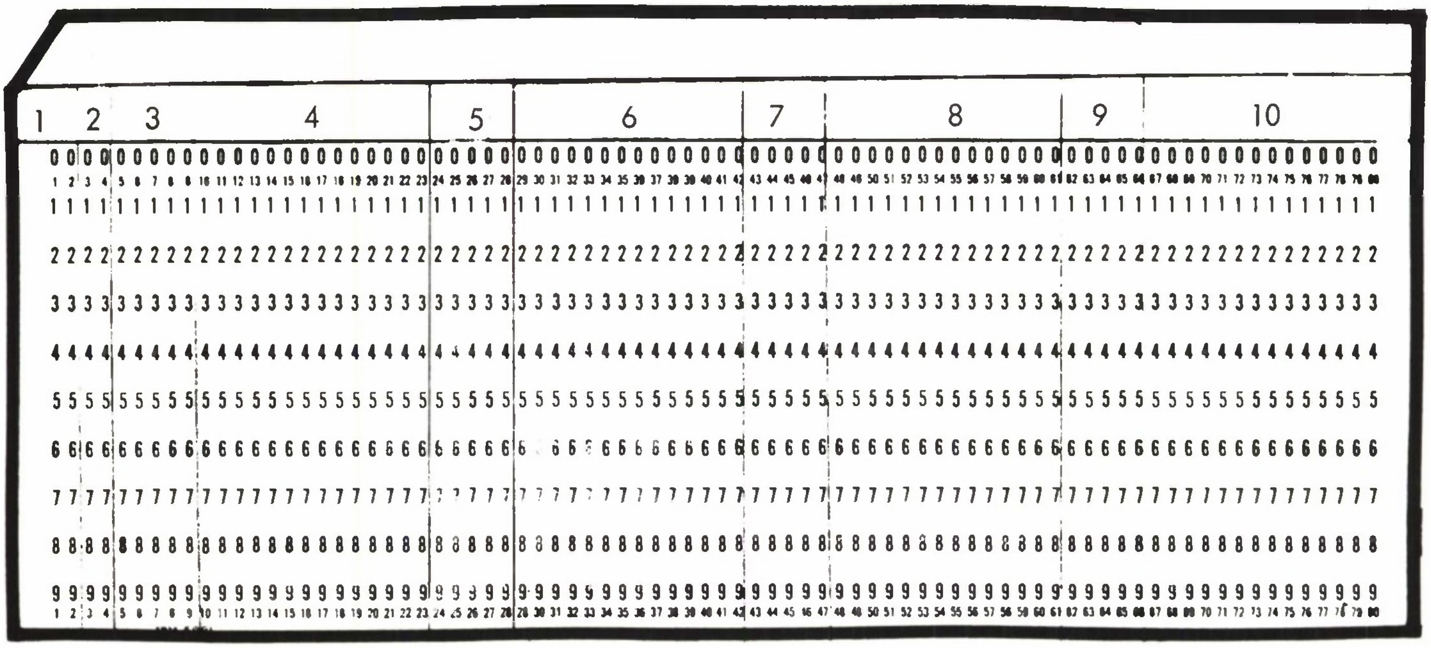


Column	Content	Description
1-3	JDC	Identifies JDC card
4-7	XXXX	Vehicle number-right adjusted
8-17	XXXX	Vehicle name
18-29	XXXX	User's header
30	0	Cold start
	1	Conditioned start
	2	Conditional start
31	0	Sensor and observation data not to be processed
	1	Sensor and observation data to be processed
32	0	Do not print sensor data
	1	Print sensor data
33	0	Do not print observations
	1	Print observations
34	0	Sensors on SEAI tape
	1	Sensors not on SEAI tape
35	0	Observations on SRADU tape
	1	Observations not on SRADU tape

Figure 2-8. Job Description Card Format

Column	Content	Description
36	0	Do not print program constants
	1	Print program constants
37-40	Not used	
41	0	ESP0DDC not needed
	1	ESP0DDC needed
42	0	*A priori* S matrix not input this run
	1	*A priori* S matrix input this run
43	0	Do not punch $(A^T A)^{-1}$ this run
	1	Punch $(A^T A)^{-1}$ this run
44	0	Do not punch $A^T A$ this run
	1	Punch $A^T A$ this run
45	0	UVW residuals print
	1	STW residuals print
	2	LLH residuals print
46	0	Use proved elements
	1	Use new elements
47-50	Not used	
51	0	ESP0DEPH not needed this run
	1	ESP0DEPH needed this run
52	0	x, y, z, T_D, T_{FD} not present this run
	1	x, y, z, T_D, T_{FD} present this run
53	0	Do not generate special binary empheris tape on this run
	1	Generate special binary ephemeris tape on this run
54	Not used	
55	0	Do not perform matrix update this run
	1	Perform matrix update this run
56	0	Do not punch inverse of updated covariance matrix
	1	Punch inverse of covariance matrix
57-80	Not used	

Figure 2-8. Job Description Card Format (Continued)



Field No.	Field Name	Column	Content	Description
1		1-2	NN	Sequence number identifying successive cards starting with first and having the same identifier in Field 3 or special identifier: 99—identifies 99 card 08, 12 } DAC Cards 01, 60 } SIGMA Cards
2		3-4	NN	Iteration number; identifies punched output from successive iterations
3	I-Field 1	5-9	XXXXX	Principal variable Identifier
4	V-Field 1	10-23	XXXXX	Value of first variable
5	I-Field 2	24-28	XXXXX	Name of second variable
6	V-Field 2	29-42	XXXXX	Value of second variable
7	I-Field 3	43-47	XXXXX	Name of third variable
8	V-Field 3	48-61	XXXXX	Value of third variable
9	I-Field 4	62-66	XXXXX	Name of fourth variable
10	V-Field 4	67-80	XXXXX	Value of fourth variable

Figure 2-9. Field Format of Preliminary Data Card

To readily locate any particular preliminary data input card a list of the card formats by title in order of appearance in this section is given below.

Card Title	Function in ESPOD	Page
ICTYP	Initial conditions	2-25
IC0ND No. 1	Initial conditions	2-27
IC0ND No. 2	Initial conditions	2-29
ITIME No. 1	Initial conditions	2-31
ITIME No. 2	Initial conditions	2-33
SPADATS-7 No. 1	Initial conditions	2-35
SPADATS-7 No. 2	Initial conditions	2-37
SPADATS-7 No. 3	Initial conditions	2-39
SPADATS-7 No. 4	Initial conditions	2-41
SPADATS-7 No. 5	Initial conditions	2-43
SPADATS-7 No. 6	Initial conditions	2-45
SPADATS-7 No. 7	Initial conditions	2-47
DNREV	Initial conditions	2-49
CAT1	Solution variables	2-51
CAT2	Solution variables	2-55
BNDS	Solution variables	2-57
BISES	Solution variables	2-61
NITER	Convergence control	2-63
TSTEP	Integration control	2-65
DELET	Data editing	2-67
STYPE	Data editing	2-69
TMAX	Data editing	2-71
SIGMA	Data editing	2-73
DRAG	Drag	2-75
APF10	Drag	2-77
Z0NAL	Earth potential	2-83
SECTR	Earth potential	2-85
TESSR	Earth potential	2-86
Z0NAL-M0D2	Earth potential	2-89
99-M0D2	Earth potential	2-91

Card Title	Function in ESPOD	Page
SECTR-M0D3	Earth potential	2-93
SECTR-M0D4	Earth potential	2-95
TESSR-M0D4	Earth potential	2-97
RADPR	Radiation pressure	2-99
SMAT	Matrix inputs	2-101
UPMAT	Matrix inputs	2-105
DELTT	ESP0DEPH options	2-111
DAC No. 1	ESP0DEPH options	2-113
DAC No. 2	ESP0DEPH options	2-115
DAC No. 3	ESP0DEPH options	2-117
PRDCT	ESP0DEPH options	2-119
99	Constants	2-121
ENDPR	End preliminary data	2-123

The following sections give the details of the various inputs on the preliminary data cards and how to specify the available options.

2.1.3.1 Specification of Initial Conditions

The initial conditions can be specified in any of four different types of input coordinates defined in sections which follow. The input cards can appear in three different forms.

- The ICTYP card specifying the coordinate system; the IC0ND cards providing the initial conditions; and the ITIME card giving the epoch for the input solution vector completely define the initial conditions.
- The ICTYP card specifying SPADATS 7-card elements; and an optional DNREV card (to update to new epoch) define a set of initial conditions.
- A third form is obtaining initial conditions from the SEAI tape and an optional DNREV card.

2.1.3.1.1 ICTYP Card Description. The variable field associated with this name, derived from Initial Condition Type, is an integer between 1 and 4 which indicates the type of initial conditions, input by the IC0ND set or by the 7-card elements. The coordinate systems and type are listed below:

1. ECI Polar Spherical, Right Ascension Reference (ADBARV)

α	Right ascension	(degrees)
δ	Declination	(degrees)
β	Flight path angle	(degrees)
A	Azimuth	(degrees)
R	Radius	(km)
v	Velocity	(km/sec)

2. ECI Polar Spherical, Longitude Reference

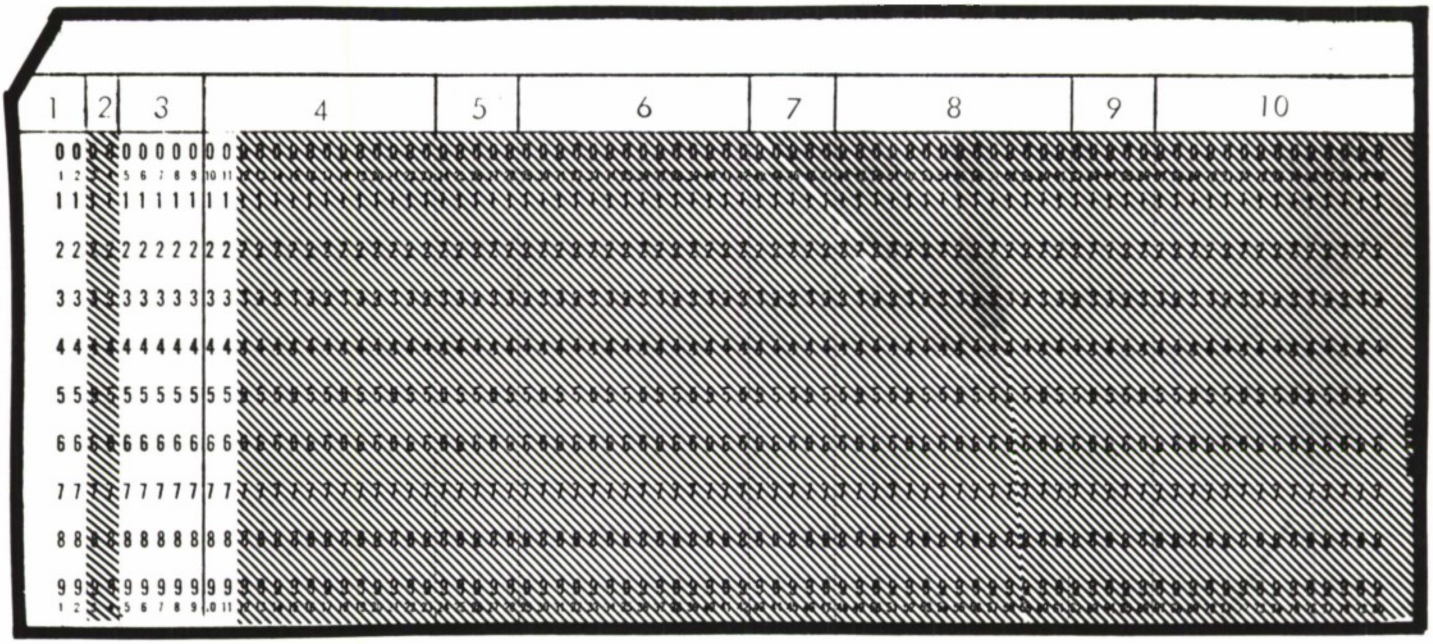
λ	Longitude	(degrees)
δ	Declination	(degrees)
β	Flight path angle	(degrees)
A	Azimuth	(degrees)
R	Radius	(km)
v	Velocity	(km/sec)

3. ECI Cartesian

x	Position coordinates	(km)
y		(km)
z		(km)
$\dot{x}$	Velocity coordinates	(km/sec)
$\dot{y}$		(km/sec)
$\dot{z}$		(km/sec)

4. SPADATS-7-Card Mean Elements

a	Semimajor axis	(km)
e	Eccentricity	(degrees)
i	Inclination	(degrees)
P_n	Nodal period	(days/rev.)



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	ICTYP	Principal variable identifier
4	10-11	1., 2., 3., or 4.	
4	12-23	Not used	
5-10	24-80	Not used	

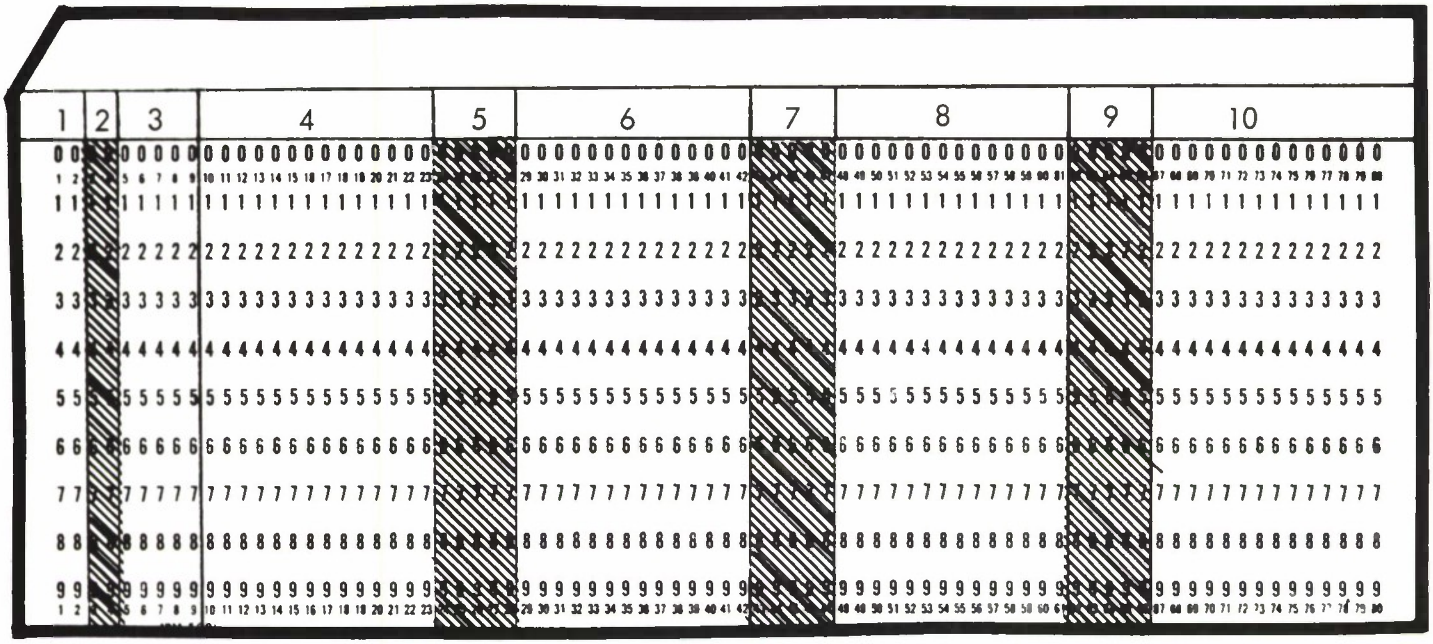
Figure 2-10. ICTYP Card Format

Ω_o	Right ascension of ascending node	(degrees)
ω_o	Argument of perigee	(degrees)
t	Time of epoch	(days)

2.1.3.1.2 ICØND. This name, derived from Initial Conditions, identifies the initial position and velocity for the following coordinates:

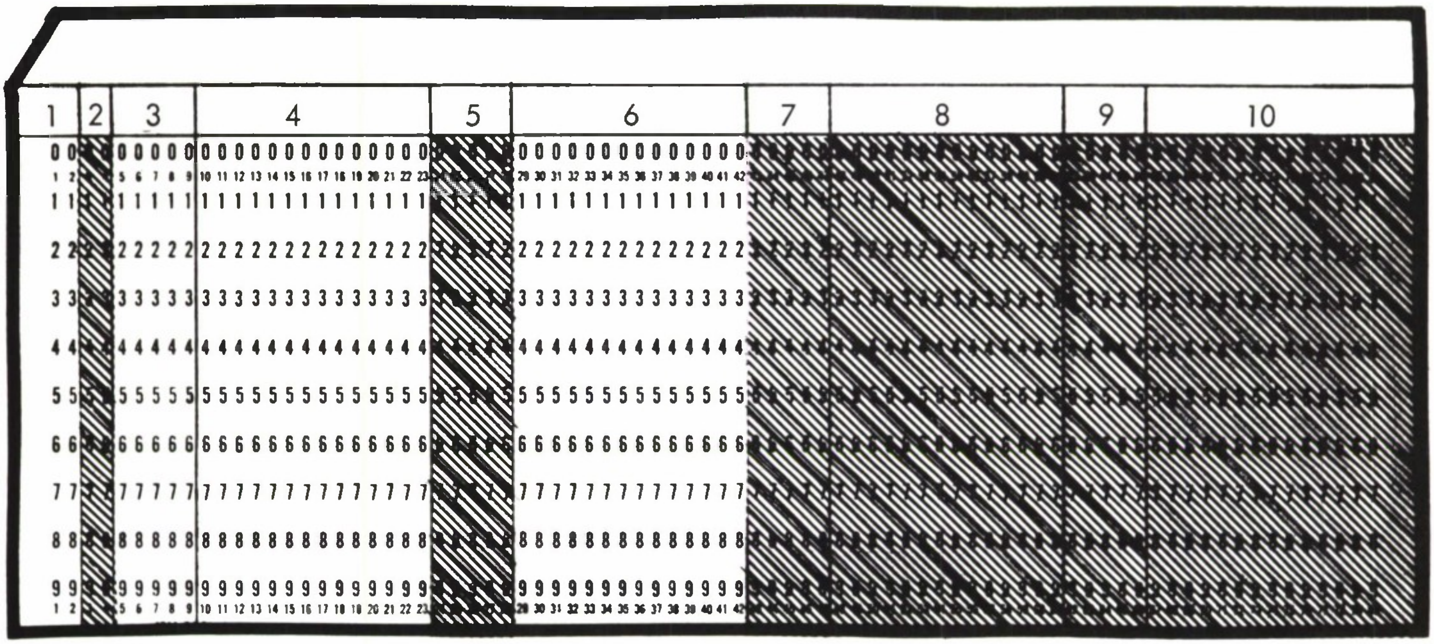
1. (ICTYP No. 1) ECI polar spherical—α, δ, β, A, R, v
2. (ICTYP No. 2) ECI polar spherical—λ, δ, β, A, R, v
3. (ICTYP No. 3) ECI Cartesian—x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$

The ICØND cards are only for these first three types of initial conditions. The SPADATS 7-card element set is discussed in Section 2.1.3.1.4. Since six variables specify the initial conditions, two cards constitute an ICØND set. The ICØND card format is delineated by field and content (see Figures 2-11 and 2-12). The field format corresponds to the standard preliminary data card and the Load Sheet description (Section 2.2).



Field	Columns	Content of Field		
		ICTYP 1	ICTYP 2	ICTYP 3
1	1-2	01	01	01
2	3-4	Blank	Blank	Blank
3	5-9	ICØND	ICØND	ICØND
4	10-23	α	λ	x
5	24-28	Blank	Blank	Blank
6	29-42	δ	δ	y
7	43-47	Blank	Blank	Blank
8	48-61	β	β	z
9	62-66	Blank	Blank	Blank
10	67-80	A	A	$\dot{x}$

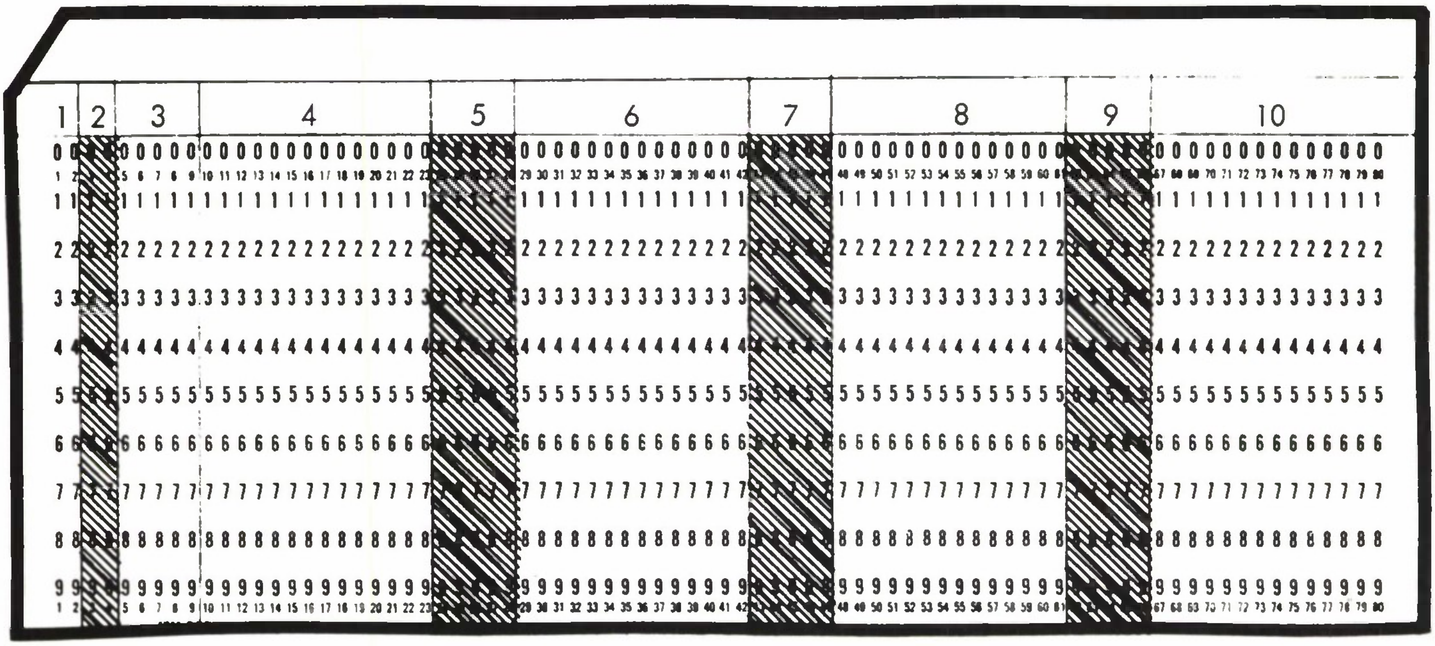
Figure 2-11. ICØND Card Format No. 1



		Content of Field		
Field	Columns	ICTYP 1	ICTYP 2	ICTYP 3
1	1-2	02	02	02
2	3-4	Blank	Blank	Blank
3	5-9	ICØND	ICØND	ICØND
4	10-23	R	R	$\dot{y}$
5	24-28	Blank	Blank	Blank
6	29-42	v	v	$\dot{z}$
7	43-47	Blank	Blank	Blank
8	48-61	Blank	Blank	Blank
9	62-66	Blank	Blank	Blank
10	67-80	Blank	Blank	Blank

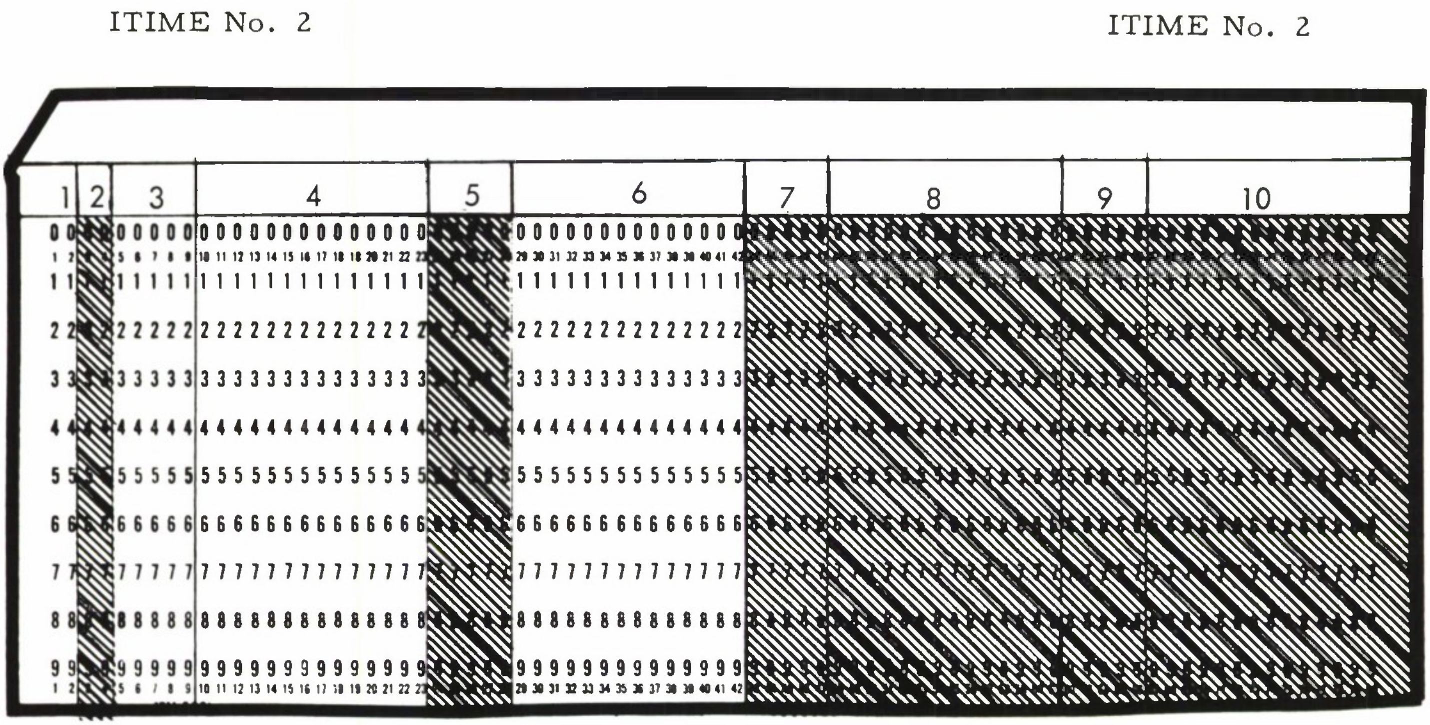
Figure 2-12. ICØND Card Format No. 2

2.1.3.1.3 ITIME. This name, derived from Initial Time, identifies the instant in time when the initial conditions are valid, that is, the epoch. Epoch is specified by year, month, day, hours, minutes, and seconds. Two ITIME cards are needed. They are meaningless alone and are used only to accompany an ICTYP 1, 2, or 3 card and the corresponding ICØND cards to complete the specification of the input vector. The format of the card is listed below. See also Section 2.2 (Load Sheets).



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	ITIME	Principal variable identifier
4	10-23	Y	Year
5	24-28	Blank	
6	29-42	M	Month number
7	43-47	Blank	
8	48-61	D	Day number
9	62-66	Blank	
10	67-80	H	Hour of day

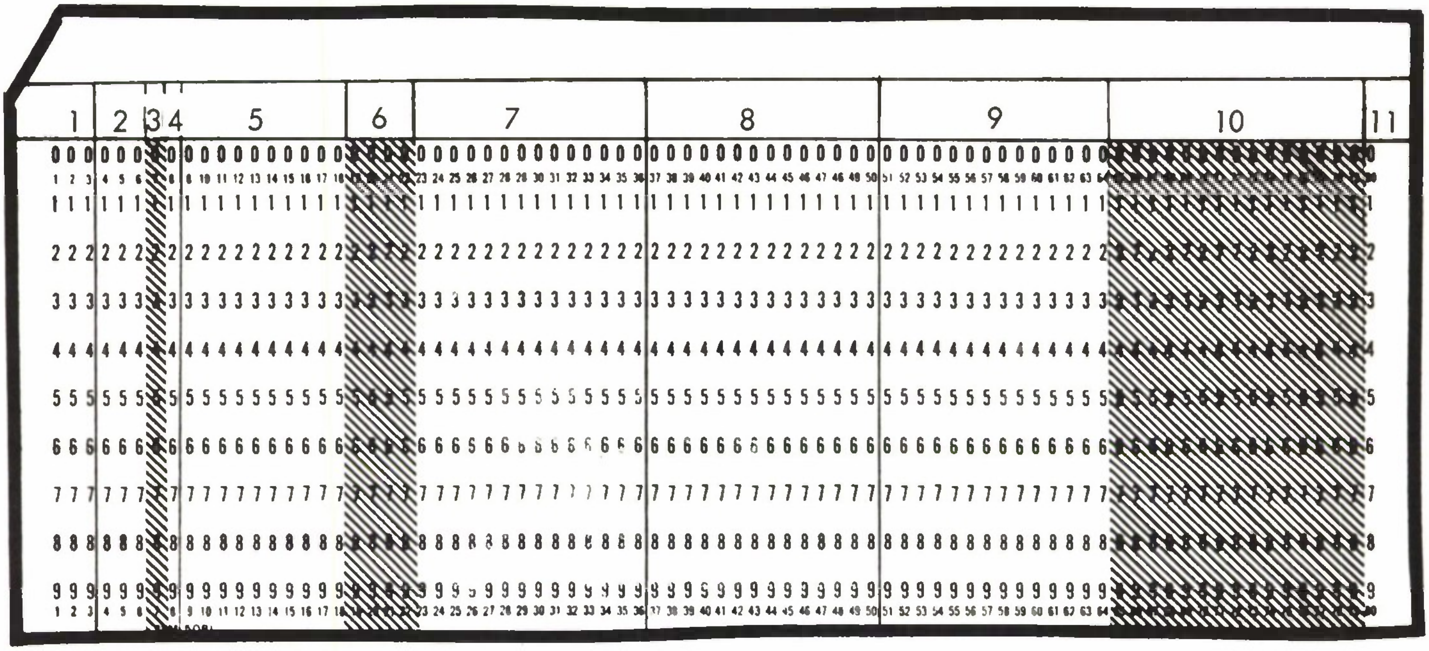
Figure 2-13. ITIME Card Format Card No. 1



Field	Column	Content	Description
1	1-2	02	Sequence number
2	3-4	Blank	Iteration number
3	5-9	ITIME	Principal variable identifier
4	10-23	Min	Minutes
5	24-28	Blank	
6	29-42	Sec	Seconds
7-10	43-80	Not used	

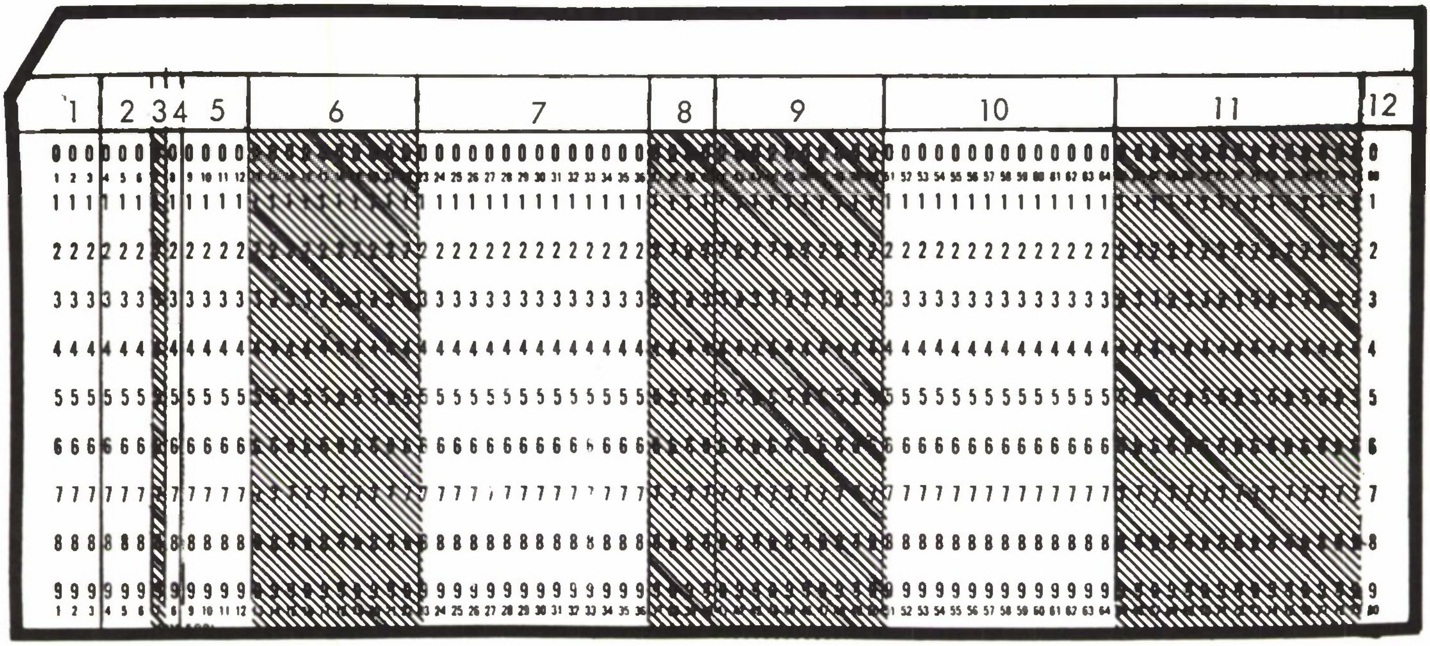
Figure 2-14. ITIME Card Format Card No. 2

2.1.3.1.4 SPADATS 7-Card Mean Elements. These cards are standard to the SPADATS system. ESPOD accepts the standard 7-card element set as input (ICTYP 4). The shaded columns are not used. The formats for these cards appear on the following pages.



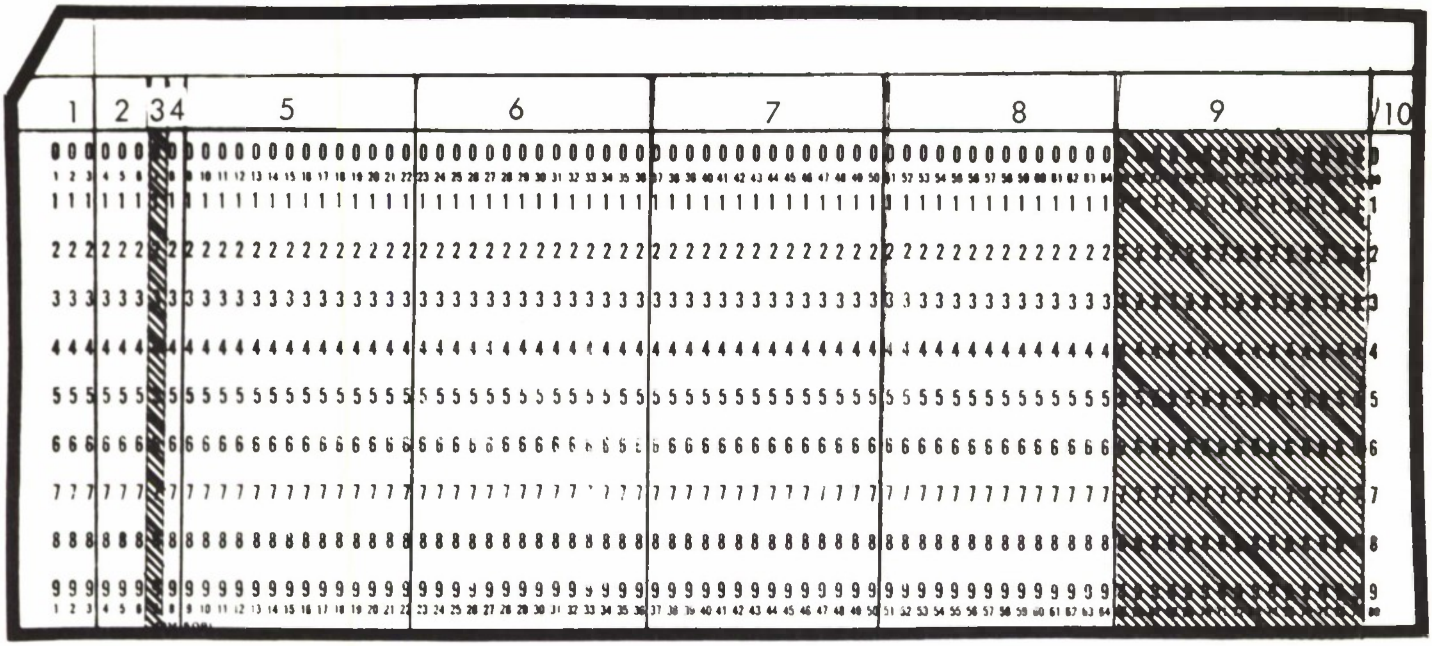
Field	Column	Description
1	1-3	Satellite number—justified right
2	4-6	Element set number—justified right
3	7	Not used
4	8	Card number (card # = 1)
5	9-18	Satellite name for Element File Update
6	19-22	Not used
7	23-36	N_o—Epoch revolution
8	37-50	e—eccentricity
9	51-64	i—inclination (degrees)
10	65-79	Not used
11	80	Card type, E = Nodal Elements

Figure 2-15. SPADATS-7 Element Card Format, Card No. 1



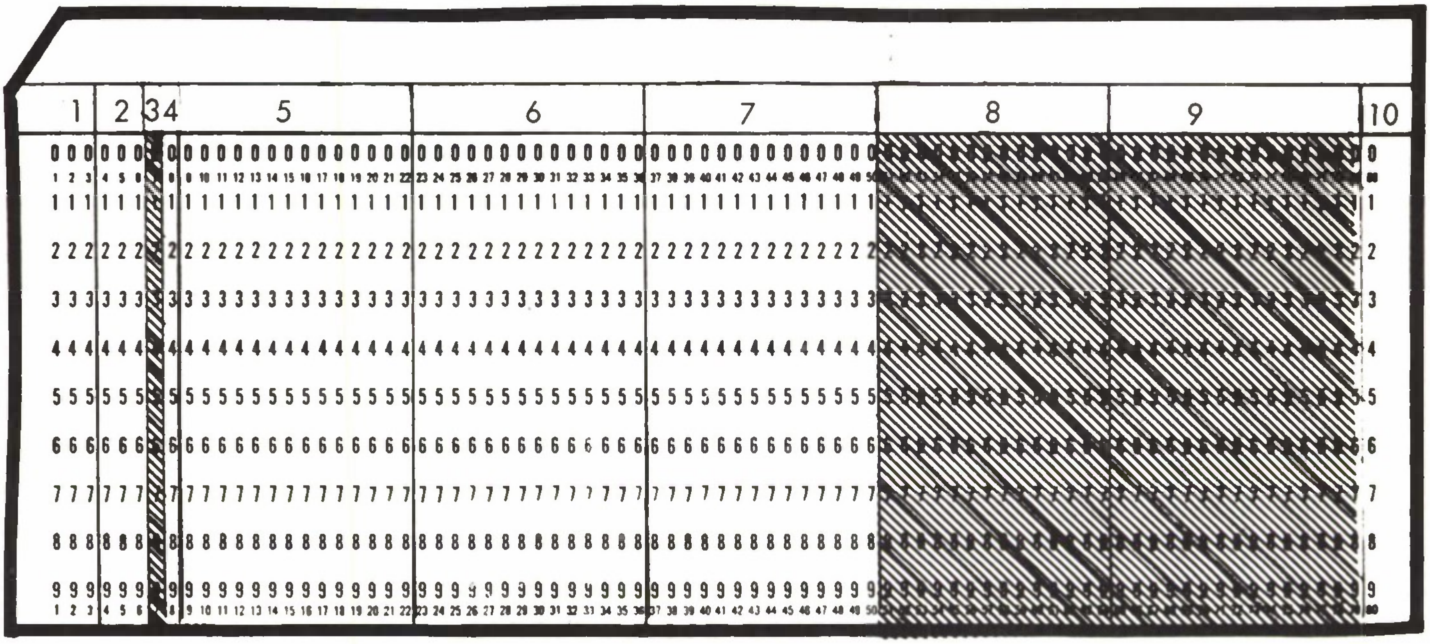
Field	Column	Description
1	1-3	Satellite number—justified right
2	4-6	Element set number
3	7	Not used
4	8	Card number (Card # = 2)
5	9-12	Year of T_o
6	13-22	Not used
7	23-36	T_o—Time of Epoch (day of year and fraction of day)
8	37-40	Not used
9	41-50	Not used
10	51-64	L_o—Mean Longitude—degrees
11	65-79	Not used
12	80	Card Type, E = Nodal Elements

Figure 2-16. SPADATS-7 Element Card Format, Card No. 1



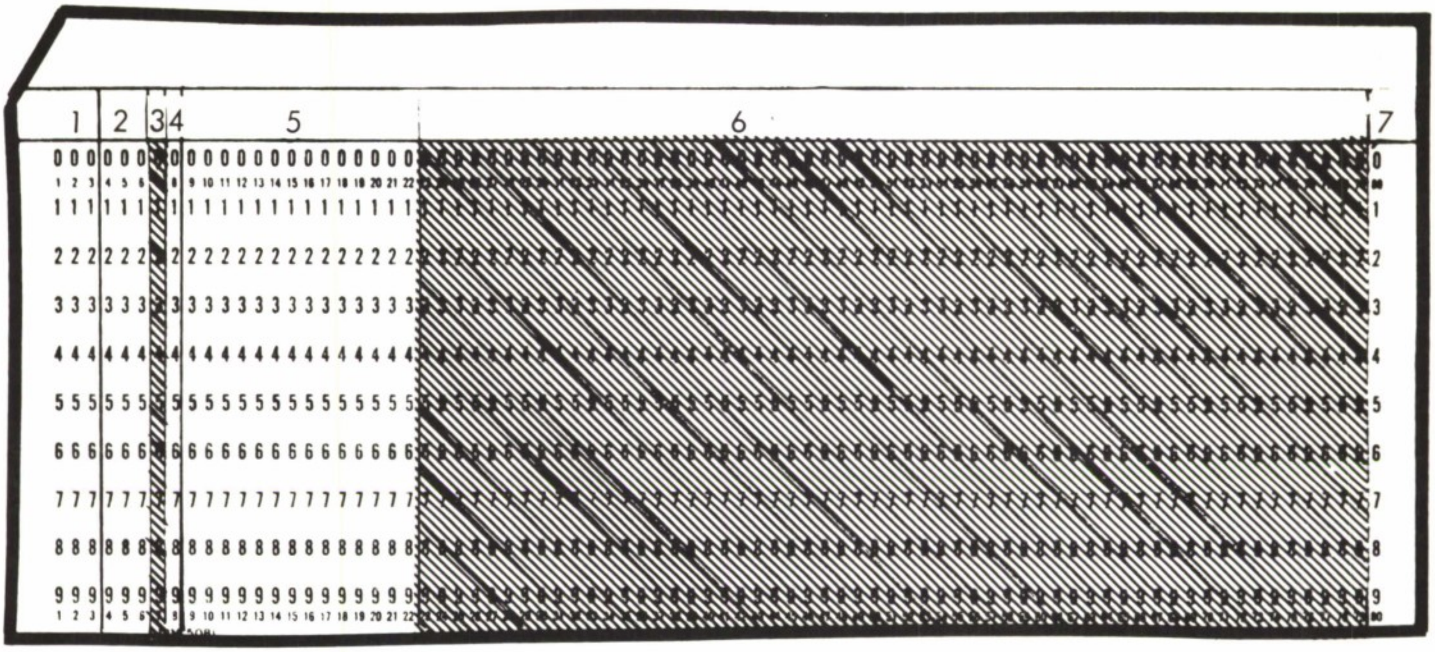
Field	Column	Description
1	1-3	Satellite number—justified right
2	4-6	Element set number—justified right
3	7	Not used
4	8	Card number (Card # = 3)
5	9-22	P_a—Anomalistic period at Epoch—days/rev
6	23-36	Ω_o—Right ascension of ascending node degrees
7	37-50	ω_o—Argument of perigee—degrees
8	51-64	q_o—Perigee distance—Earth radii
9	65-79	Not used
10	80	Card type, E = Nodal Elements

Figure 2-17. SPADATS-7 Element Card Format, Card No. 3



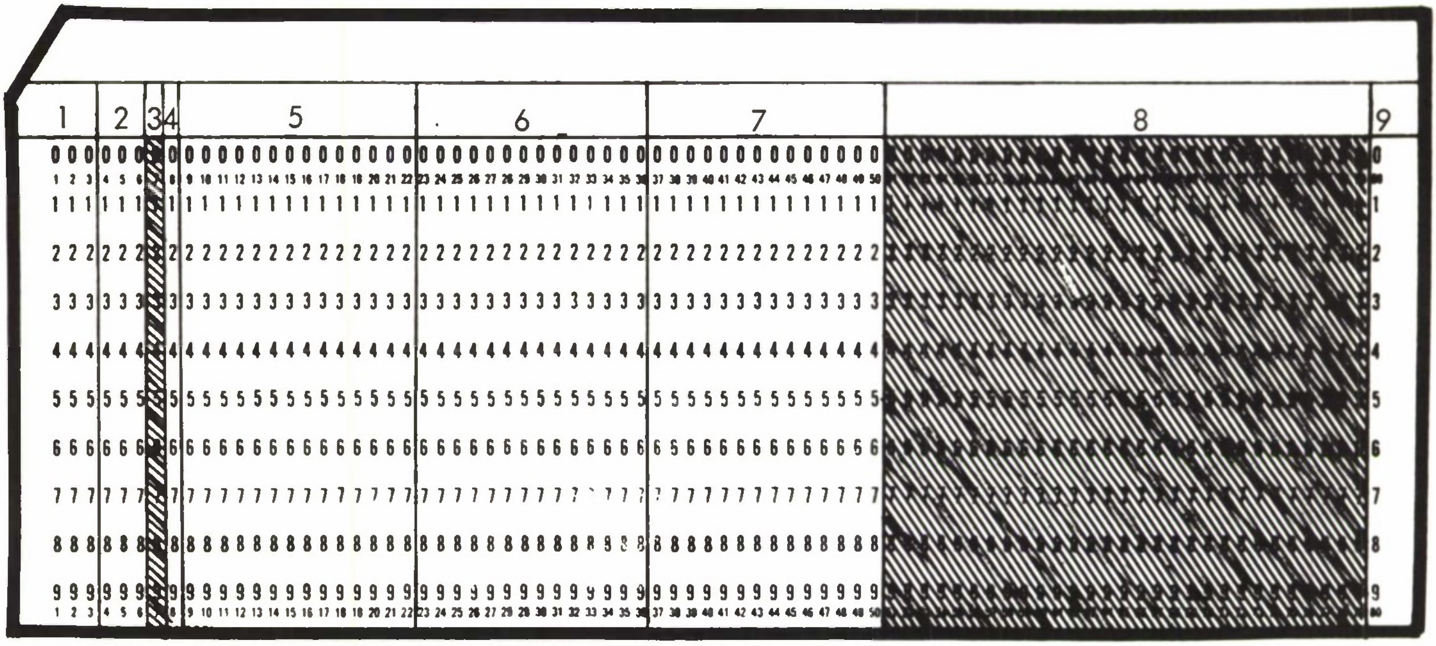
Field	Column	Description
1	1-3	Satellite number—justified right
2	4-6	Element set number—justified right
3	7	Not used
4	8	Card number (Card # = 4)
5	9-22	C—Rate of change of period—days/(rev)^2
6	23-36	$\dot{\Omega}_o$—Time derivative of Right ascension of ascending node—degrees/day
7	37-50	$\dot{\omega}_o$—Time derivative of argument of perigee—(degrees/day)
8	51-64	Not used
9	65-79	Not used
10	80	Card type; E = Nodal Elements

Figure 2-18. SPADATS-7 Element Card Format, Card No. 4



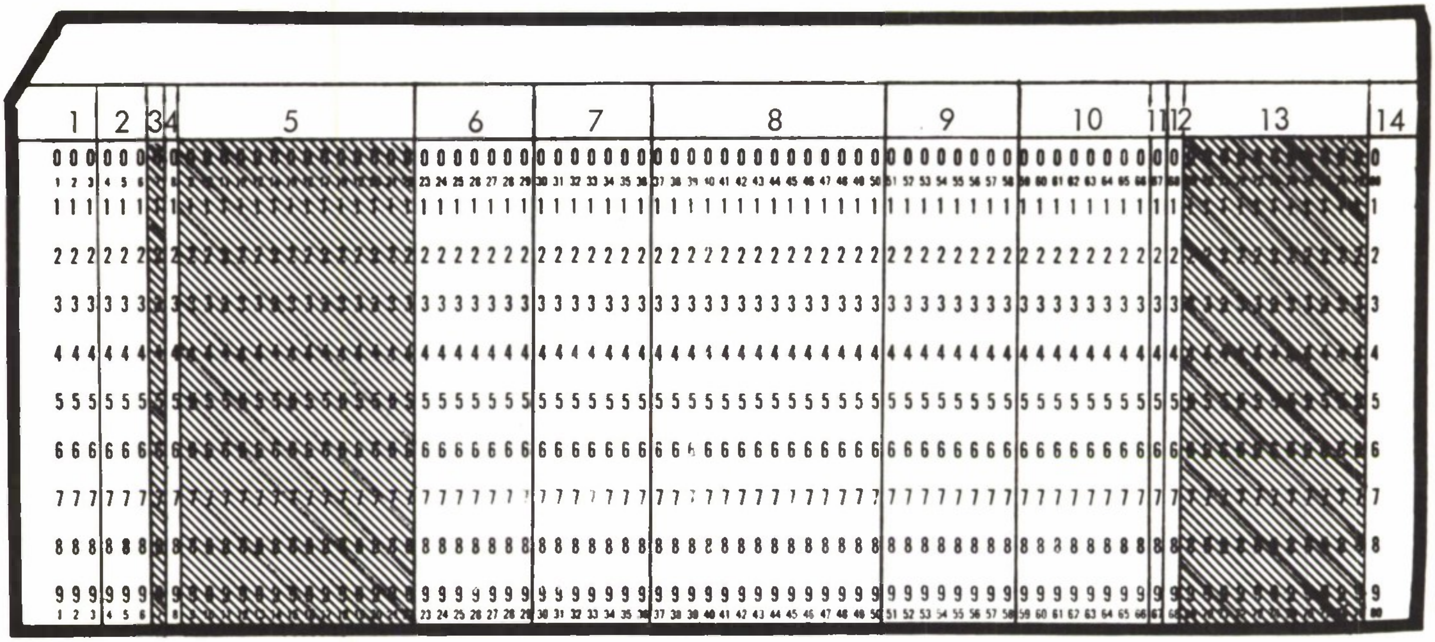
Field	Column	Description
1	1-3	Satellite number—justified right
2	4-6	Element set number—justified right
3	7	Not used
4	8	Card number (Card # = 5)
5	9-22	d—decay acceleration
6	23-79	Not used
7	80	Card type; E = Nodal Elements

Figure 2-19. SPADATS-7 Element Card Format, Card No. 5



Field	Column	Description
1	1-3	Satellite number - justified right
2	4-6	Element set number - justified right
3	7	Not used
4	8	Card number (Card # 6)
5	9-22	a - semimajor axis - Earth radii
6	23-36	P_N - Nodal period - days/rev
7	37-50	C_N - Rate of change of nodal period - days/(rev)^2
8	51-79	Not used
9	80	Card type; E = Nodal Elements

Figure 2-20. SPADATS-7 Element Card Format, Card No. 6

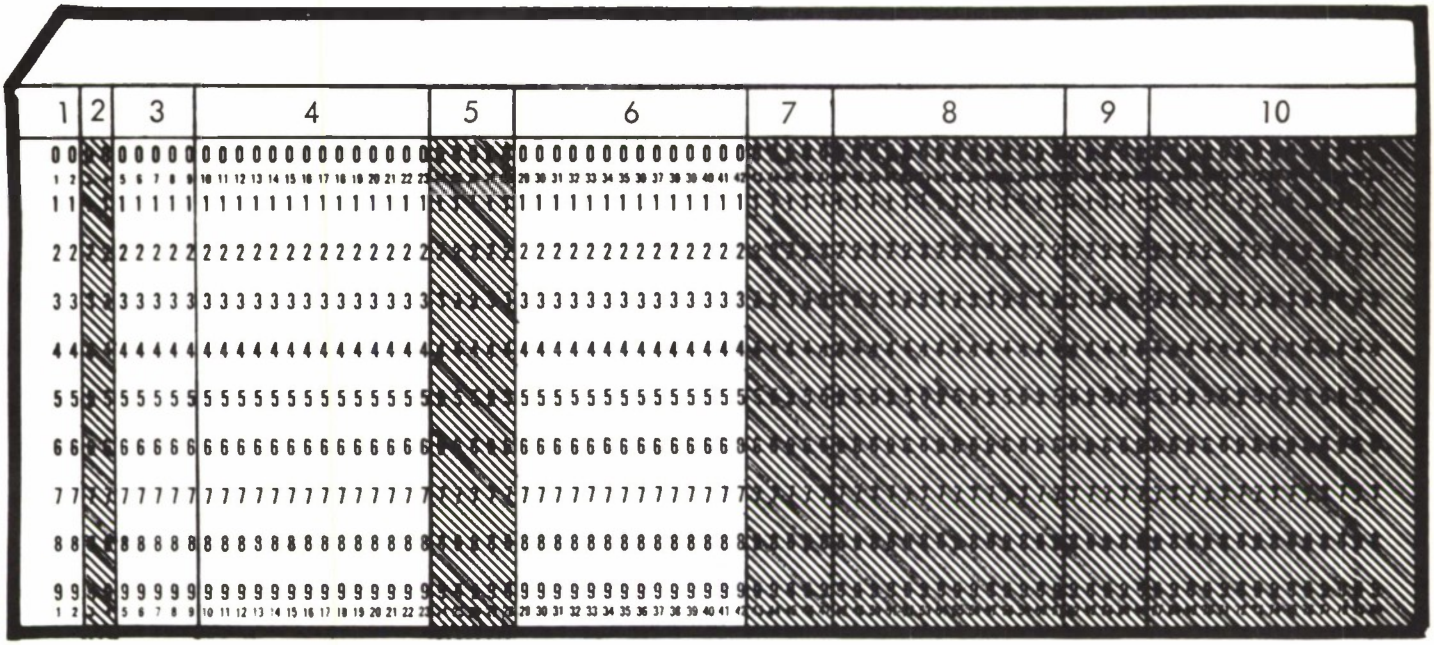


Field	Column	Description
1	1-3	Satellite number - justified right
2	4-6	Element set number - justified right
3	7	Not used
4	8	Card number (Card # = 7)
5	9-22	Not used
6	23-29	Initial revolution, decimal may be punched in column 29
7	30-36	Final revolution, decimal may be punched in column 36
8	37-50	Expiration date of Bulletin, in format; YMMDDHHMMSS. SS, decimal punched in column 48
9	51-58	RMS, in format XXXXX. XX; decimal punched in 56
10	59-66	Number of observations used in obtaining RMS
11	67	ISTØP Blank or 0 = correct the inclination element 1 = do not correct the inclination 2 = do not correct the drag parameter 4 = correct time equation only
12	68	Blank or 0 = mean elements 1 = K-25 elements 2 = osculating elements
13	69-79	Not used
14	80	Card type; E = Nodal Elements

Figure 2-21. SPADATS-7 Element Card Format, Card No. 7

2.1.3.1.5 DNREV. This function, from Delta Number of Revolutions, controls the update of SPADATS 7-card elements from the epoch given with them to the epoch required for ESPØD. The DNREV card may be omitted if automatic program logic will establish the desired epoch. It also controls the update when file elements (SEAI tape) are used. When the input vector is obtained from the SEAI tape, the epoch is automatically chosen as the last time of observation. If desired, an alternate epoch may be selected with the DNREV card.

The first variable is assigned one of the following four values: "1.", "2.", "3.", or "-1.". These numbers indicate the manner in which the second variable is interpreted.



Field	Content	Description
1	01	Sequence Number
2	Blank	Iteration Number
3	DNREV	Principal variable identifier
4	X.0	X = -1.0, 1.0, 2.0 or 3.0
5	Blank	
6	y	Specification of new epoch, with units and reference update as specified in tabulation below.

x (first variable)	y (second variable)
1.0	Time in days (D) and fractions of days (DF) from first of year. 1.0 = 00 hrs, universal time, on 1 January of year.
2.0	Number of revolutions (REVS) and fractions of revolutions (REVS F) from epoch given with SPADATS mean elements or on the SEAI tape, to epoch required for ESPØD.
3.0	Revolutions (REVS) and fraction of revolutions (REVS F) from launch (first ascending node = REV 1.0) to epoch desired for ESPØD.
-1.0	Variable fields are left blank. This specifies the updated epoch when SPADATS, mean elements are used to the time of last observations.

If no automatic update to the time of last observation is desired when using file elements (SEAI tape), a value of X = 2.0 and y = 0.0 is selected.

FIELDS 7, 8, 9 and 10 are not used.

Figure 2-22. DNREV Card Format

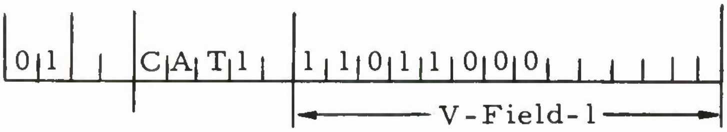
2.1.3.2 Specification of Solution Variables

Solution variables are specified with two different cards having different formats. These cards set up solutions for the orbit elements and the sensor parameters respectively.

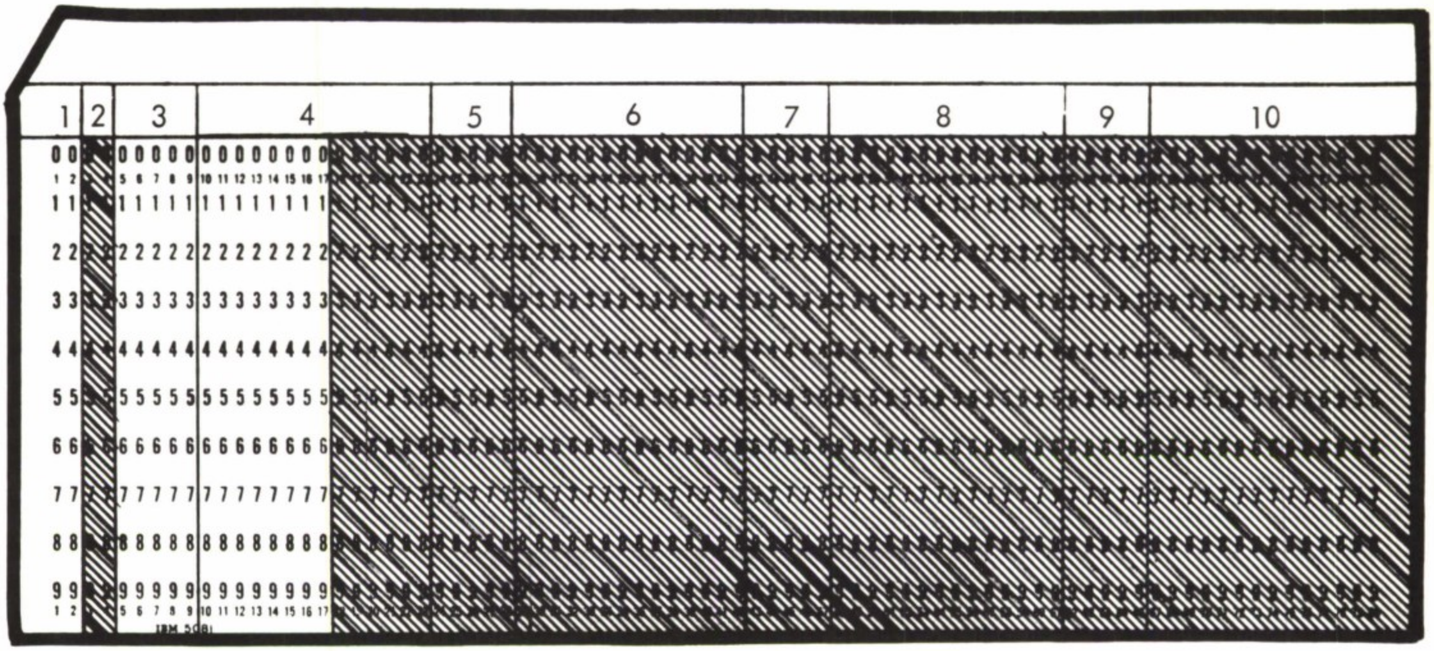
2.1.3.2.1 CAT1—Category 1 Variables

Symbol	Name	Corresponding Card Column
α_o	Right ascension	10
δ_o	Declination	11
β_o	Flight path angle	12
A_o	Azimuth	13
R_o	Radius	14
V_o	Velocity	15
$C_DA/2m$	Drag parameter	16
K	Drag parameter variation	17

The first eight columns of the V-Field-1 in the CAT1 card correspond in the order listed above to the Category 1 variables to be solved for. The V-Field columns must contain either "ones" or "zeros." A "1" punched in a column of the V-Field indicates that the corresponding variable is to be solved for. A "0" punched in the same column indicates that the corresponding variable is not to be solved for. This convention holds true for eight Category 1 variables. For example, a card punched as follows



indicates that on this run the variables α_o, δ_o, A_o, and R_o are to be solved and that β_o, V_o, $C_DA/2m$, and K will be held constant. Note that the six righthand columns of the V-Field-1 are left blank.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	CAT1	Principal variable identifier
4	10-17	XXXXXXXX	X = 0 variable not to be solved X = 1 variable to be solved
4	18-23	Blank	
5-10	24-80	Not used	

Figure 2-23. CAT1 Card Format

2.1.3.2.2 CAT2—Category 2 Variables

Symbol	Name	Corresponding Card Column
R_b	Range bias	14 33 52 71
A_b	Azimuth bias	15 34 53 72
E_b	Elevation bias	16 35 54 73
R_b	Range Rate bias	17 36 55 74
RA_b	Right Ascension bias	18 37 56 75
D_b	Declination bias	19 38 57 76
t_b	Time bias	20 39 58 77
ϕ_b	Latitude bias	21 40 59 78
λ_b	Longitude bias	22 41 60 79
h_b	Height bias	23 42 61 80

Category 2 variables are solved for selected sensors. Any combination of CAT2 variables may be solved for the same sensor. The convention for specifying CAT2 variables to be solved is similar to that used in CAT1 cards.

The 14 columns of the V-fields are partitioned into two subfields of four columns and ten columns respectively.

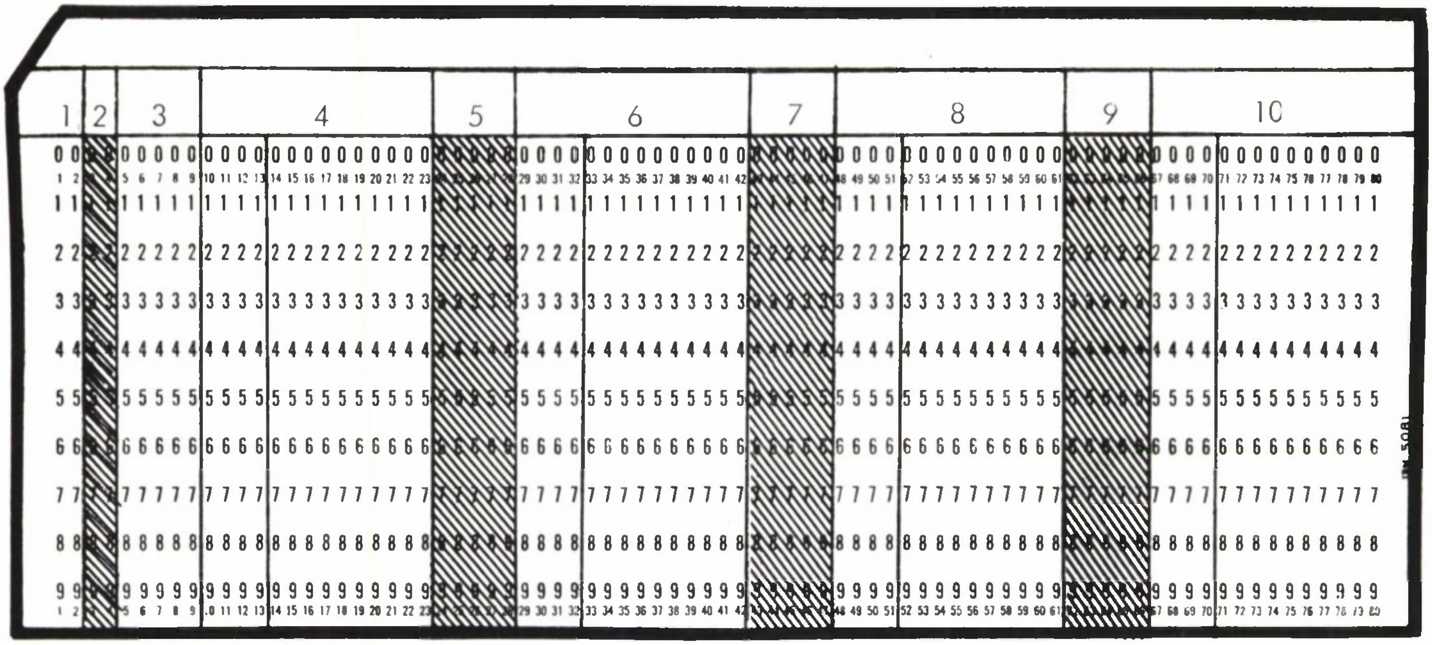
- The first 4 columns contain the sensor number right adjusted
- The last 10 columns correspond in the order listed above to the Category 2 variables to be solved for.

For example, the card punched as follows indicates by means of the contents of the V-Field-1 that R_b, A_b, E_b, and h_b of sensor 324 are to be solved for.

```
01  |CAT2 |03241110000001|     |
```

If a CAT2 card is omitted, no Category 2 variables are solved for. Unlike the Category 1 variables, no initial estimates of the Category 2 variables are needed, although initial bias estimates can be specified (see Section 2.1.3.2.4).

If additional station biases (CAT2 variables) are to be solved, more CAT2 cards must be added. The only format difference from card to card is the first field location, the sequence number.

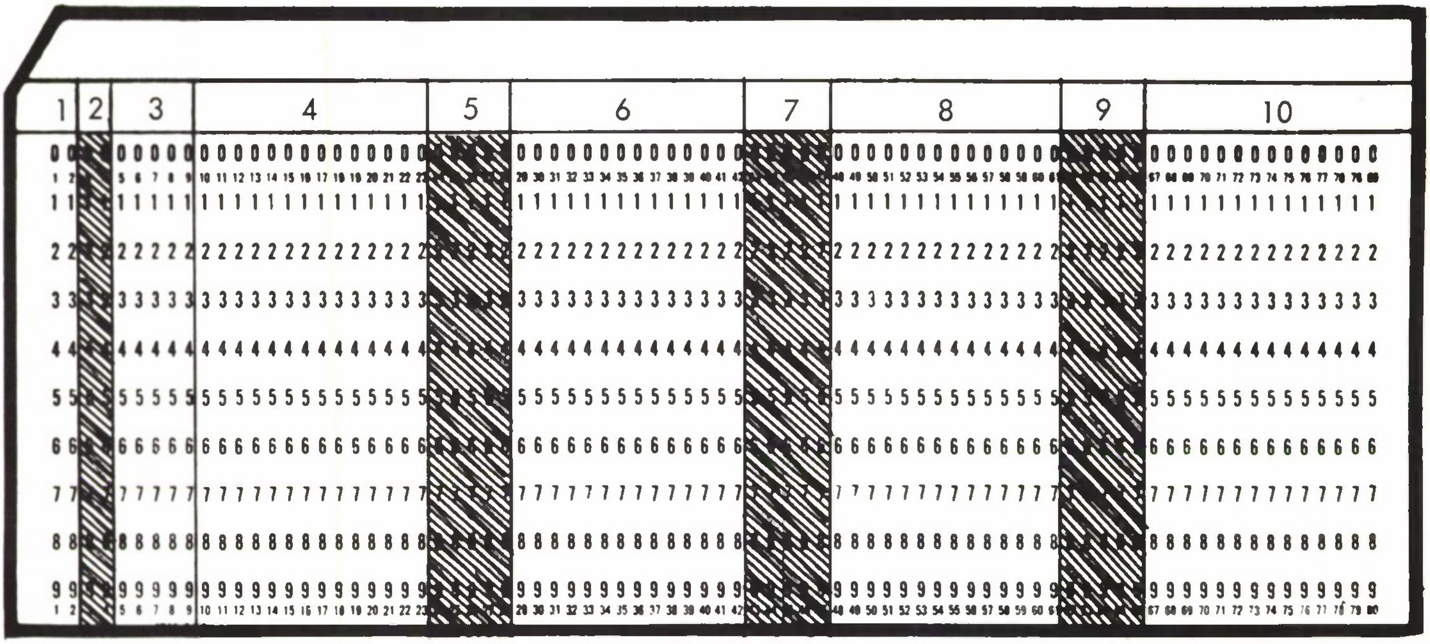


Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	CAT2	Principal variable identifier
4	10-13	XXXX	First sensor number (right adjusted)
4	14-23	XXXX	X = 0 variable not to be solved for X = 1 variable to be solved for
5	24-28	Blank	
6	29-32	XXXX	Second sensor number
6	33-42	XXXX	X = 0 variable not to be solved for X = 1 variable to be solved for
7	43-47	Blank	
8	48-51	XXXX	Third sensor number
8	52-61	XXXX	X = 0 variable not to be solved for X = 1 variable to be solved for
9	62-66	Blank	
10	67-70	XXXX	Fourth sensor number
10	71-80	XXXX	X = 0 variable not to be solved for X = 1 variable to be solved for

Figure 2-24. CAT2 Card Format

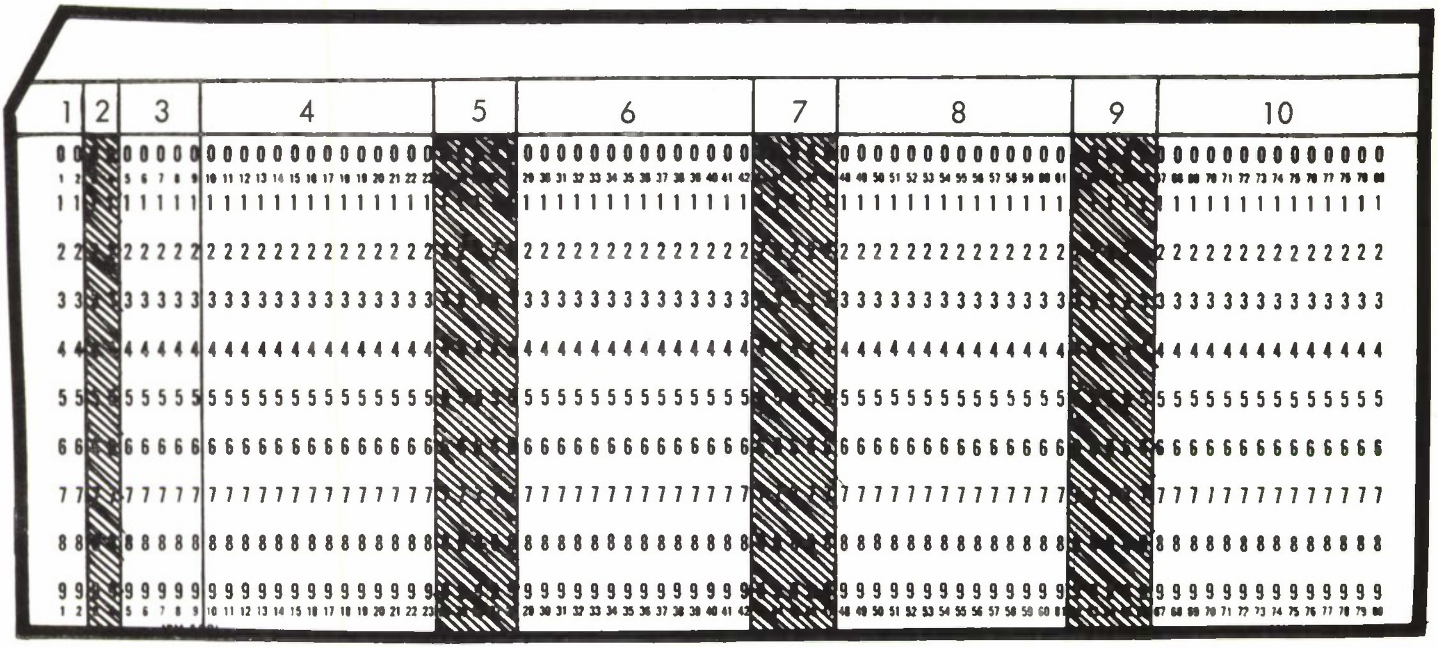
2.1.3.2.3 Bounds on Variable Changes. BNDS (abbreviation from bounds) identifies the start of an array which contains the bounds to be used in the differential correction process. Nominal values for bounds are stored in the program, but if any of these is to be modified, a new set of bounds must be provided. For each variable selected for solution by either a Category 1 or Category 2 card, a bound on the size of correction is specified to control convergence. The variables selected for solution are placed in the same order as the columns of the Category 1 and Category 2 cards. Multiple Category 2 cards are taken in their sequential order. The total count of variables tagged with a "1" is the dimension of the solution vector. A set of bounds, corresponding one-to-one with the elements of the solution vector, is listed in the same order starting in the first variable field on the bounds card and continuing with no intervening blank variable fields across the first card and through any necessary following cards until the proper number of bounds is specified.

Figures 2-25 and 2-26 show variable field assignments for the bounds which correspond to the solution vector of the CAT1 and CAT2 variables given in the previous section.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	BNDS	Principal variable identifier
4	10-23	B_α	Bound on right ascension
5	24-28	Blank	
6	29-42	B_δ	Bound on declination
7	43-47	Blank	
8	48-61	B_A	Bound on azimuth
9	62-66	Blank	
10	67-80	B_R	Bound on radius

Figure 2-25. BNDS Card Format, Card No. 1



Field	Column	Content	Description
1	1-2	02	Sequence number
2	3-4	Blank	Iteration number
3	5-9	BNDS	Principal variable identifier
4	10-23	B_{R_b}	Bound on range bias
5	24-28	Blank	
6	29-42	B_{A_b}	Bound on azimuth bias
7	43-47	Blank	
8	48-61	B_{E_b}	Bound on elevation bias
9	62-66	Blank	
10	67-80	B_{h_b}	Bound on height bias

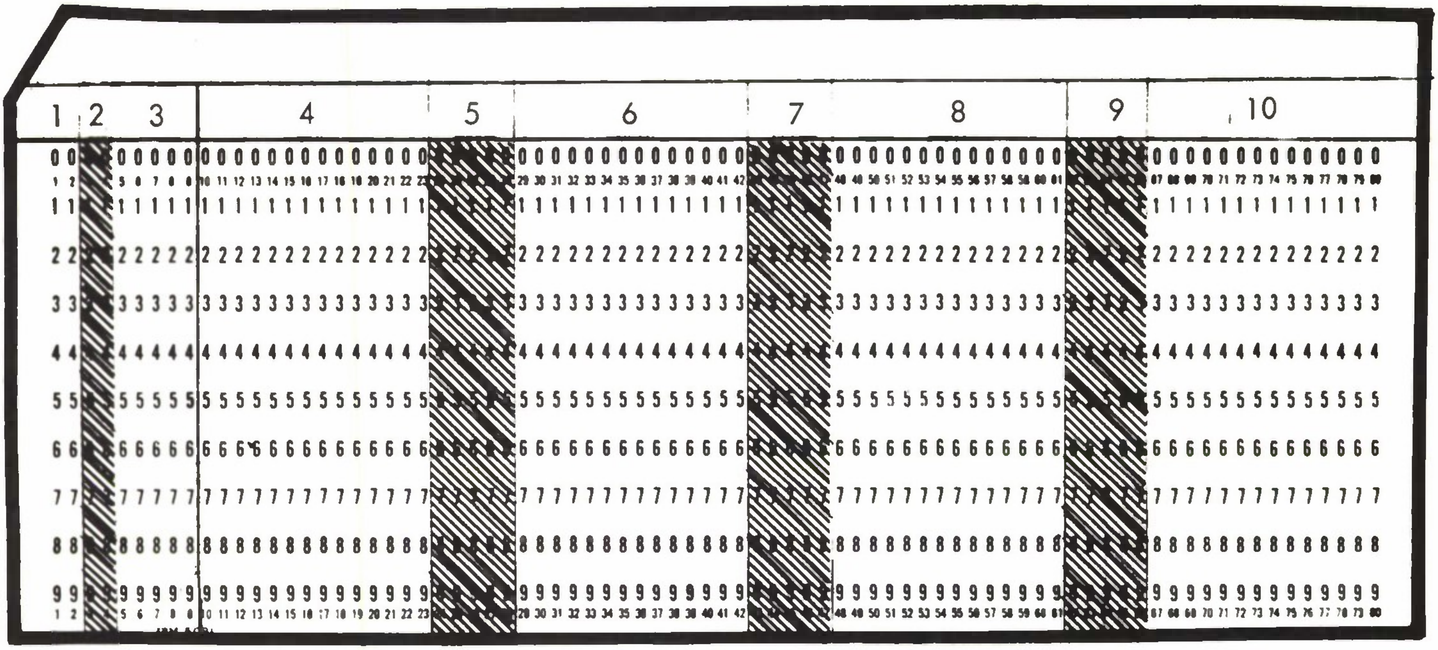
Figure 2-26. BNDS Card Format, Card No. 2

2.1.3.2.4 BISES. This name, derived from BIAS ESTIMATE, identifies the start of an array which contains the initial bias estimates of the Category 2 variables in the differential correction solution vector. They are specified in the same order as that for bounds. (See Section 2.1.3.2.3.) If any Category 2 initial estimate is specified, all must be specified. If a particular initial estimate is not known, zero (0.0) may be entered. The first four initial estimates of the set are entered in V-Field 1-4 of the first BISES card. Additional bias estimates, if any, are arranged in successive cards with no intervening blank V-Fields.

The following example illustrates the format of the BISES card. The bias estimates correspond to the Category 2 variables discussed in a previous section.

Category 2 initial estimates (and later improved values) are algebraically subtracted from the measured observations in the bias correction portion of ESPØD. If it is desired to remove a known bias, and not to allow it to change, the following procedure can be used:

- Specify a bias estimate with BISES
- Select the appropriate Category 2 variable in the solution vector with CAT2
- Set the corresponding bound to zero (0.0) with the BNDS input.

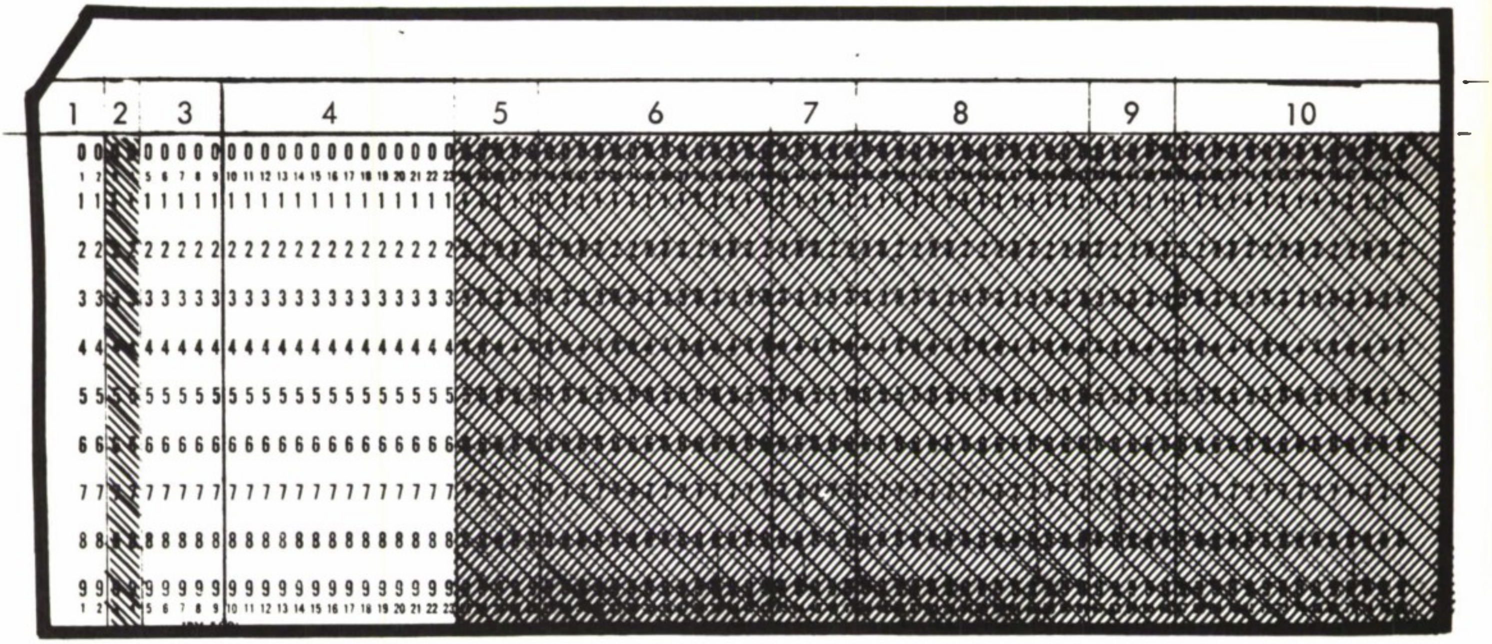


Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	BISES	Principal variable identifier
4	10-23	Estimated R_b	Range bias estimate
5	24-28	Blank	
6	29-42	Estimated A_b	Azimuth bias estimate
7	43-47	Blank	
8	48-61	Estimated E_b	Elevation bias estimate
9	62-66	Blank	
10	67-80	Estimated h_b	Height bias estimate

Figure 2-27. BISES Card Format

2.1.3.3 Convergence Control—NITER

ESPOD will automatically come to a stop if the solution either converges or diverges according to internal criteria. Under certain cases of slow convergence or instability ESPOD could run an undesirably long time. For this reason, it is necessary to limit the number of iterations which the program will be permitted to try. This is accomplished automatically with an internally contained value (5), but the value may be changed with a NITER (N iterations) card (see Figure 2-28).

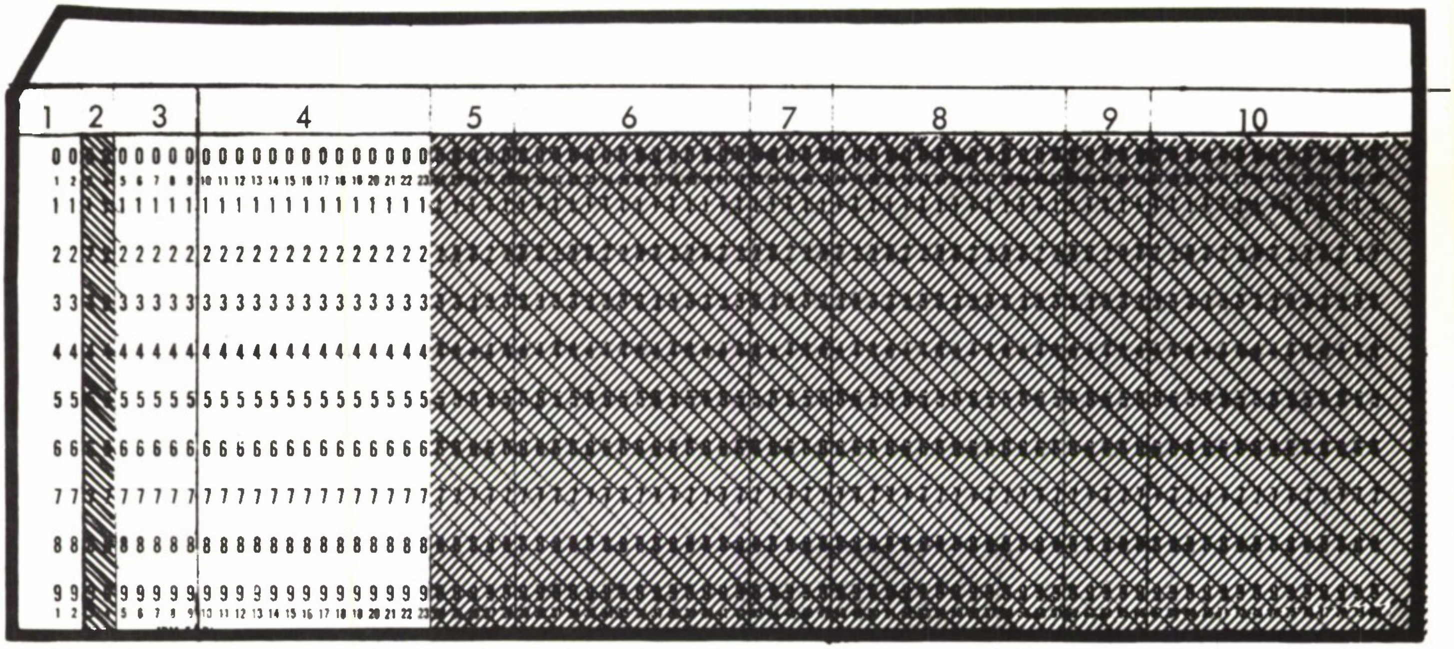


Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	NITER	Principal variable identifier
4	10-23	N.	Maximum iterations permitted
5-10	24-80	Not used	

Figure 2-28. NITER Card Format

2.1.3.4 Integration Control

ESP0D assumes an initial step size of numerical integration of one minute unless a TSTEP (Time STEP) card is provided (see Figure 2-29). Any other value of initial step size equal to $(P)(2)^{\pm m}$ (in minutes) where P and m are integers which may be specified. The maximum initial step size allowed is 128 minutes. The initial step size specifies the integration step at the beginning of the integration. ESP0D internal logic varies the step size to optimize the integration process. The maximum and minimum integration time step limits, and other constants in the integration process can be changed with a 99-card input (see Section 5.7 of ESD-TDR-64-395).



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	TSTEP	Principal variable identifier
4	10-23	X. 0	Nominal step size, in minutes
5-10	24-80	Not used	

Figure 2-29. TSTEP Card Format

2.1.3.5 Data Editing

This section is concerned with editing residuals and rejecting those which are not to be included in the differential correction. Items may be manually identified for rejection, and/or they may be rejected by comparison with a gross outlier test, and/or they may be rejected by comparison with some multiple K of the root mean square of the weighted residuals from the previous iteration, and/or they may be rejected if the corresponding observations are removed more than some arbitrary time from epoch. The following inputs are provided to correspond to the above options:

a. DELET card

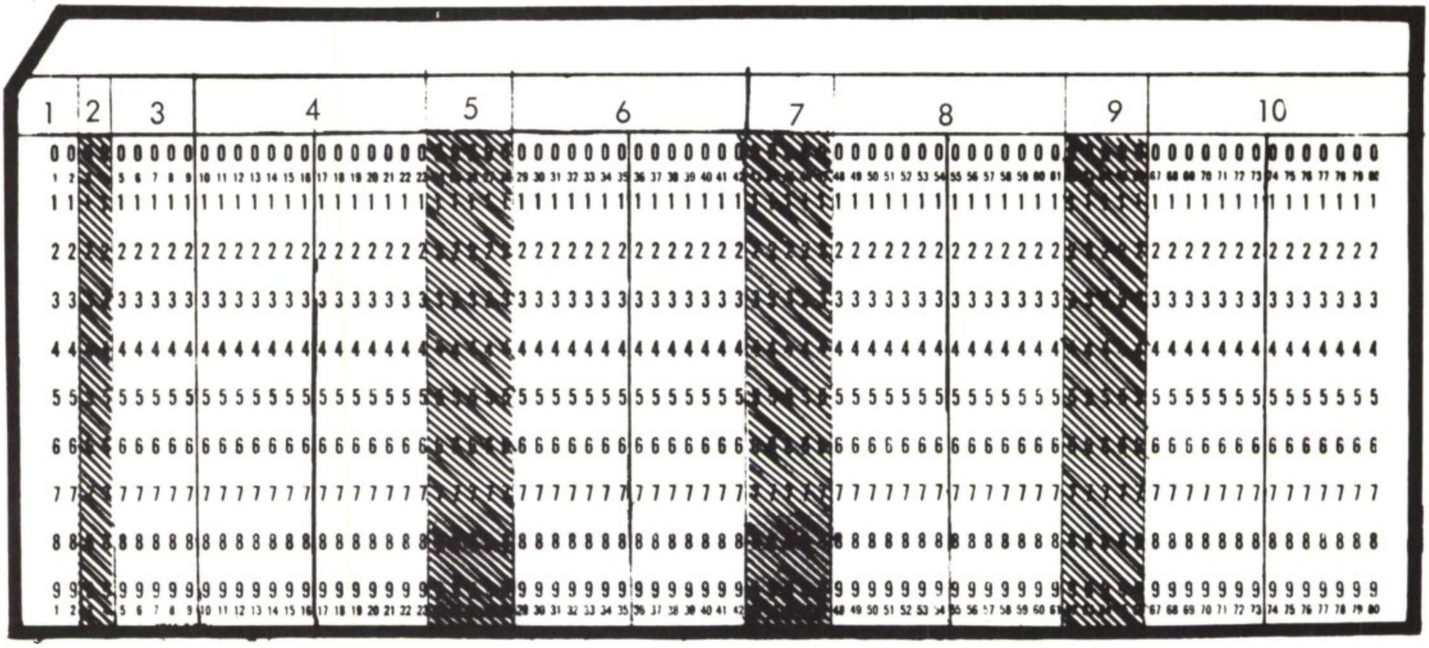
b. STYPE card to change gross outlier criterion and/or refractivity

c. 99-card item 452 to change K

d. TMAX to limit time from epoch

Residuals are weighted by the reciprocal of the standard deviation associated with the observation type and the sensor class. The sensor class is specified in a table stored in the program which can be changed with a STYPE card, item b. The standard deviations are also in a table stored in the program which can be changed with a SIGMA card (see Section 5.3 of ESD-TDR-64-395, "ESPOD Mathmatical and Subroutine Description").

2.1.3.5.1 DELET. DELET marks the beginning of a table of identification numbers of residuals to be deleted. The identification numbers are taken from the residuals listing output after running the computer at least once with the case in hand (see Section 4.2.5). V-Fields in DELET cards are specified in pairs (a, b) which mark respectively the first and last residual of a list of residuals to be deleted. The program deletes all residuals whose identification number lies between a and b inclusive. If a = b, a single residual is deleted. Up to 100 lists may be deleted.



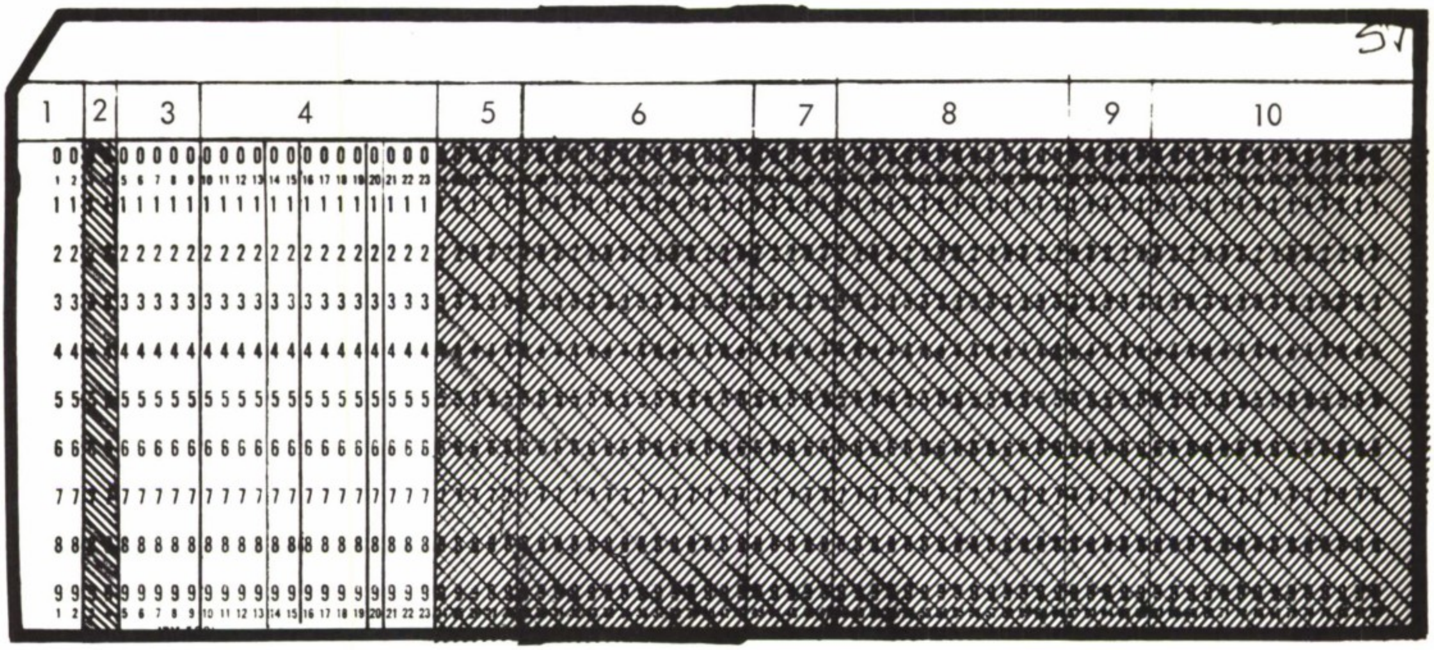
Field	Column	Content	Description
1	1-2	01	Sequence number (max = 25)
2	3-4	Blank	Iteration number
3	5-9	DELET	Principal variable identifier
4	10-16	a_1	First residual of first list to be deleted
4	17-23	b_1	Last residual of first list to be deleted
5	24-28	Blank	
6	29-35	a_2	First residual of second list to be deleted
6	36-42	b_2	Last residual of second list to be deleted
7	43-47	Blank	
8	48-54	a_3	First residual of third list to be deleted
8	55-61	b_3	Last residual of third list to be deleted
9	62-66	Blank	
10	67-73	a_4	First residual of fourth list to be deleted
10	74-80	b_4	Last residual of fourth list to be deleted

Figure 2-30. DELET Card Format

2.1.3.5.2 STYPE. Sensor characteristics contained in the sensor table can be changed with an STYPE card. The following parameters are contained in the sensor table identified by sensor numbers (corresponding card):

Symbol	Name
σ_t	Sigma type
G_s	Gross outliers criterion
R	Refraction flag
$\bar{N}_s$	Mean surface value of refractivity

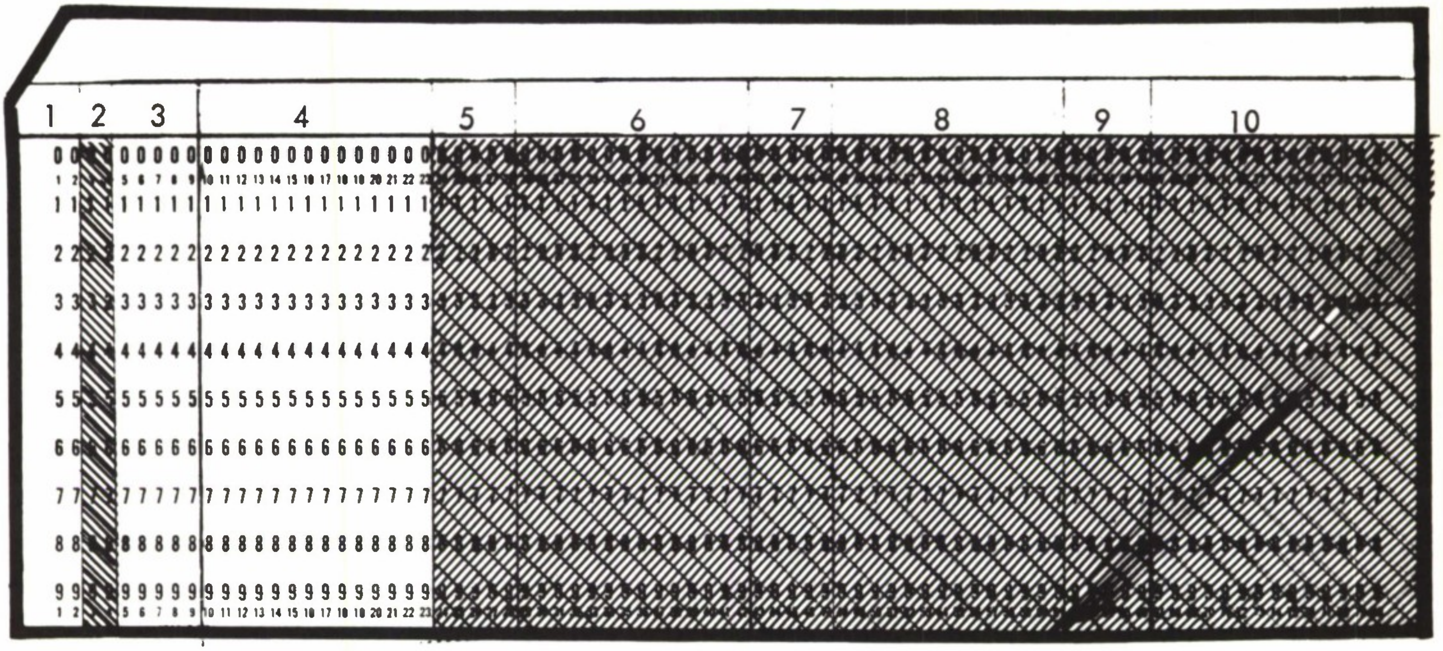
Format of the STYPE card is shown in Figure 2-31.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	STYPE	Principal variable identifier
4	10-13	No.	Sensor number
4	14-15	σ_T	Sigma type
4	16-19	G_s	Gross outliers criterion
4	20	RF	Refraction flag 0 = no refraction correction 1 = refraction correction
4	21-23	$\bar{N}_s$	Mean surface value of refractivity
5-10	24-80	Not used	

Figure 2-31. STYPE Card Format

2.1.3.5.3 TMAX. ESPOD will automatically reject observations which are more than ten days from epoch. This criterion interval can be changed with a TMAX (TIME Maximum) card.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	TMAX	Principal variable identifier
4	10-23	N. XX	Integration limit from epoch in days
5-10	24-80	Not used	

Figure 2-32. TMAX Card Format

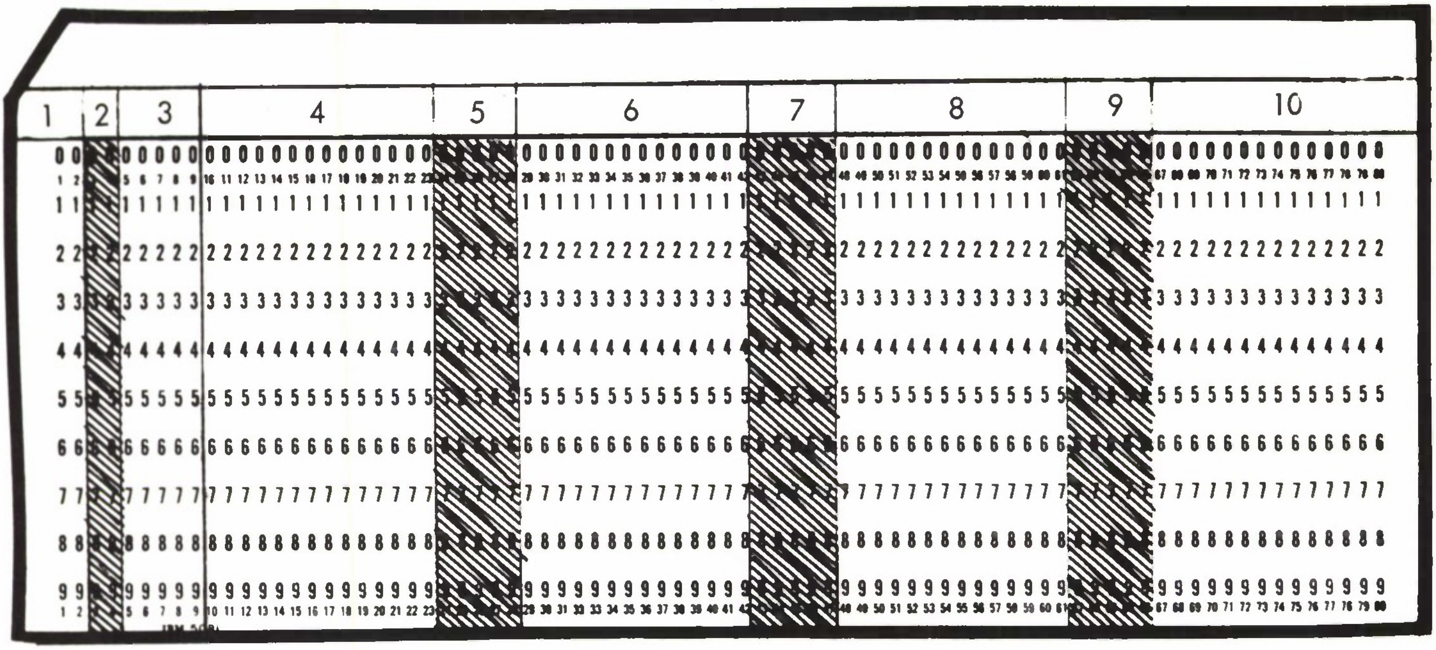
2.1.3.5.4 SIGMA. ESPOD always performs a weighted differential correction. Weights are assigned to observations from a row of the standard deviation (SIGMA) table. The row is selected appropriate to a particular sensor. The row number is the "sigma type" (see field 4 of STYPE card, Section 2.1.3.5.2) recorded in the sensor table. There are 60 rows in the SIGMA table. Each row contains four values which are interpreted differently for radar measurements than for camera measurements.

Table 2-I. SIGMA Table

	Value 1	Value 2	Value 3	Value 4
RADAR	σ_R	σ_A	σ_E	$\sigma_{\dot{R}}$
Banker Nunn Camera	σ_α (FR)	σ_δ (FR)	σ_α (PR)	σ_δ (PR)

(FR) Field Reduced Data
(PR) Precision Reduced Data

Any line entry of the SIGMA table can be changed with a SIGMA card. As many may be changed as necessary. Nominal values stored in the program may be printed for review on option. See Figure 2-33 for field layout.



Field	Column	Content	Description
1	1-2	NN	Sensor type
2	3-4	Blank	Iteration number
3	5-9	SIGMA	Principal variable identifier
4	10-23	σ_R	Radar: Standard deviation in range
		σ_α (FR)	Camera: Standard deviation in right ascension, field reduced
5	24-28	Blank	
6	29-42	σ_A	Radar: Standard deviation in azimuth
		σ_δ (FR)	Camera: Standard deviation in declination, field reduced
7	43-47	Blank	
8	48-61	σ_E	Radar: Standard deviation in elevation
		σ_α (PR)	Camera: Standard deviation in right ascension, precision reduced
9	62-66	Blank	
10	67-80	$\sigma_{\dot{R}}$	Radar: Standard deviation in range rate
		σ_δ (PR)	Camera: Standard deviation in declination, precision reduced

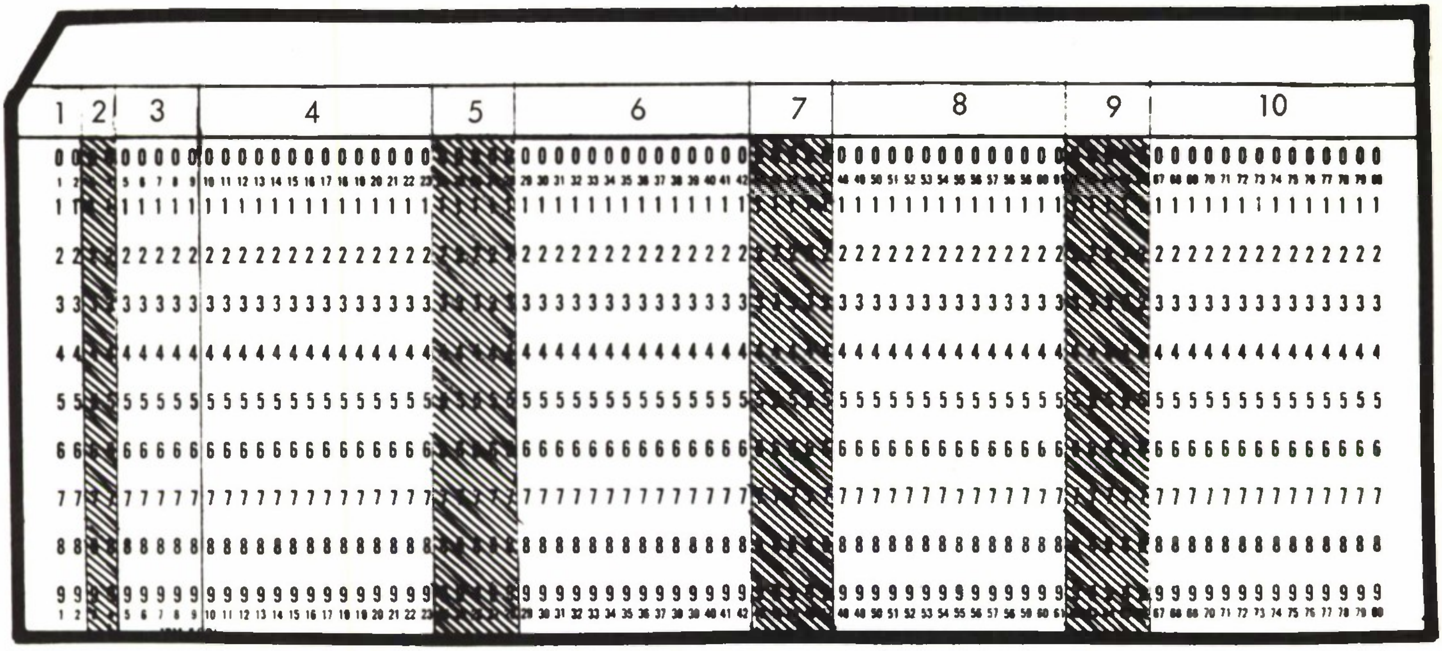
Figure 2-33. SIGMA Card Format

2.1.3.6 Atmospheric Drag

ESPOD provides on option three drag models and four atmosphere models. Two of the atmosphere models require the specification of the parameters A_p and F_{10}. Refer to Section 5.10 of ESD-TDR-64-395, "ESPOD Mathematical and Subroutine Description," for full information regarding the use of the atmospheric drag options.

2.1.3.6.1 Drag. To include atmospheric drag in the Category 1 variables a DRAG card must be input. The following items are specified on the DRAG card:

Symbol	Description
$C_DA/2m$ ($\neq 0$)	Drag parameter estimate
K($\neq$ 0)	Drag variation options: Blank 0. } No variation 1. Secular variation 2. Periodic variation
	Model Atmosphere Options: Blank 0. } COESA 62 Static 3. 1. ARDC 59 2. Paetzold dynamic 4. COESA dynamic

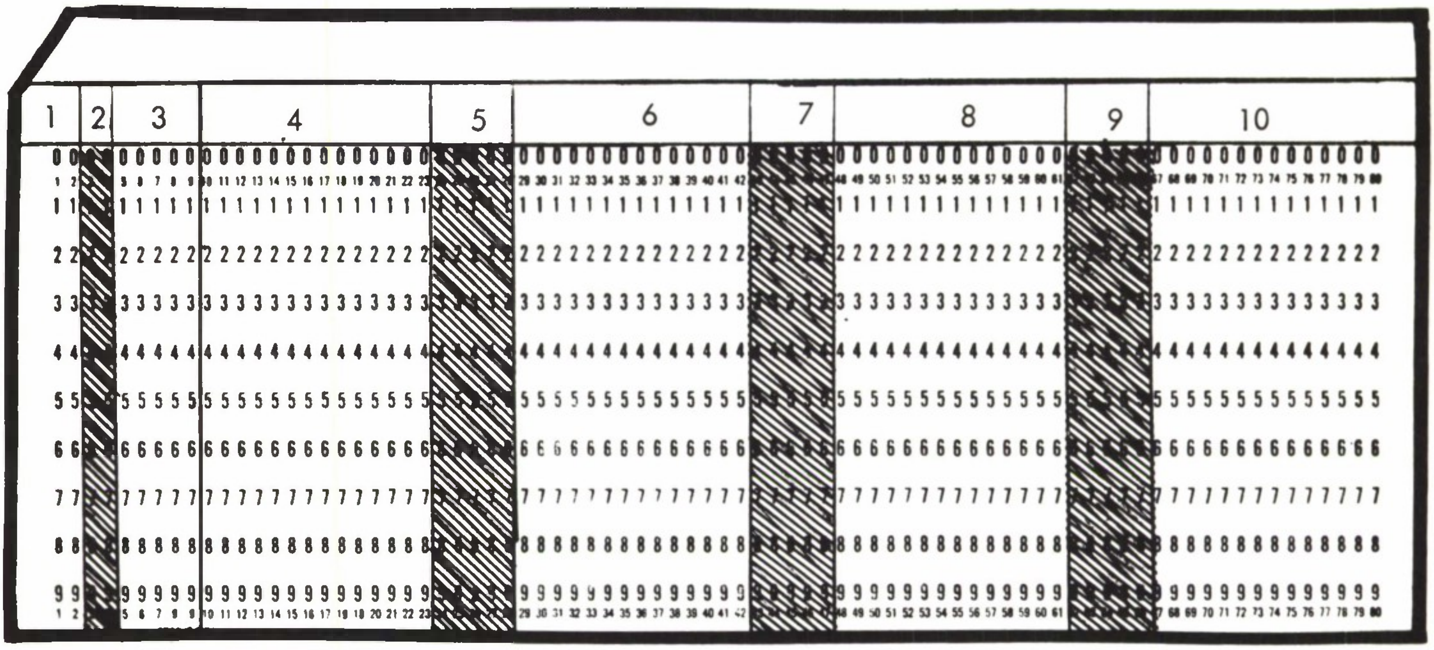


Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	DRAG	Principal variable identifier
4	10-23	$C_DA/2m$	Drag parameter estimate $(\neq 0)$
5	24-28	Blank	
6	29-42	K	Drag parameter variation estimate $(\neq 0)$
7	43-47	Blank	
8	48-61	1. or 2.	Drag model option
9	62-66	Blank	
10	67-80	1., 2., 3., or 4.	Atmospheric model options

Figure 2-34. DRAG Card Format

2.1.3.6.2 APF10. When a dynamic atmosphere is chosen on the DRAG card, an APF10 card(s) must be supplied. A_p is the daily geomagnetic planetary amplitude or an approximation to it. F_{10} is the 10.7 centimeter solar flux. See Section 5.10.4 of ESD-TDR-64-395, "ESPOD Mathematical and Subroutine Description," for sources of A_p and F_{10}.

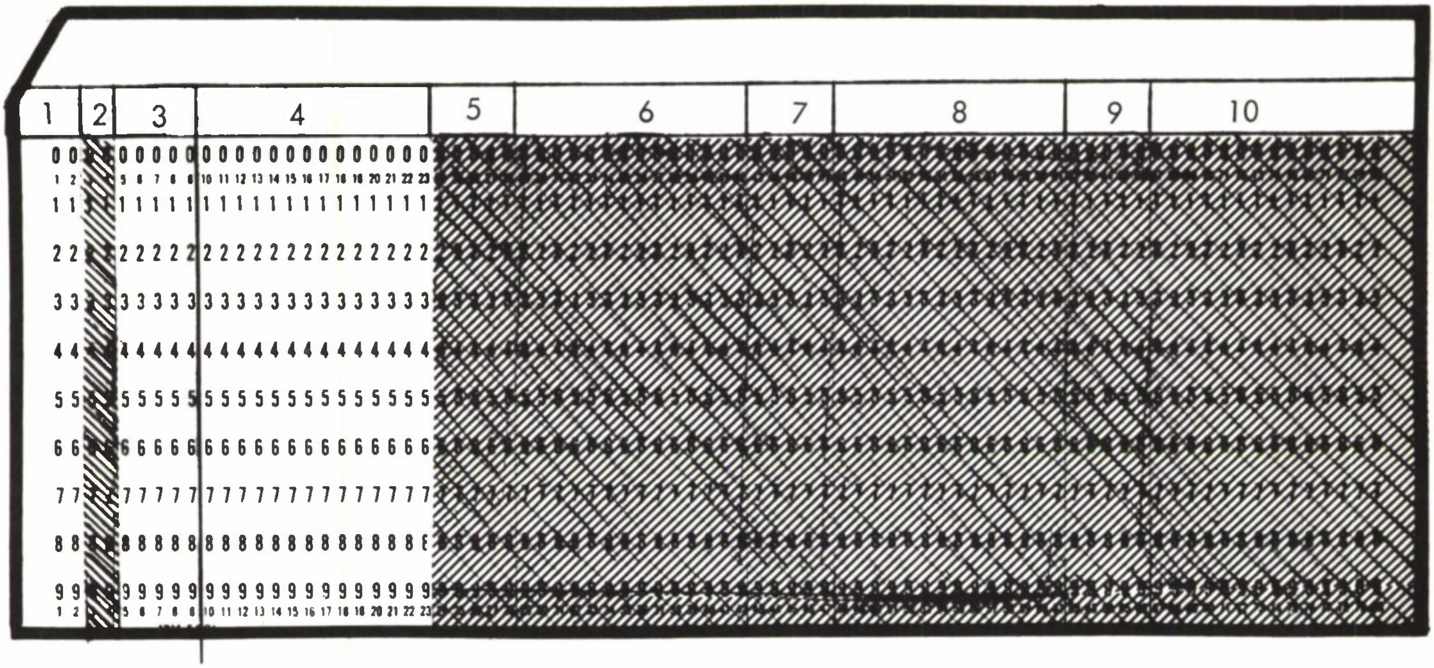
A single value of A_p and F_{10} specified only for the day of epoch indicates that it is intended as an average value, and ESPOD will use it for each day covered by the curve fit or trajectory. Values of A_p and F_{10} may be specified separately for each day of integration.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	APF10	Principal variable identifier
4	10-13	NNN.	Day of year corresponding to values of A_p, F10.
4	14-18	A_p	Geomagnetic planetary amplitude
4	19-23	F_{10}	10.7 cm solar flux
5	24-28	Blank	
6	29-32	NNN.	Day of year
6	33-37	A_p	
6	38-42	F_{10}	
7	43-47	Blank	
8	48-51	NNN.	
8	52-56	A_p	
8	57-61	F_{10}	
9	62-66	Blank	
10	67-70	NNN.	
10	71-75	A_p	
10	76-80	F_{10}	

Figure 2-35. APF10 Card Format, Card No. 1

APF10, No. 2 APF10, No. 2



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	APF10	Principal variable identifier
4	10-13	NNN.	Day of epoch
4	14-18	A_p	Geomagnetic planetary amplitude, average value
4	19-23	F_{10}	10.7 cm solar flux, average value
5-10	24-80	Not used	

Figure 2-36. APF10 Card Format, Card No. 2

2.1.3.7 Earth Potential Model

ESPOD automatically provides a simple Earth potential model in the absence of any specified input (see Model 1 in Table 2-II). For different or more complicated models, modifications to the stored parameters and callouts for higher potential harmonics are required. See Section 5.8 of ESD-TDR-64-395, "ESPOD Mathematical and Subroutine Description," for detailed discussion of the Earth's gravitational potential model.

Modifications to the stored constants are made by means of "99" cards (see Section 2.1.3.11). Callout of higher potential harmonics are made by means of the ZONAL, SECTR, and TESSR cards. For the ZONAL and SECTR cards, a "1" in a particular column indicates that the corresponding coefficient of the spherical harmonic is to be included. See Table 2-II for card column assignments. In the TESSR card, the order of callout is not important. A "42" in an allowed subfield indicates that the $J_{4,2}$ tesseral harmonic is to be included. The range of coefficients of the tesseral harmonics permissible (14 in all) is given in Table 2-II.

Table 2-II is a summary of the potential models and the respective harmonic coefficients. Model 1 is the nominal model; that is, it is the model which ESPOD will use when none other is specified. Note that the coefficients of the zonal harmonics J_{10}, J_{11}, and J_{12} are nominally zero in the program. The same is true for the coefficients of the sectorial and tesseral harmonics of order 5 and 6. Values for these coefficients, whose core locations are indicated, may be input on 99-cards.

Table 2-II. Earth Potential Model Options and Nominal Values of Harmonics

		Stored in Program		Model 1		Model 2		Model 3		Model 4		99 Card ID		PRELIM Card Format to Select Term	
n	m	$J_{n,m} \times 10^{+6}$	$\lambda_{n,m}$	$J_{n,m} \times 10^{6}$	$\lambda_{n,m}$	$J_{n,m} \times 10^{6}$	$\lambda_{n,m}$	$J_{n,m} \times 10^{6}$	$\lambda_{n,m}$	$J_{n,m} \times 10^{6}$	$\lambda_{n,m}$	$J_{n,m}$	$\lambda_{n,m}$	Card	Column
2		1082.30		1082.30		1082.48[*]		Use Model 2		Use Model 2		159		ZØNAL	10
3		-2.3		-2.3		-2.562[*]						160		ZØNAL	11
4		-1.8		-1.8		-1.84[*]						161		ZØNAL	12
5		-0.064		OMIT		-0.064						162		ZØNAL	13
6		0.390				0.390						163		ZØNAL	14
7		-0.470				-0.470						164		ZØNAL	15
8		-0.020				-0.020						165		ZØNAL	16
9		0.117				0.117						166		ZØNAL	17
10												167		ZØNAL	18
11												168		ZØNAL	19
12												169		ZØNAL	20
1	1	0		OMIT		OMIT						170		--	--
2	1	0										171		TESSR	Specify 2, 1
2	2	2.32	-37.5					2.32	-37.5	2.32	-37.5	177	206	SECTR	10
3	1	3.95	22							3.95	22	172	182	TESSR	Specify 3, 1
3	2	0.41	31							0.41	31	178	183	TESSR	Specify 3, 2
3	3	1.91	51.3							1.91	51.3	184	207	SECTR	11

---

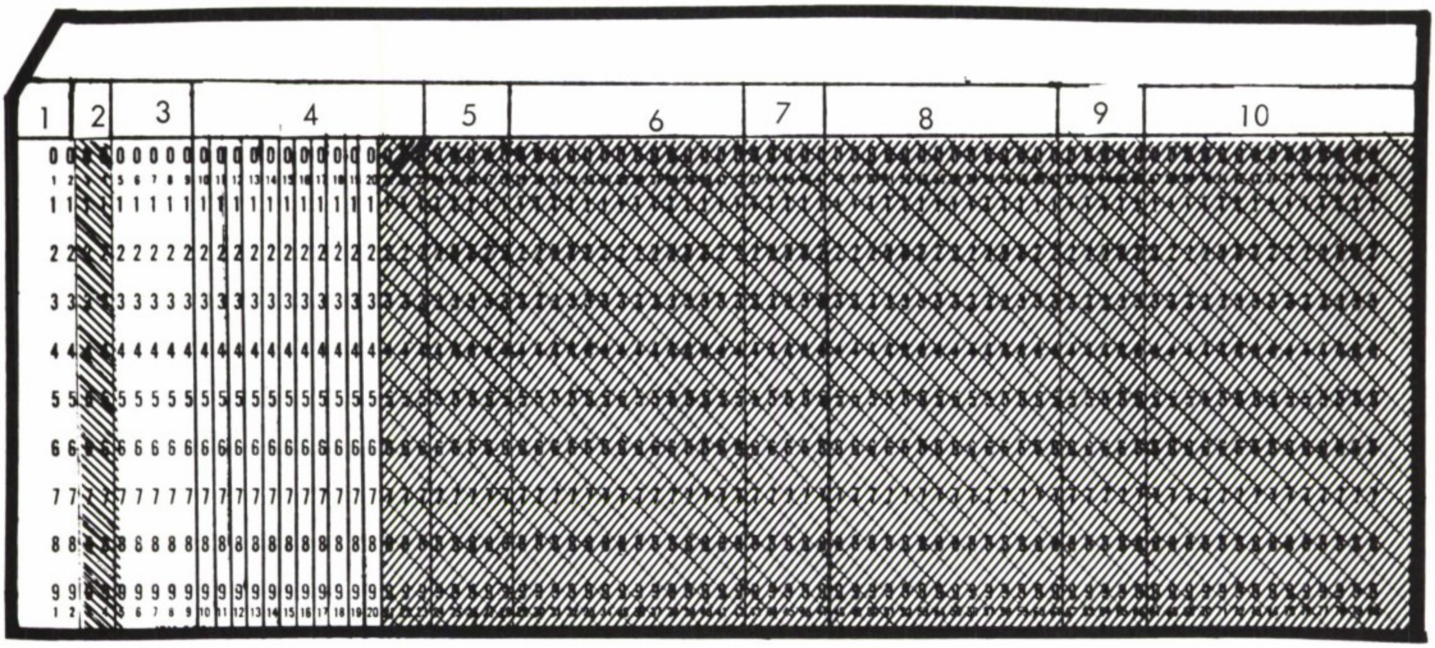
[*] These values must be specially inserted by 99-card input when using Models 2, 3, and 4. See Section 5.0, ESPOD Operating Instructions and Card Formats.

Table 2-II. Earth Potential Model Options and Nominal Values of Harmonics (Continued)

		Stored in Program		Model 1		Model 2		Model 3		Model 4		99 Card ID		PRELIM Card Format to Select Term	
n	m	$J \times 10^{+6}$	λ	$J \times 10^{6}$	λ	$J \times 10^{6}$	λ	$J \times 10^{6}$	λ	$J \times 10^{6}$	λ			Card	Column
4	1	2.64	163.5	OMIT		OMIT				2.64	163.5	173	188	TESSR	Specify 4, 1
4	2	1.67	54.							1.67	54.	179	189	TESSR	Specify 4, 2
4	3	0.46	-13.							0.46	-13.	185	190	TESSR	Specify 4, 3
4	4	0.56	50.3							0.56	50.3	191	208	SECTR	12
5	1	0	0									174	194	TESSR	Specify 5, 1
5	2	0	0									180	195	TESSR	Specify 5, 2
5	3	0	0									186	196	TESSR	Specify 5, 3
5	4	0	0									192	197	TESSR	Specify 5, 4
5	5	0	0									198	209	SECTR	13
6	1	0	0									175	200	TESSR	Specify 6, 1
6	2	0	0									181	201	TESSR	Specify 6, 2
6	3	0	0									187	202	TESSR	Specify 6, 3
6	4	0	0									193	203	TESSR	Specify 6, 4
6	5	0	0									199	204	TESSR	Specify 6, 5
6	6	0	0									205	210	SECTR	14

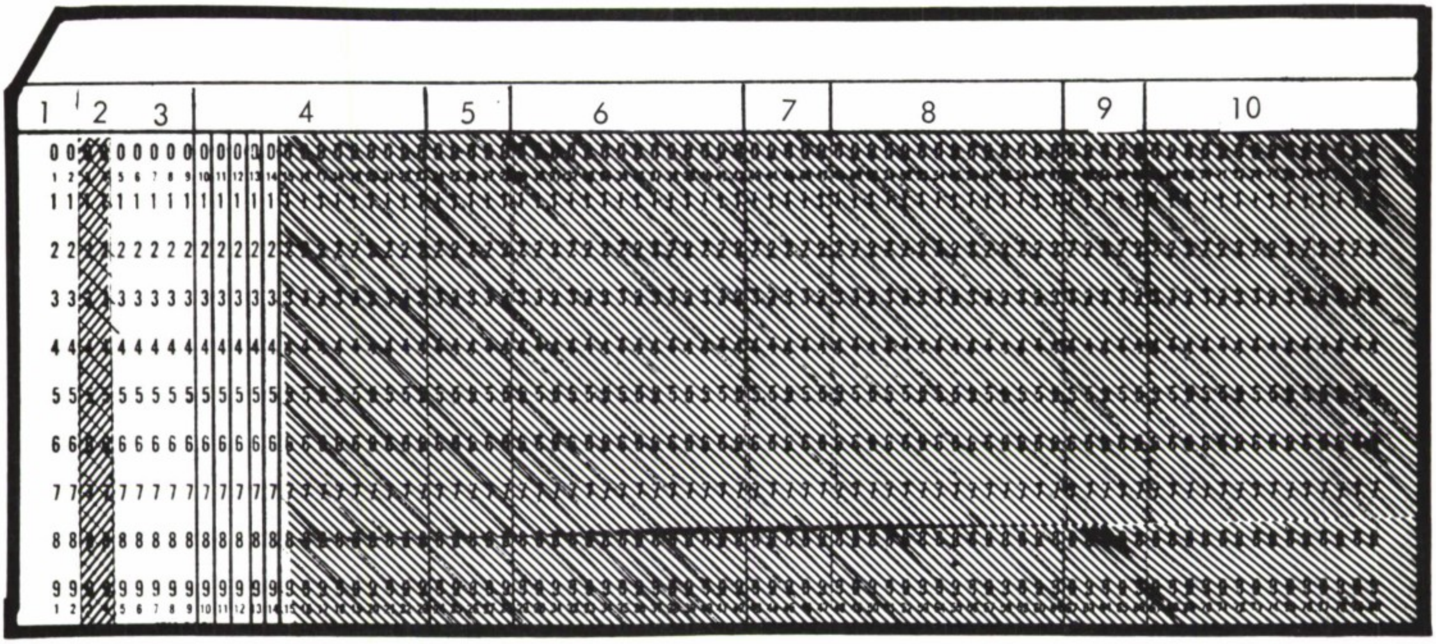
---

*These values must be specially inserted by 99-card input when using Models 2, 3, and 4. See Section 5.0, ESPOD Operating Instructions and Card Formats.



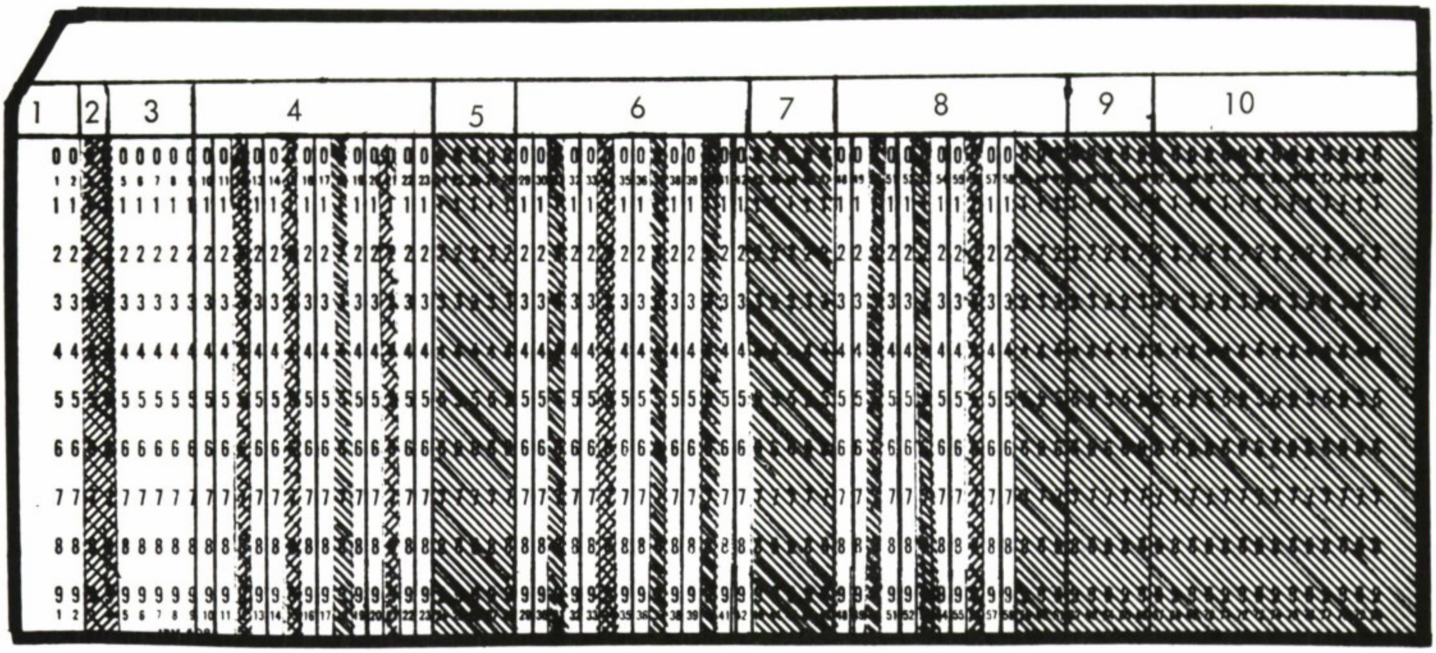
Field	Column	Content	Description	
1	1-2	01	Sequence number	
2	3-4	Blank	Iteration number	
3	5-9	ZØNAL	Principal variable identifier	
4	10	0 or 1	J_2	0 = delete 1 = include
4	11	0 or 1	J_3	0 = delete 1 = include
4	12	0 or 1	J_4	0 = delete 1 = include
4	13	0 or 1	J_5	0 = delete 1 = include
4	14	0 or 1	J_6	0 = delete 1 = include
4	15	0 or 1	J_7	0 = delete 1 = include
4	16	0 or 1	J_8	0 = delete 1 = include
4	17	0 or 1	J_9	0 = delete 1 = include
4	18	0 or 1	J_{10}	0 = delete 1 = include
4	19	0 or 1	J_{11}	0 = delete 1 = include
4	20	0 or 1	J_{12}	0 = delete 1 = include
4	21-23	Not used		
5-10	24-80	Not used		

Figure 2-37. ZØNAL Card Format



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	SECTR	Principal variable identifier
4	10	0, 1	$J_{2,2}$ 0 = delete 1 = include
4	11	0, 1	$J_{3,3}$ 0 = delete 1 = include
4	12	0, 1	$J_{4,4}$ 0 = delete 1 = include
4	13	0, 1	$J_{5,5}$ 0 = delete 1 = include
4	14	0, 1	$J_{6,6}$ 0 = delete 1 = include
4	15-23	Not used	
5-10	24-80	Not used	

Figure 2-38. SECTR Card Format



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	TESSR	Principal variable identifier
4	10, 11	n, m	$J_{n,m}$
4	12	Blank	
4	13, 14	n, m	$J_{n,m}$
4	15	Blank	
4	16, 17	n, m	$J_{n,m}$
4	18	Blank	
4	19, 20	n, m	$J_{n,m}$
4	21	Blank	
4	22, 23	n, m	$J_{n,m}$
5	24-28	Blank	
6	29, 30	n, m	$J_{n,m}$
6	31		
6	32, 33	n, m	$J_{n,m}$

Figure 2-39. TESSR Card Format

Field	Column	Content	Description
6	34	Blank	
6	35, 36	n, m	$J_{n,m}$
6	37	Blank	
6	38, 39	n, m	$J_{n,m}$
6	40	Blank	
6	41, 42	n, m	$J_{n,m}$
7	43-47	Blank	
8	48, 49	n, m	$J_{n,m}$
8	50	Blank	
8	51, 52	n, m	$J_{n,m}$
8	53	Blank	
8	54, 55	n, m	$J_{n,m}$
8	56	Blank	
8	57, 58	n, m	$J_{n,m}$
8	59-61	Not used	
9-10	62-80	Not used	

For $J_{n,m}$: $n = 3, \cdots 6$, $m = 1, \cdots 5$, and $n > m$. Fourteen values of $J_{n,m}$ are possible and any number of values from one through 14 may be used. They need not be in order for n or m but two or more identical values of $J_{n,m}$ on any one card are not permitted.

Figure 2-39. TESSR Card Format (Continued)

2.1.3.7.1 Deck Setup for Potential Model 2. This model includes the coefficients of the zonal harmonics J_2 through J_9. A 99-card is required to change the zonal constants J_2, J_3 and J_4 from those stored in program.

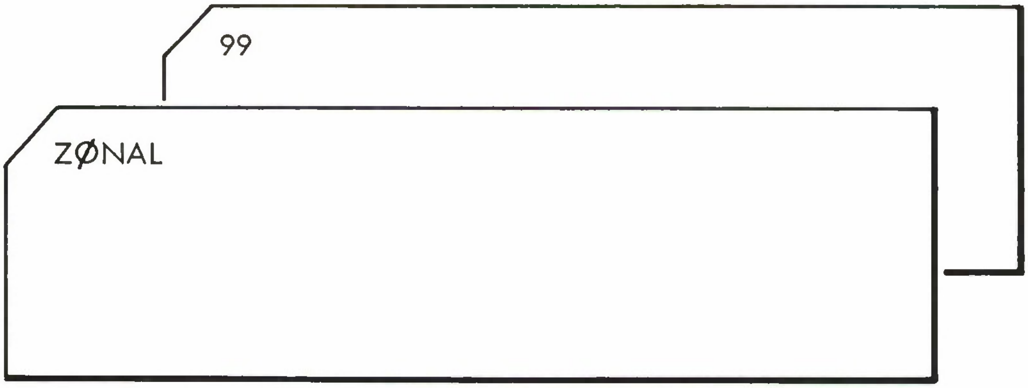
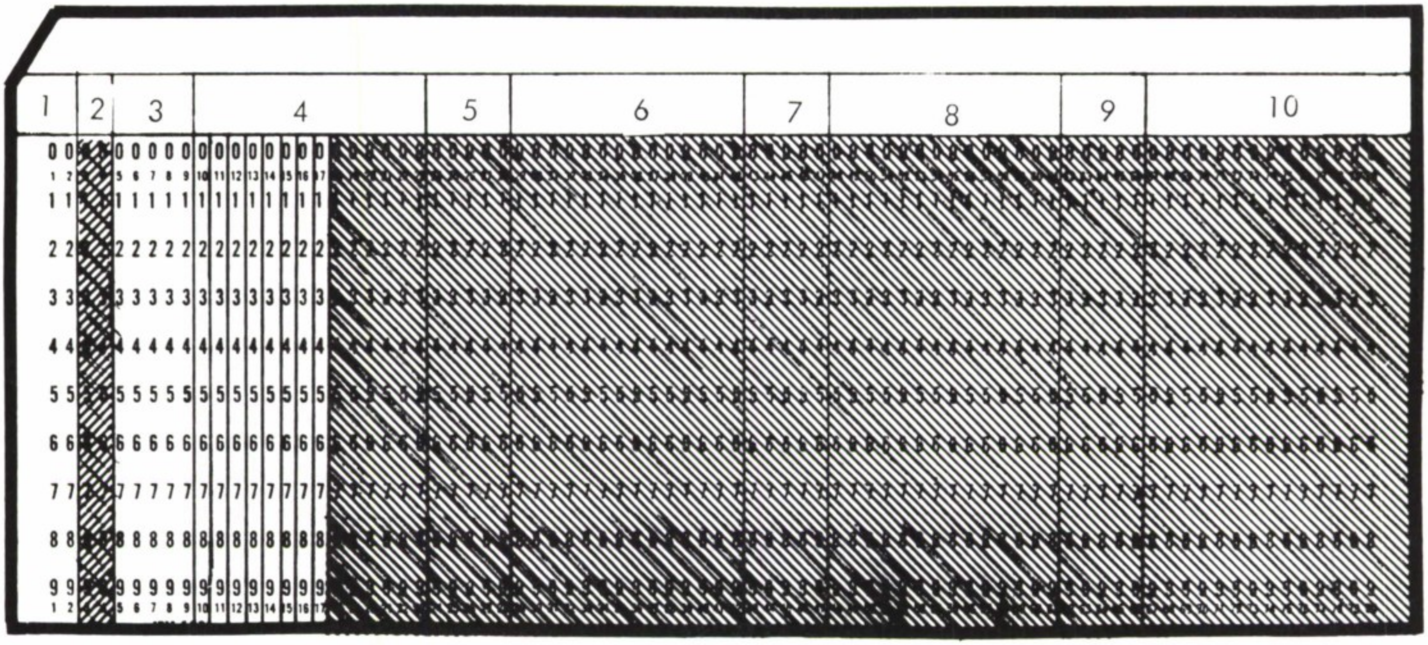
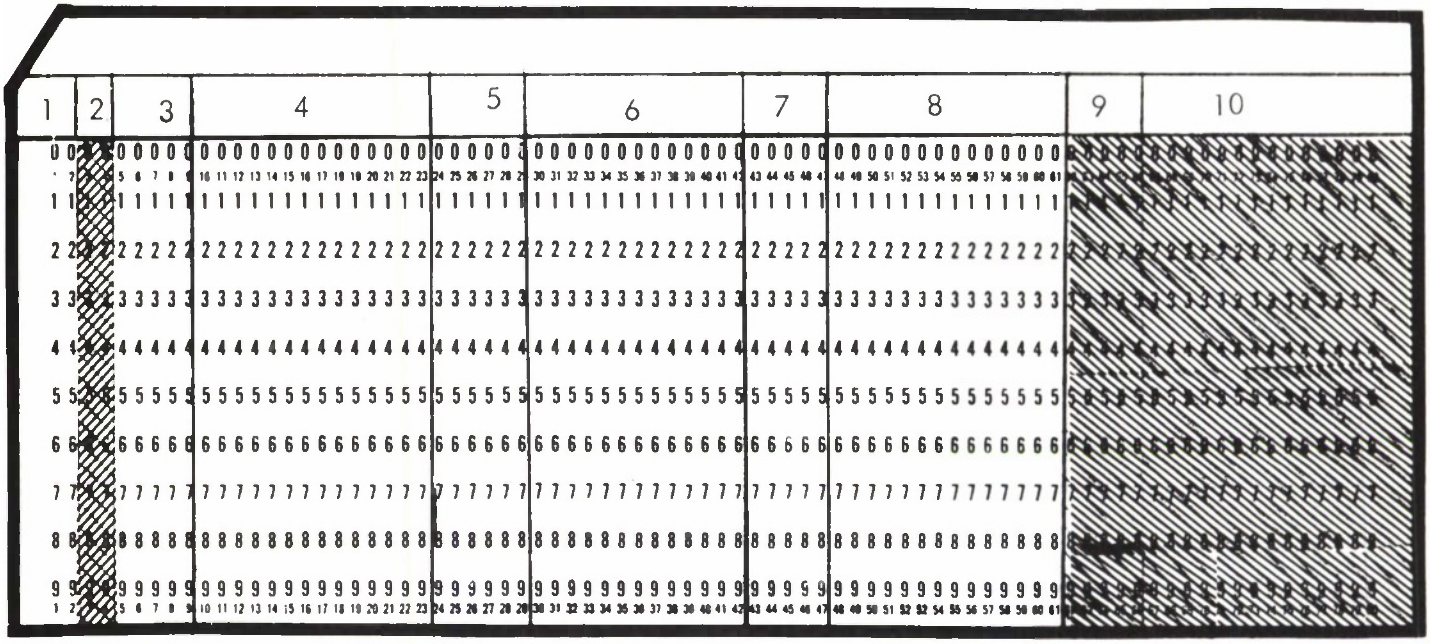


Figure 2-40. Model 2 Card Setup



Field	Column	Content
1	1-2	01
2	3-4	Blank
3	5-9	ZØNAL
4	10-17	"1" in every column
4	18-20	Blank
4	21-23	Not used
5-10	24-80	Not used

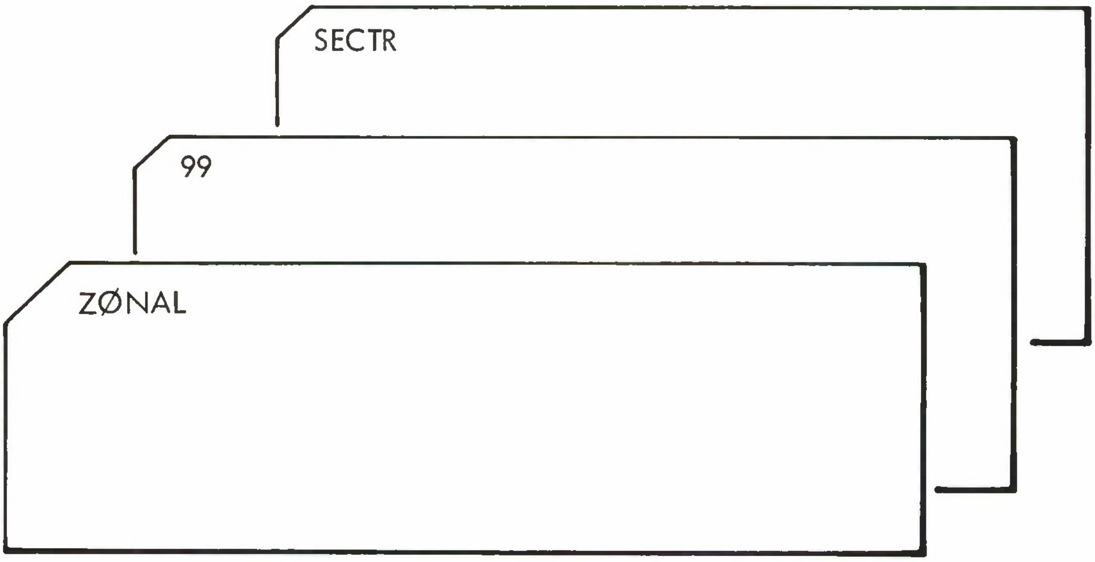
Figure 2-41. ZØNAL Card Format, Potential Model 2



Field	Column	Content
1	1-2	99
2	3-4	Blank
3	5-9	00159
4	10-23	1082.48 ΔΔΔΔ -06
5	24-28	00160
6	29-42	-2.562 ΔΔΔΔΔ -06
7	43-47	00161
8	48-61	-1.84 ΔΔΔΔΔΔ -06
9 and 10	62-80	Blank

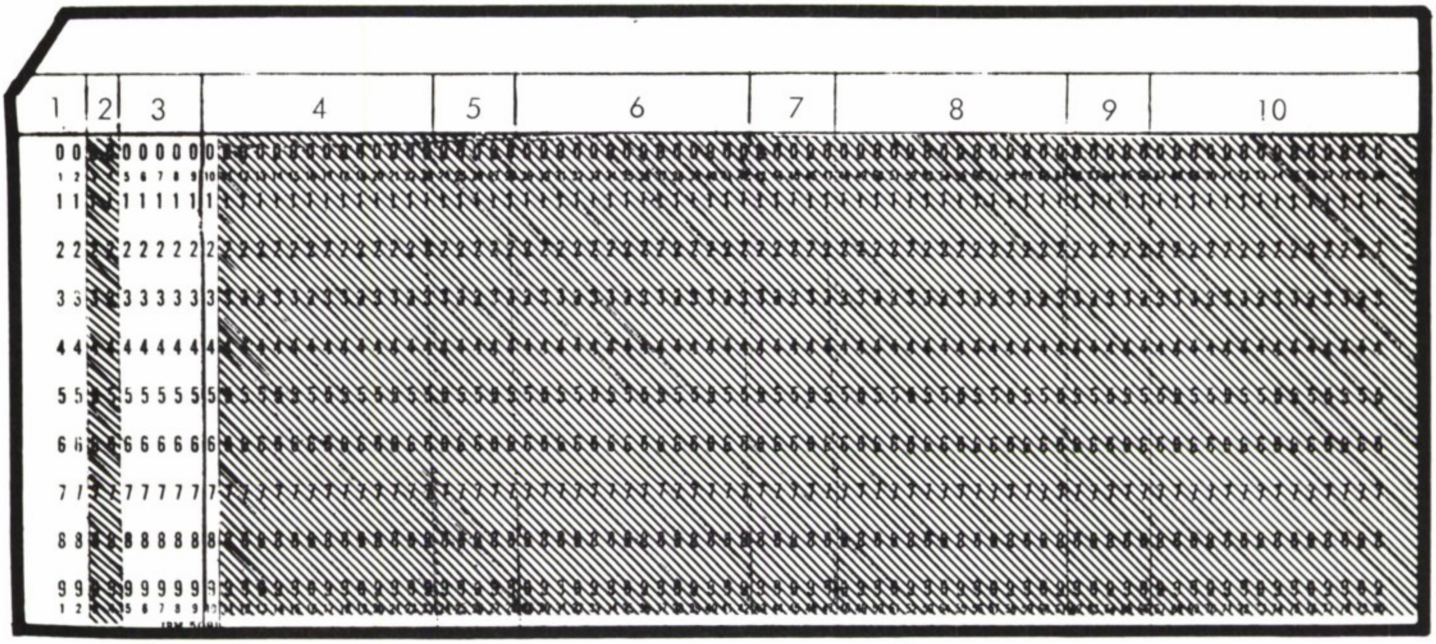
Figure 2-42. 99-Card Format, Potential Model 2

2.1.3.7.2 Deck Setup for Potential Model 3. Model 3 consists of the coefficients of the zonal harmonics through J_9. (J_2, J_3, J_4 are the alternate values) and the second coefficient of the sectorial harmonic, $J_{2,2}$.



ZØNAL Card format shown in Figure 2-41.
99 Card format shown in Figure 2-42.

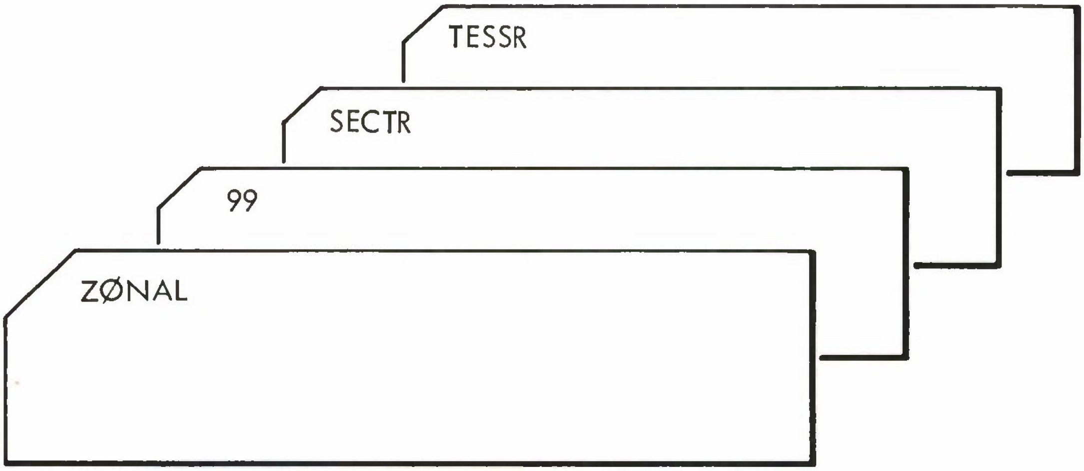
Figure 2-43. Model 3 Card Set-up



Field	Column	Content
1	1-2	01
2	3-4	Blank
3	5-9	SECTR
4	10	"1"
4	11-14	Blank
4	15-23	Not used
5-10	24-80	Not used

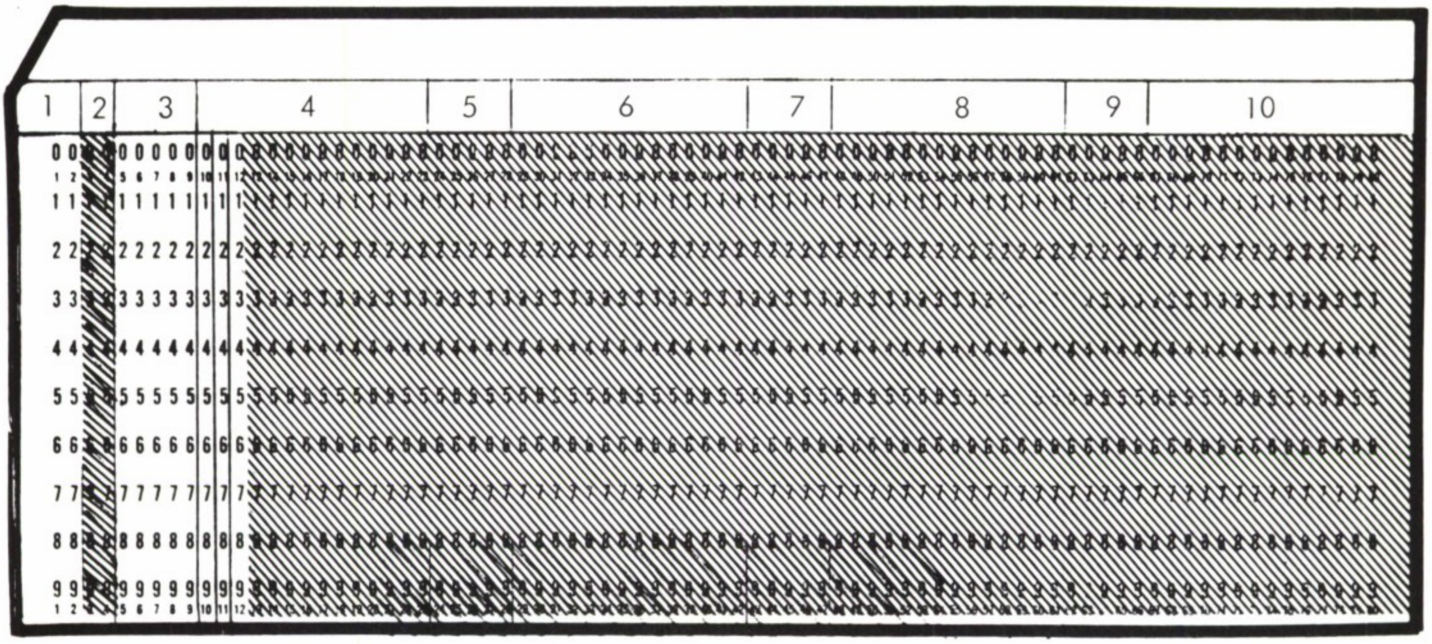
Figure 2-44. SECTR Card Format, Potential Model 3

2.1.3.7.3 Deck Setup for Potential Model 4. Model 4 includes the coefficients of the zonal harmonics through J_9, the second, third, and fourth coefficients of the sectorial harmonics, and the coefficients of the tesseral harmonics through $J_{4,3}$. Alternate values of J_2, J_3, J_4 are required as in Model 2.



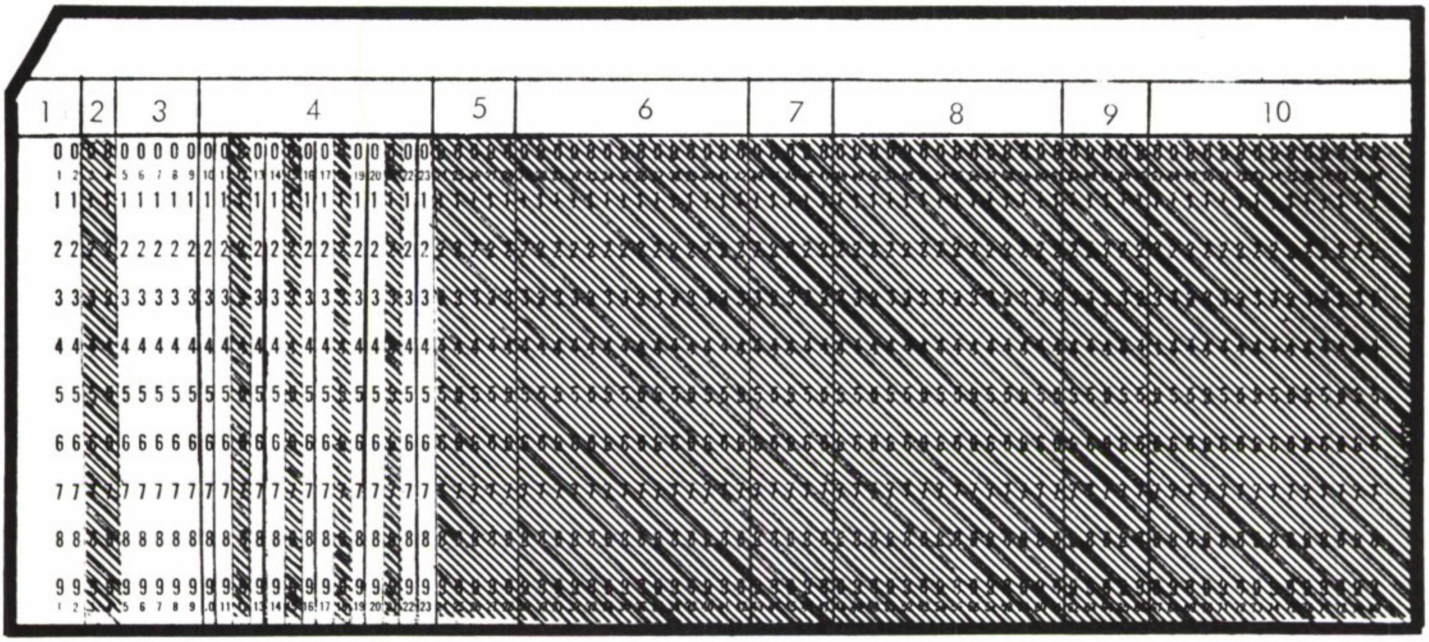
ZØNAL Card format shown in Figure 2-41.
99 Card format shown in Figure 2-42.

Figure 2-45. Model 4 Card Setup



Field	Column	Content
1	1-2	01
2	3-4	Blank
3	5-9	SECTR
4	10-12	"1" in every column
4	13-14	Blank
4	15-23	Not used
5-10	24-80	Not used

Figure 2-46. SECTR Card Format, Potential Model 4



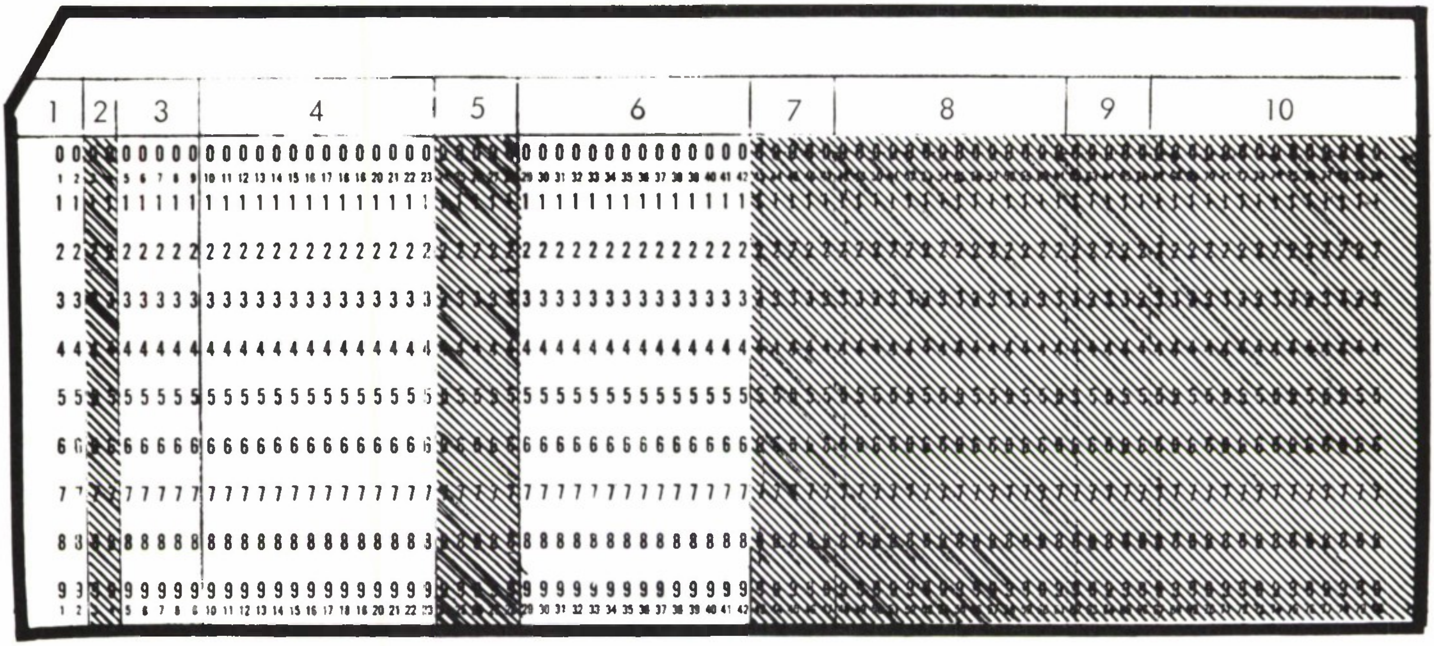
Field	Column	Content
1	1-2	01
2	3-4	Blank
3	5-9	TESSR
4	10-11	31
4	12	Blank
4	13-14	32
4	15	Blank
4	16-17	41
4	18	Blank
4	19-20	42
4	21	Blank
4	22-23	43
5	24-28	Blank
6	29-42	Blank
7	43-47	Blank
8	48-58	Blank
8	59-61	Not used
9-10	62-80	Not used

Figure 2-47. TESSR Card Format, Potential Model 4

2.1.3.8 Radiation Pressure

ESPOD accounts for radiation pressure as a function of spacecraft mass and effective area. The effective area is a complex function of the surface reflection and the type of reflection. See ESD-TDR-64-395, "Mathematical and Subroutine Description," Section 5.11, for a discussion of the radiation pressure model in ESPOD. However, the effective area is at least equal to the spacecraft area and is typically 10 percent greater. The effect of satellite eclipsing may be accounted for by multiplying the effective area by (1 - f), where f is the fraction representing the time the satellite is in earth shadow.

For the inclusion of radiation pressure effects, a RADPR card specifying the mass and area (modified, if needed) must be included in the preliminary data. Its format is shown in Figure 2-48.



Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	RADPR	Principal variable identifier
4	10-23	M^2	Effective area of the spacecraft in square meters
5	24-28	Blank	
6	29-42	Kg	Mass of the spacecraft in kilograms
7-10	43-80	Not used	

Figure 2-48. RADPR Card Format

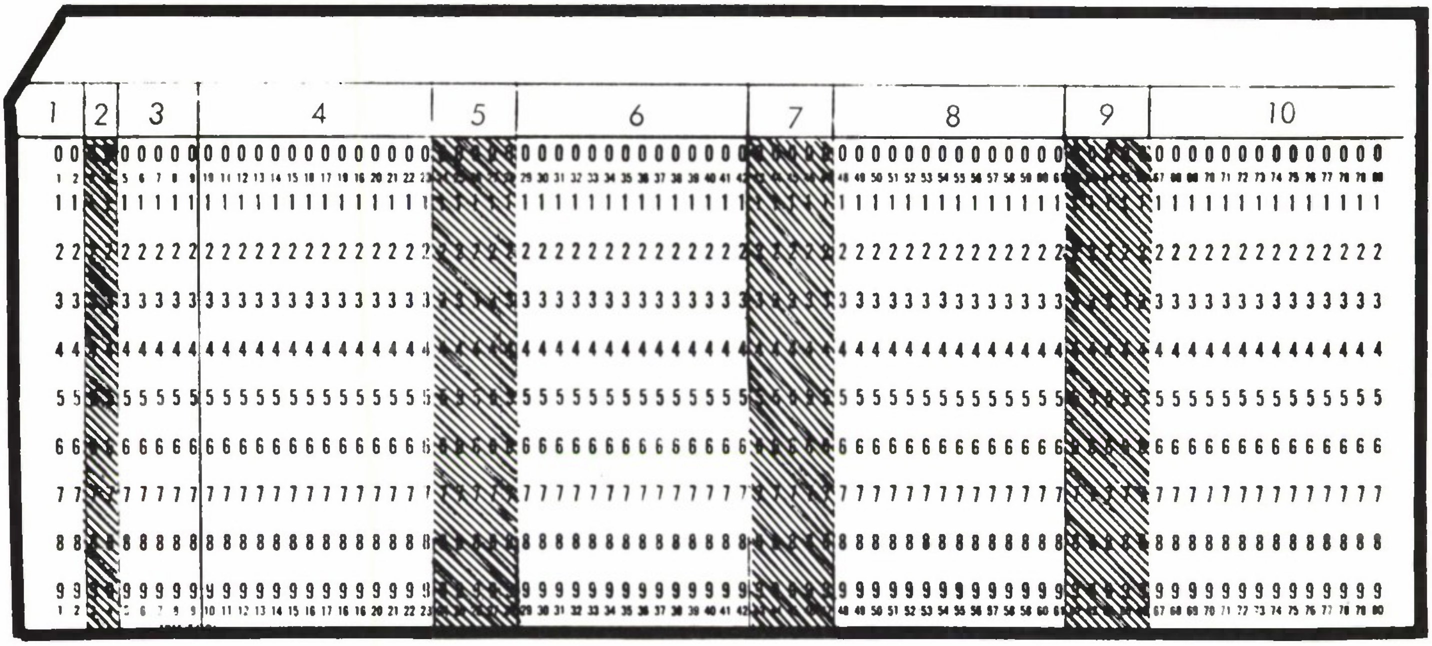
2.1.3.9 Matrix Inputs

Two matrix inputs are used by ESPOD. SMAT conditions the A^TA matrix before a one-pass differential correction. UPMAT provides an *a priori* covariance matrix for an ESP0DEPH run only.

2.1.3.9.1 SMAT. For a standard run by ESPOD, all observations will be present in the input. However, ESPOD can accept an *a priori* A^TA-matrix (input flag on column 42 of JDC card) which brings into the differential correction summarized data from observations already processed on previous runs of ESPOD. The *a priori* A^TA-matrix will be valid only if the initial conditions for the new differential correction are the same set which generated the *a priori* A^TA-matrix. Note that the new differential correction will cause the initial conditions to vary from iteration to iteration. Hence, the *a priori* A^TA-matrix is valid for only one iteration.

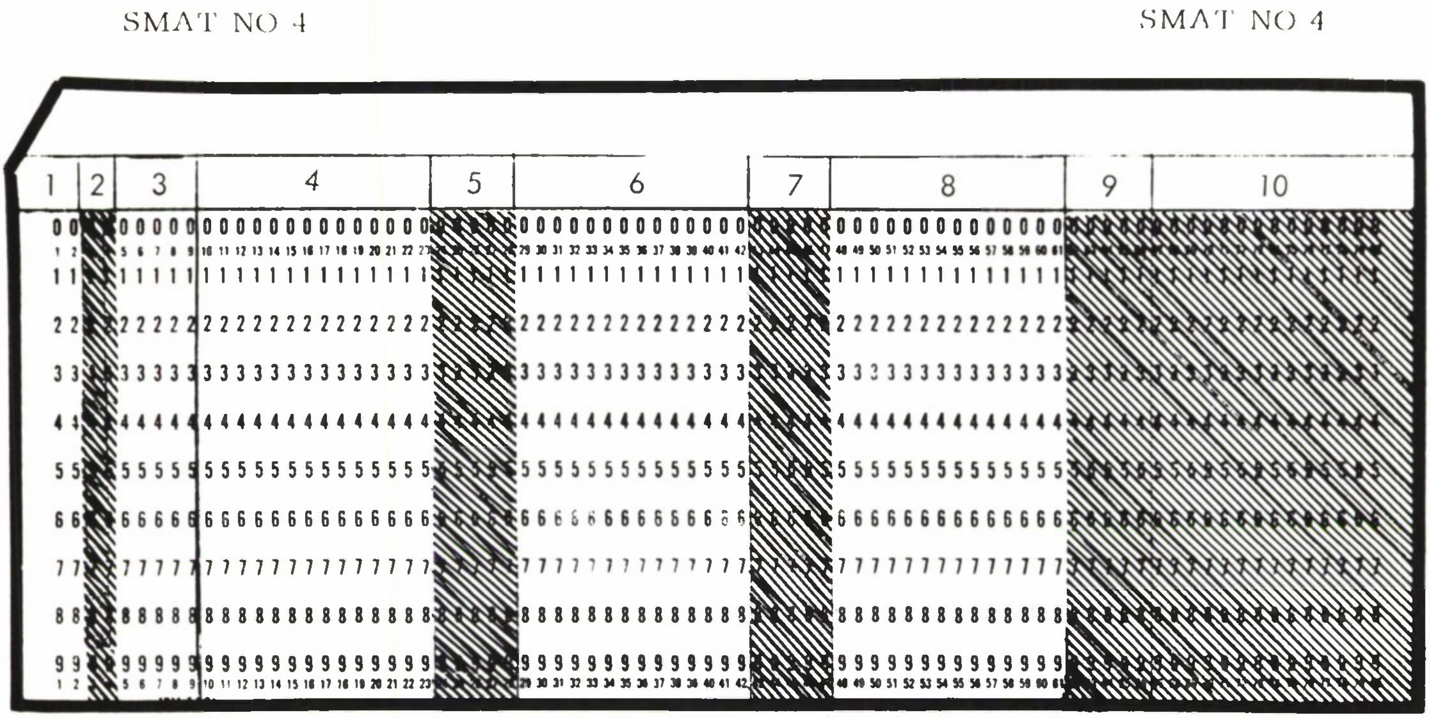
The *a priori* A^TA-matrix (S-matrix) is input as an upper triangular matrix on SMAT (S-matrix) cards. The total number of variables input is N(N + 1)/2, the maximum order being 27. They are ordered by row and columns within row, starting with the first element input. The following example indicates the placement of elements for a 5 x 5 S-matrix:

Card 1:	$S_{11}, S_{12}, S_{13}, S_{14}$
Card 2:	$S_{15}, S_{22}, S_{23}, S_{24}$
Card 3:	$S_{25}, S_{33}, S_{34}, S_{35}$
Card 4:	S_{44}, S_{45}, S_{55}



Field	Column	Content		
		Card 1	Card 2	Card 3
1	1-2	01	02	03
2	3-4	Blank	Blank	Blank
3	5-9	SMAT	SMAT	SMAT
4	10-23	S_{11}	S_{15}	S_{25}
5	24-28	Blank	Blank	Blank
6	29-42	S_{12}	S_{22}	S_{33}
7	43-47	Blank	Blank	Blank
8	48-61	S_{13}	S_{23}	S_{34}
9	62-66	Blank	Blank	Blank
10	67-80	S_{14}	S_{24}	S_{35}

Figure 2-49. SMAT Card Format, Cards 1, 2, and 3



Field	Column	Content
1	1-2	04
2	3-4	Blank
3	5-9	SMAT
4	10-23	S_{44}
5	24-28	Blank
6	29-42	S_{45}
7	43-47	Blank
8	48-61	S_{55}
9-10	62-80	Blank

Figure 2-50. SMAT Card Format, Card 4

2.1.3.9.2 UPMAT. ESPØDEPH can be operated with or without ESPØDDC. If it is preceded by ESPØDDC, the covariance matrix resulting from the differential correction is available for propagating uncertainties. If it is not preceded by ESPØDDC, UPMAT is available for inputting an *a priori* covariance matrix. Note that uncertainties in orbit elements are updated by ESPØDEPH, thus UPMAT is restricted to being 6 x 6, 7 x 7, or 8 x 8 matrix depending on whether a 6 x 6, drag and drag variation are or are not included. The covariance matrix is symmetric and only the lower triangular portion is input.

As an example, a 6 x 6 matrix is illustrated showing the order of assigning matrix elements to cards, followed by the format of the UPMAT cards.

$$\begin{array}{llllll}
U_{11} \\
U_{21} & U_{22} \\
U_{31} & U_{32} & U_{33} \\
U_{41} & U_{42} & U_{43} & U_{44} \\
U_{51} & U_{52} & U_{53} & U_{54} & U_{55} \\
U_{61} & U_{62} & U_{63} & U_{64} & U_{65} & U_{66}
\end{array}$$

UPMAT, card input order:

Card 1: U_{11}, U_{21}, U_{22}, U_{31}

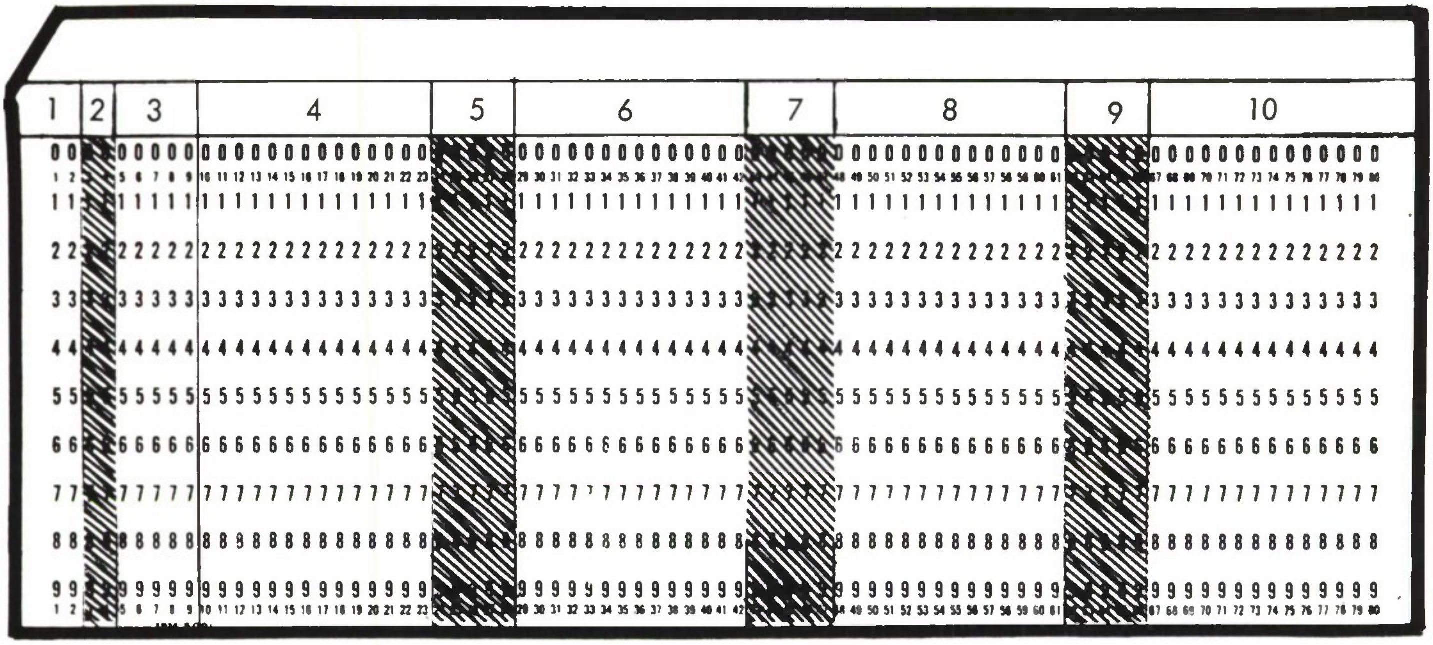
Card 2: U_{32}, U_{33}, U_{41}, U_{42}

Card 3: U_{43}, U_{44}, U_{51}, U_{52}

Card 4: U_{53}, U_{54}, U_{55}, U_{61}

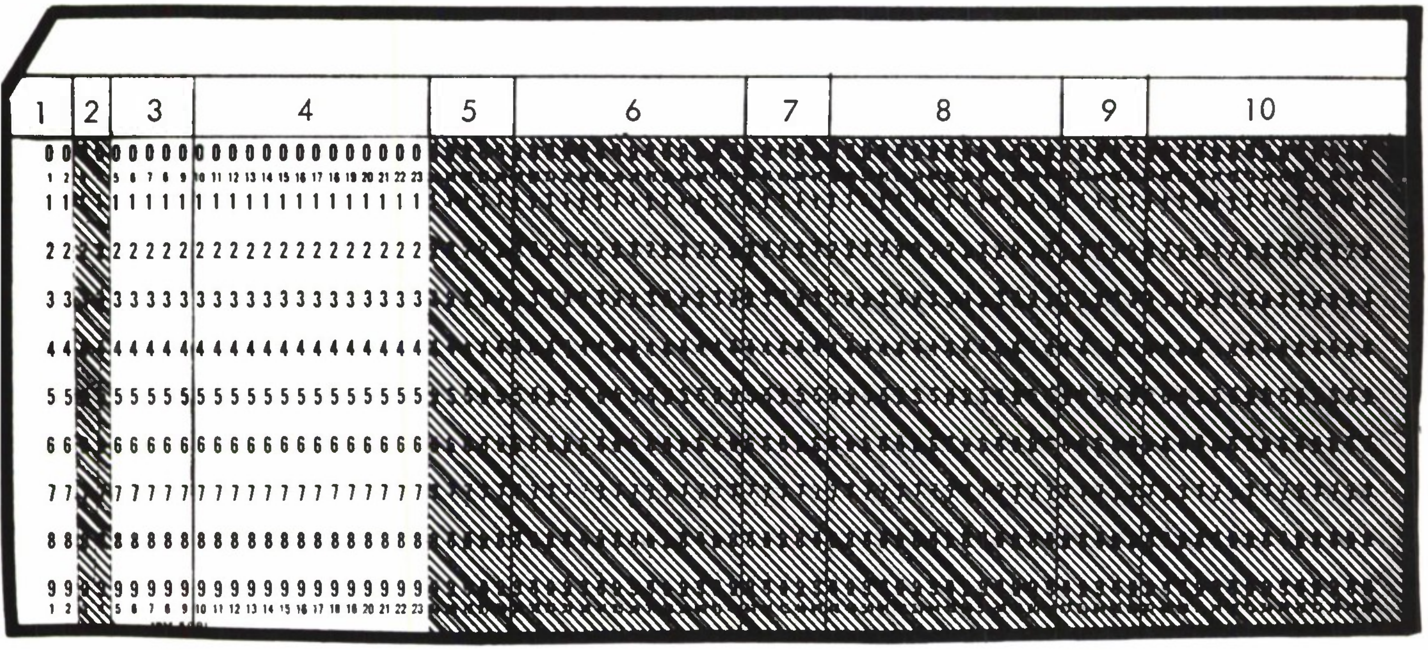
Card 5: U_{62}, U_{63}, U_{64} U_{65}

Card 6: U_{66}



Field	Column	Content				
		Card 1	Card 2	Card 3	Card 4	Card 5
1	1-2	01	02	03	04	05
2	3-4	Blank	Blank	Blank	Blank	Blank
3	5-9	UPMAT	UPMAT	UPMAT	UPMAT	UPMAT
4	10-23	U_{11}	U_{32}	U_{43}	U_{53}	U_{62}
5	24-28	Blank	Blank	Blank	Blank	Blank
6	29-42	U_{21}	U_{33}	U_{44}	U_{54}	U_{63}
7	43-47	Blank	Blank	Blank	Blank	Blank
8	48-61	U_{22}	U_{41}	U_{51}	U_{55}	U_{64}
9	62-66	Blank	Blank	Blank	Blank	Blank
10	67-80	U_{31}	U_{42}	U_{52}	U_{61}	U_{65}

Figure 2-51. UPMAT Card Format, Cards 1, 2, 3, 4, and 5



Field	Column	Content
1	1-2	06
2	3-4	Blank
3	5-9	UPMAT
4	10-23	U_{66}
5-10	24-80	Blank

Figure 2-52. UPMAT Card Format, Card 6

2.1.3.10 ESPØDEPH Options

ESPØDEPH integrates the orbit from epoch to some specified time or times, computes the position and velocity, and can compute the uncertainty in position and velocity. Specification of update times at which the satellite position will be calculated can be input on three types of cards. Only one type of input card must be used. They are discussed separately below.

2.1.3.10.1 DELTT. Update times may be specified at which the satellite position will be calculated and printed by the DELTT (ΔT and T) table. Times are measured from epoch and integration proceeds monotonically away from epoch in either a positive or a negative direction. When the direction changes, integration is reinitiated at epoch.

ΔT specifies the step size between successive calculated positions; T specifies the last point at which the calculation is desired. Up to eight ΔT, T pairs (four cards) may be specified.

As an example, the positions to be calculated may be:

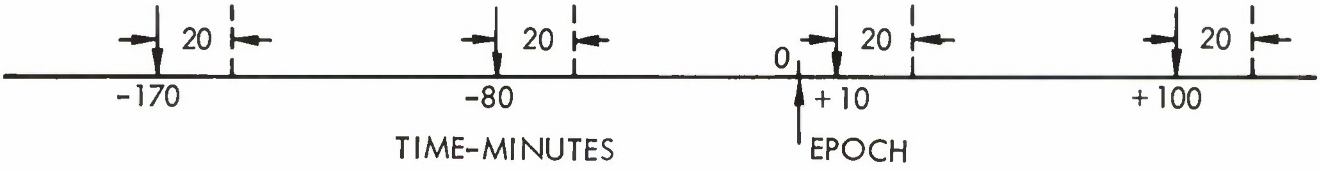
(1) 80 minutes before epoch and at every 2 minutes for 20 minutes

(2) 170 minutes before epoch and at every 2 minutes for 20 minutes

(3) 10 minutes after epoch and at every 2 minutes for 20 minutes

(4) 100 minutes after epoch and at every 2 minutes for 20 minutes

Time scale:



To specify this output, the following DELTT cards are input:

Card 1

ΔT_1 = -60

T_1 = -60

ΔT_2 = -2

T_2 = -80

Card 2

ΔT_3 = -70

T_3 = -150

ΔT_4 = -2

T_4 = -170

Card 3

ΔT_5 = 10

T_5 = 10

ΔT_6 = 2

T_6 = 30

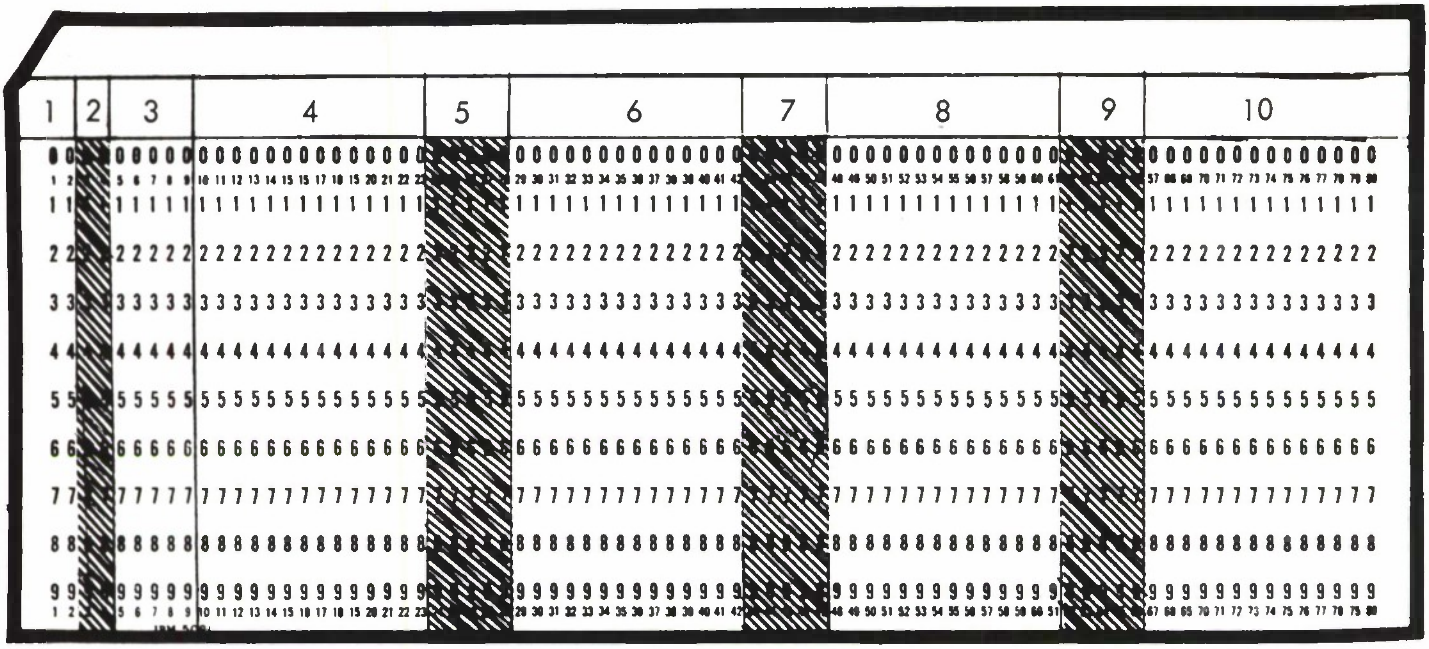
Card 4

ΔT_7 = 70

T_7 = 100

ΔT_8 = 2

T_8 = 120



Field	Content				Description
	Card 1	Card 2	Card 3	Card 4	
1	01	02	03	04	Sequence number
2	Blank	Blank	Blank	Blank	Iteration number
3	DELTT	DELTT	DELTT	DELTT	Principal variable identifier
4	ΔT_1	ΔT_3	ΔT_5	ΔT_7	
5	Blank	Blank	Blank	Blank	
6	T_1	T_3	T_5	T_7	
7	Blank	Blank	Blank	Blank	
8	ΔT_2	ΔT_4	ΔT_6	ΔT_8	
9	Blank	Blank	Blank	Blank	
10	T_2	T_4	T_6	T_8	

Figure 2-53. DELTT Card Format, Cards 1, 2, 3 and 4

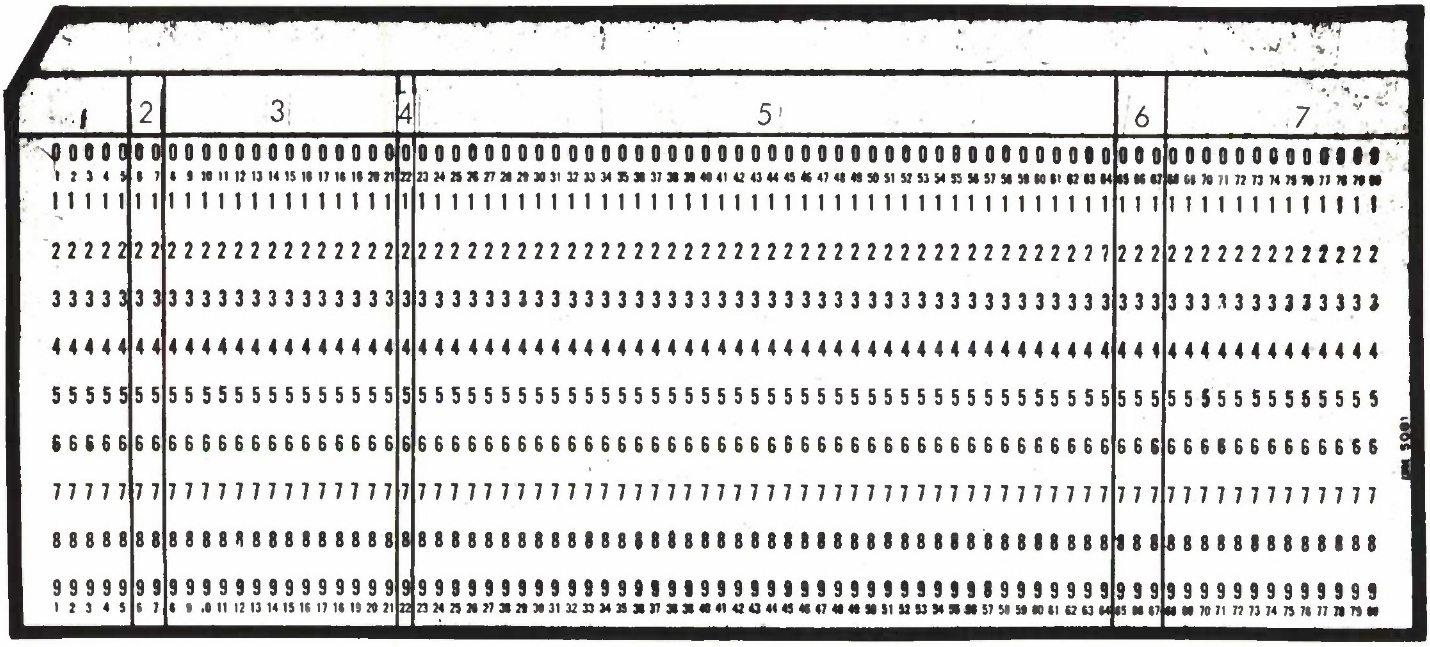
2.1.3.10.2 DAC Cards. The presence or absence of these cards is indicated in Column 52 of the JDC card (see Section 2.1.2).

DAC cards are an input to ESPOD to provide an interface with special predicting and comparison requirements. DAC cards typically come in a set of three:

1) Header card
2) "08" card with test Cartesian coordinates and days
3) "12" card with fractions of days.

The header card, if input, is ignored. The predict time is taken from the 08 and 12 cards (second and third cards of the three card set). Cartesian position is used as a comparison point for ESPOD's predicted value.

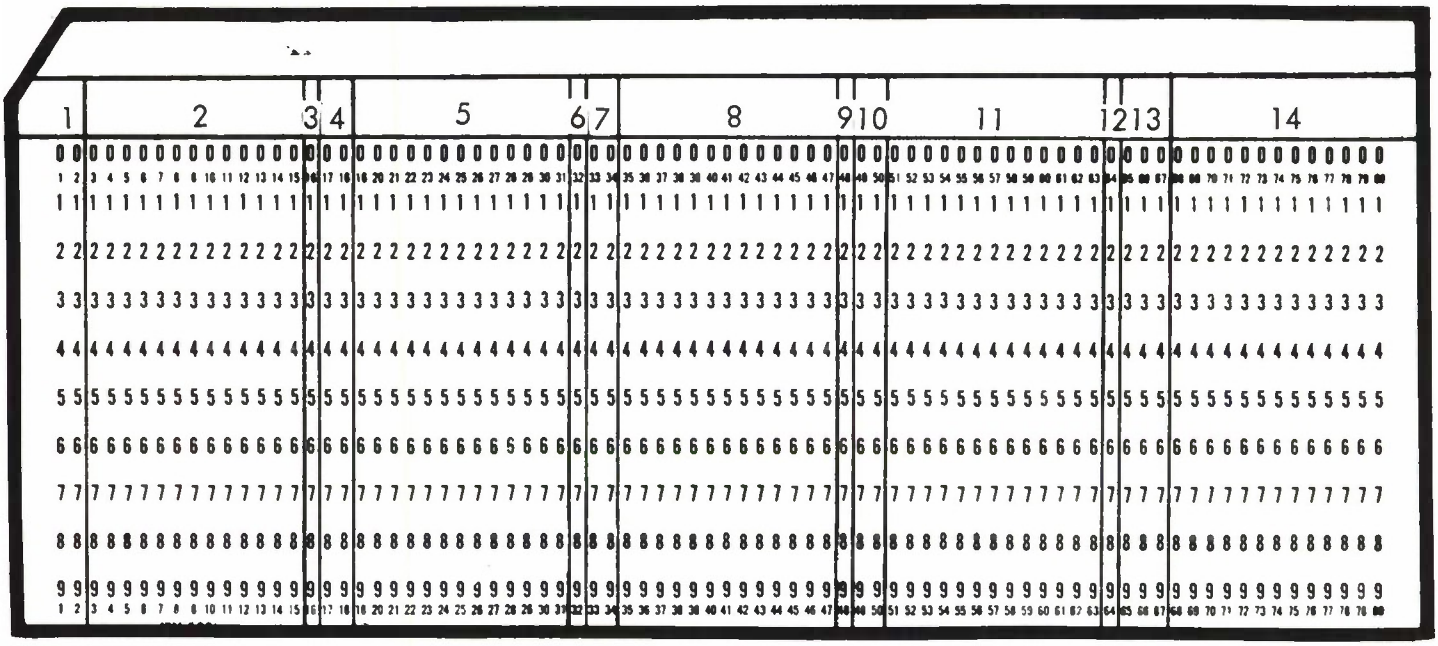
ESPOD will accept up to a maximum of four sets of DAC cards.



Field	Column	Content	Description
1	1-5		Same as Input Header Card
2	6-7	SS	Source code
3	8-21		Same as Input Header Card
4	22	N	ID number
5	23-64		Same as Input Header Card
6	65-67	NNN	Sequence number
7	68-80	, - - - ,	Filler

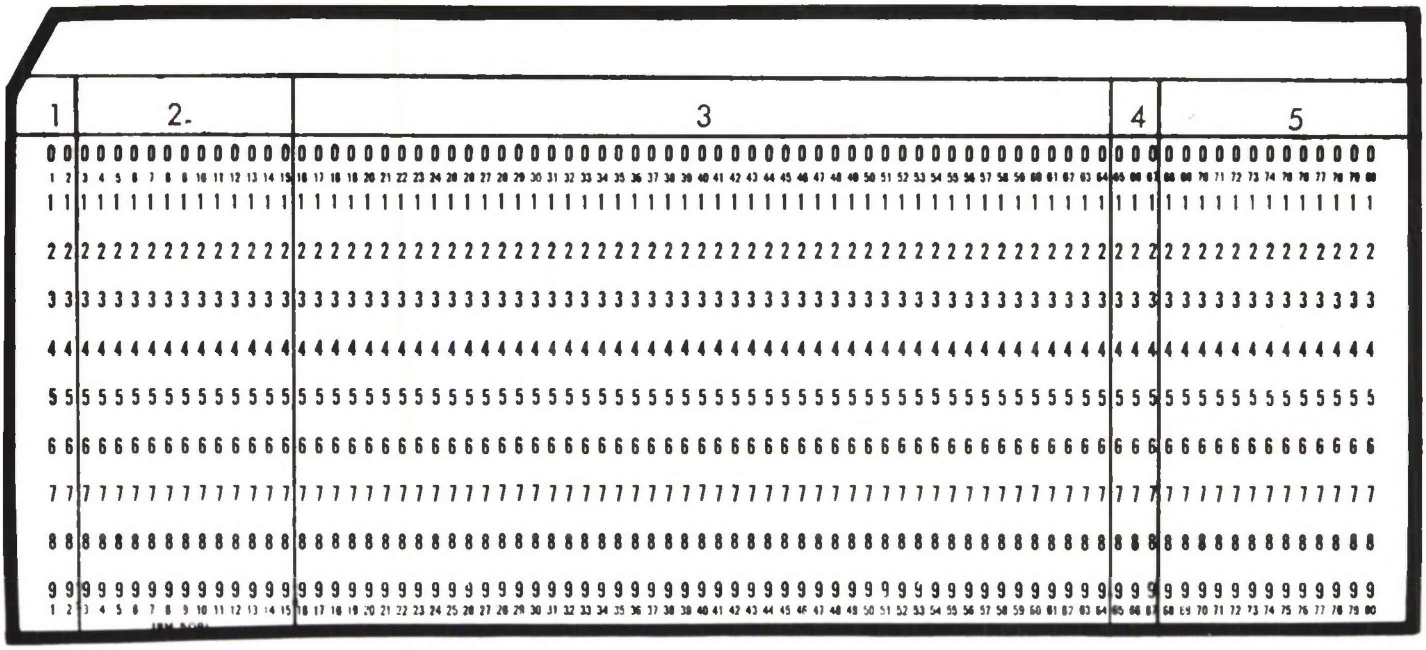
This first card of the three card set (DAC) is not necessary for input. However, ESPOD will read it and ignore the contents.

Figure 2-54. DAC Card Format, Card 1 of 3



Field	Column	Content	Description
1	1-2	08	Identifying code for X
2	3-15	±mm----mm±ee	X - Earth radii
3	16	,	Separator
4	17-18	09	Identifying code for Y
5	19-31	±mm----mm±ee	Y - Earth radii
6	32	,	Separator
7	33-34	10	Identifying code for Z
8	35-47	±mm----mm±ee	Z - Earth radii
9	48	,	Separator
10	49-50	11	Identifying code for time - whole days
11	51-63	±mm----mm±ee	Time - whole days from January 0, Jan 1 = 1
12	64	,	Separator
13	65-67	NNN	Sequence number
14	68-80	,---,	Filler

Figure 2-55. DAC Card Format, Card 2 of 3

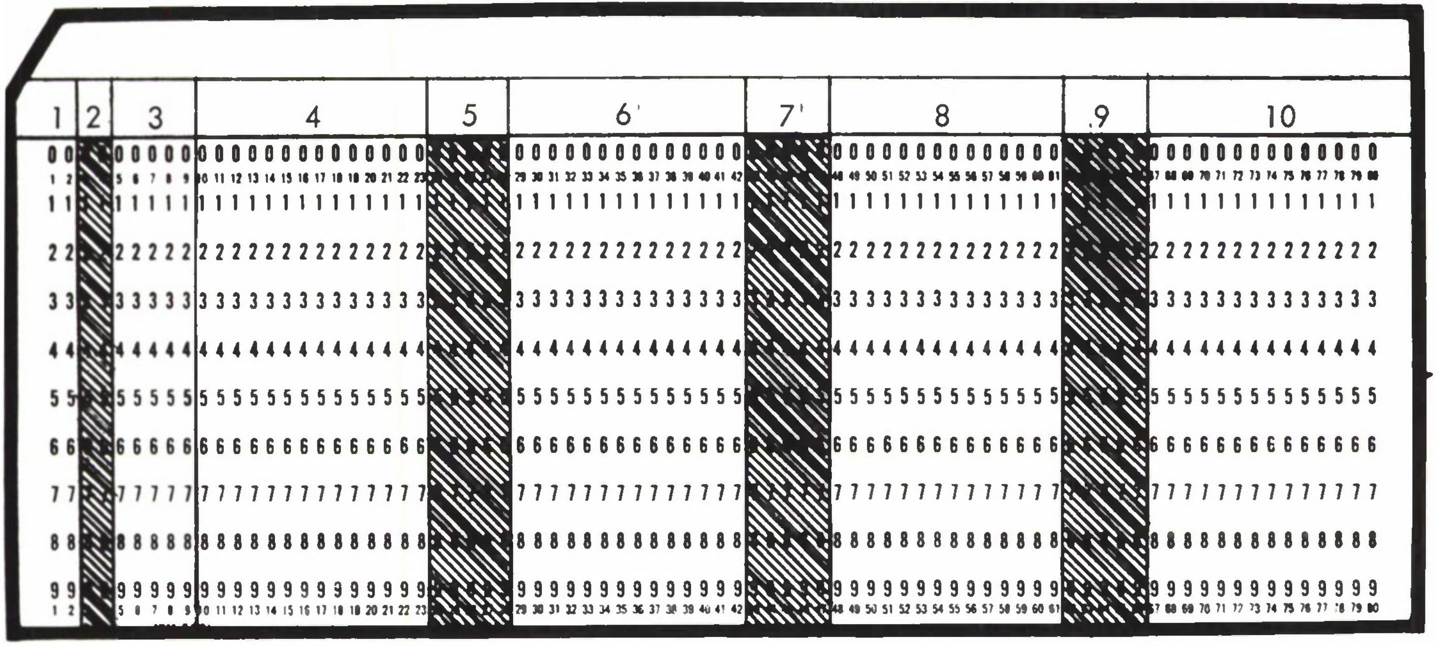


Field	Column	Content	Description
1	1-2	12	Code for time - fraction of day
2	3-15	±mm---mm±ee	Time - fraction of day
3	16-64	,---,	Filler
4	65-67	NNN	Sequence number
5	68-80	,---,	Filler

Note that the field designation of the DAC cards departs from the ESPOD preliminary data format. For DAC cards, any fields not containing input parameters are filled with commas as filler characters. This applies to field 14 of card 2, and fields 3 and 5 of card 3.

Figure 2-56. DAC Card Format, Card 3 of 3

2.1.3.10.3 PRDCT. The PRDCT card specifies from one to four separate output times at which to predict. Times are specified in days and fractions of days, given in a single variable field. Only one predict card is permitted (see Figure 2-57).

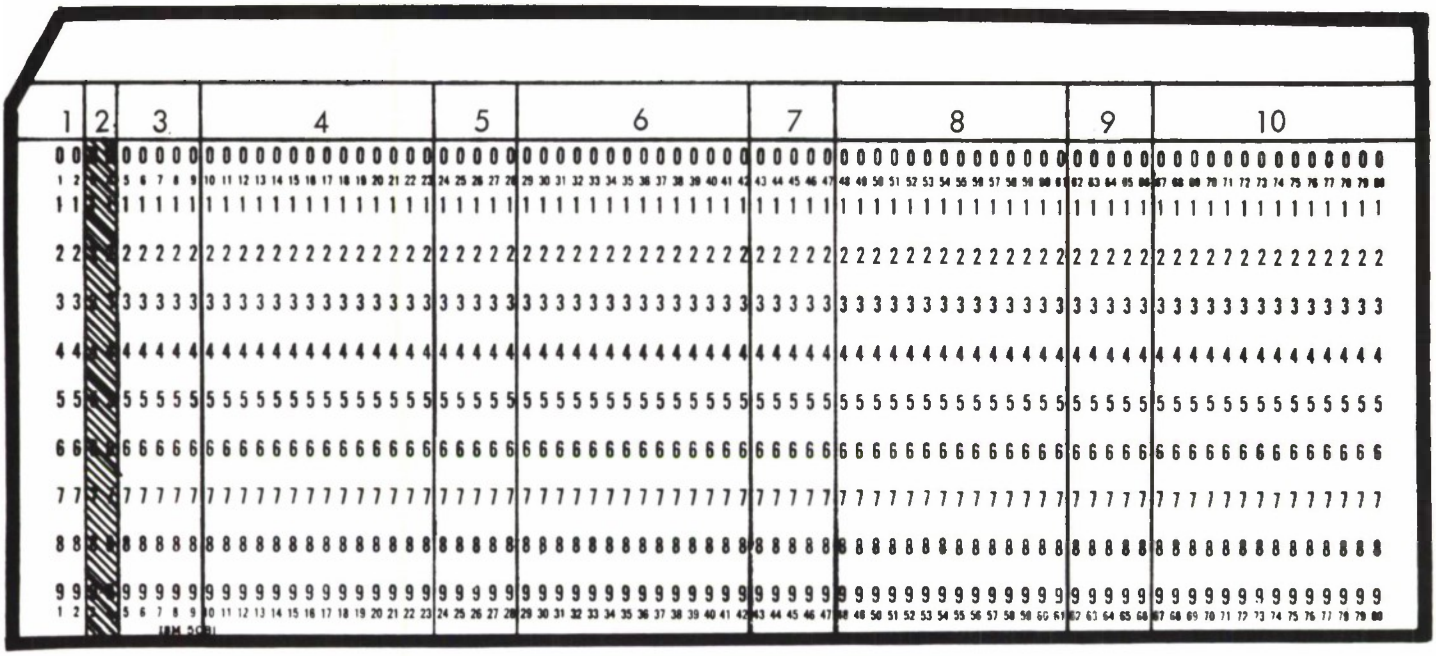


Field	Column	Content	Description
1	1-2	01	Sequence number
2	3-4	Blank	Iteration number
3	5-9	PRDCT	Principal variable identifier
4	10-23	t_1	1st update time
5	24-28	Blank	
6	29-42	t_2	2nd update time
7	43-47	Blank	
8	48-61	t_3	3rd update time
9	62-66	Blank	
10	67-80	t_4	4th update time

Figure 2-57. PRDCT Card Format

2.1.3.11 Constant Change (99 Card)

Most of the constants which are used in the ESPOD Program can be changed with a 99 card (see Figure 2-58). A list of the ESPOD constants, their numerical values, and relative core location is given in Section 5.0. A more detailed list is given in Section 3.5.2 of ESD-TDR-64-395 "ESPOD Mathematical and Subroutine Description." Full details are in the CODE EDIT listing.

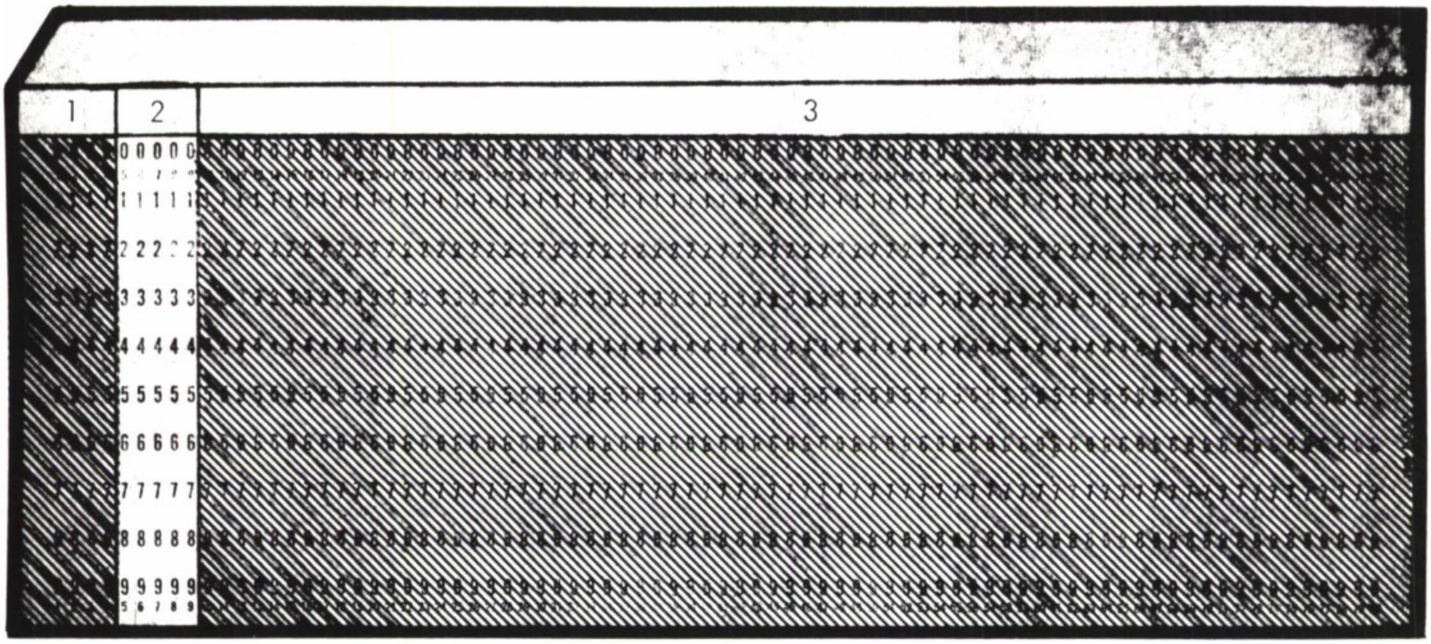


Field	Column	Content	Description
1	1-2	99	Card identifier
2	3-4	Blank	Iteration number
3	5-9	XXXXX	Core location of new constant
4	10-23	New constant	
5	24-28	XXXXX	Core location
6	29-42	New constant	
7	43-47	XXXXX	Core location
8	48-61	New constant	
9	62-66	XXXXX	Core location
10	67-80	New constant	

Figure 2-58. 99 Card Format

2.1.3.12 End of Preliminary Data

An ENDPR (End of Preliminary Data) card is mandatory whether or not any preliminary cards are present. If any are present, it must follow directly behind the last one of them. An ENDPR card is shown in Figure 2-59.



Field	Column	Content
1	1-4	Not used
2	5-9	ENDPR
3	10-80	Not used

Figure 2-59. ENDPR Card Format

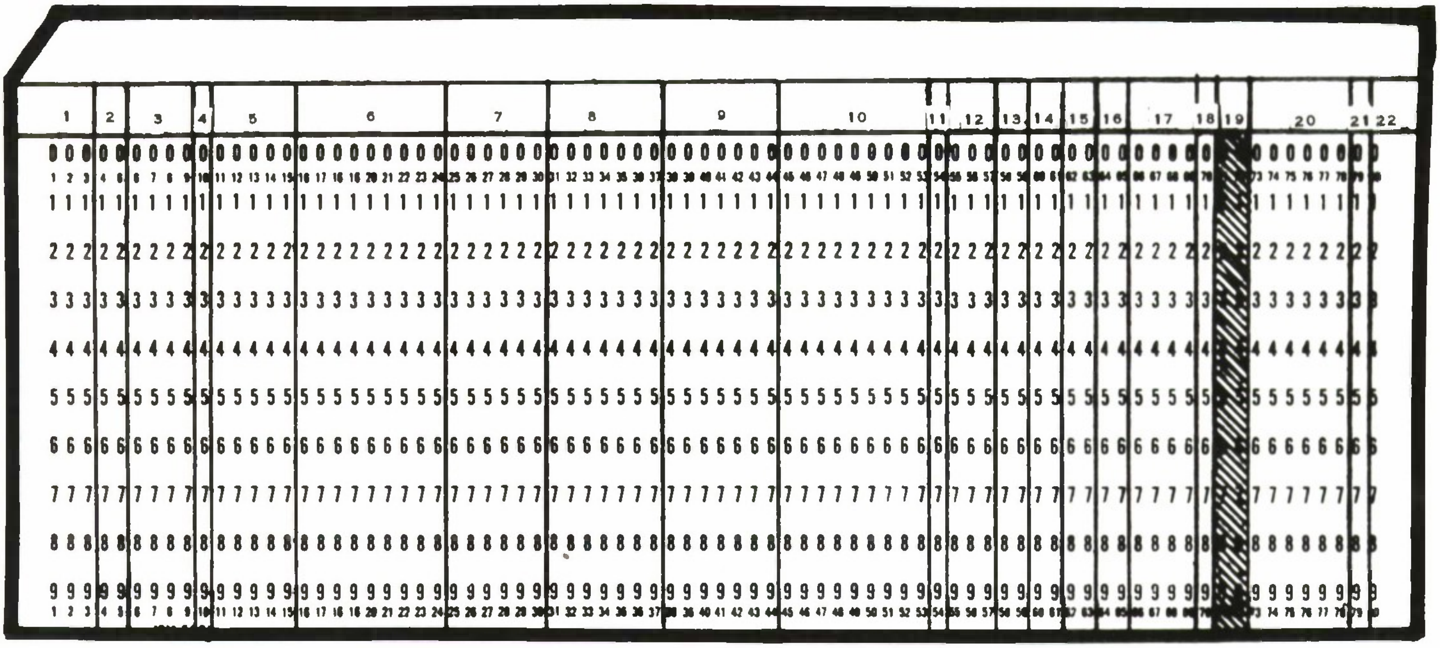
2.1.4 Observation Data

2.1.4.1 Observation Cards

ESPOD accepts the standard SPADATS observation cards, as given in **Figure 2-60**. If more than 704 observations, the maximum number, are to be processed on a single run, they must be presorted in chronological sequence before "read in." If more than 704 unsorted observations are input, the run will exit on an input error.

When more than 704 chronologically sorted observations are read in on cards, and initial conditions are specified on cards, the epoch must be at or later than the time of the last observation.

Figure 2-60 shows the format of the SPADATS observations cards.



Field	Column	Description
1	1-3	Satellite number. Column 1 contains a minus sign if this is a classified observation; column 1 cannot be double punched.
2	4-5	Equipment type
3	6-9	Station number
4	10	Accuracy or signal strength (see Supplement 1 - OBVS card, Page 2-128).
5	11-15	Date
6	16-24	Time (Z)
7	25-30	Elevation/declination. Column 25 can be overpunched + or -.
8	31-37	Azimuth/ right ascension. Column 31 can be overpunched + or -.*
9	38-44	Slant range (KM)

---

*A minus overpunch in column 31 indicates fields 7 and 8 are declination and right ascension respectively.

Figure 2-60. Observation Card Format

Field	Column	Description	
10	45-53	Range rate (KM/SEC) with implied decimal point between columns 46 and 47 or: maximum frequency shift (cycles/sec^2) with implied decimal point between columns 52 and 53.	
11	54	Code for field 10	0 or Δ indicates range rate in field 10. 1 indicates maximum frequency quency shift in field 10
12	55-57	Brightness at observation time	or: when column 58 contains a minus punch, then columns: 55-57 contain radar cross section in meters 59-63 contain the frequency, with decimal point between 60 and 61.
13	58-59	Maximum brightness	
14	60-61	Minimum brightness	
15	62-63	Time interval	
16	64-65	Date or line number (NOTE: Not used by SPS)	
17	66-69	Message number	
18	70	Equinox (see Supplement 2 - OBVS card, Page 2-129).	
19	71-72	Not used	
20	73-78	Observation number (assigned by ØRCØN)	
21	79	Switch indicator used by manual system	
22	80	Card type (code type = Any numeric between 0-9) identifies an Observation Card. 0 = unknown, 1-9 coded according to the Association Status as determined in Report Association.	

Figure 2-60. Observation Card Format (Continued)

SUPPLEMENT 1—OBSERVATION CARD (OBVS)

Either accuracy or signal strength may be indicated in column 10 according to the following:

If type in columns 4 and 5 is 31 or greater, column 10 contains signal strength. If type is 30 or less, column 10 contains accuracy.

Code	Accuracy	Signal
0	Normal observations, made under fair conditions	Signal strength good, reliable measurement
1	Observations slightly under par due to outside interference (e.g., some clouds, reduced visibility)	Signal fair
2	Observations poor only due to outside interference	Signal weak, results poor
3	Only estimates possible (malfunction of instrument, observation time span short)	Signal questionable

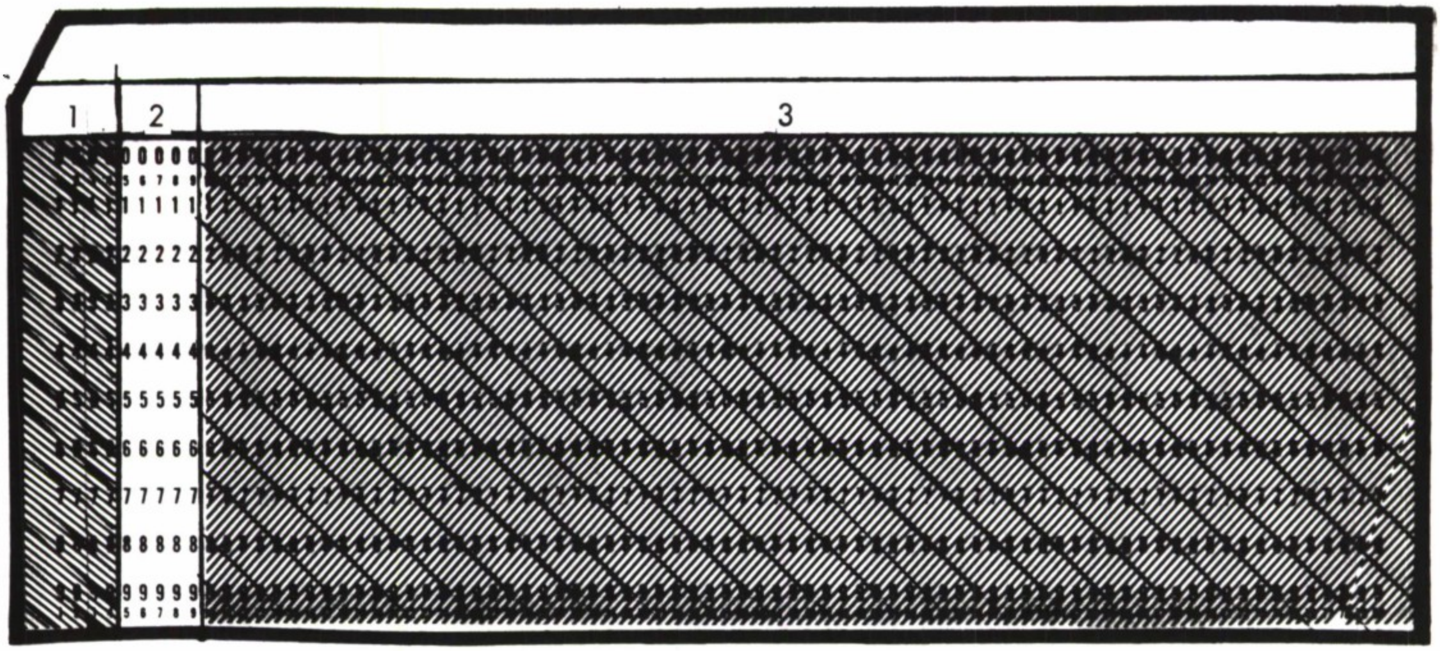
SUPPLEMENT 2—OBSERVATION CARD (OBVS)

Column 70 contains year of Equinox as specified by following:

0 Year to date
1 = 1900
2 = 1920
3 = 1950
4 = 1975
5 = 2000
6 = 1850
7 = 1855
8 = 1875
9 = 1960

2.1.4.2 End of Observation Data

Following observation cards, it is mandatory to include an ENDØB card. The format is given in Figure 2-61.



Field	Column	Content
1	1-4	Not used
2	5-9	ENDØB
3	10-80	Not used

Figure 2-61. ENDØB Card Format

2.1.5 Sensor Data

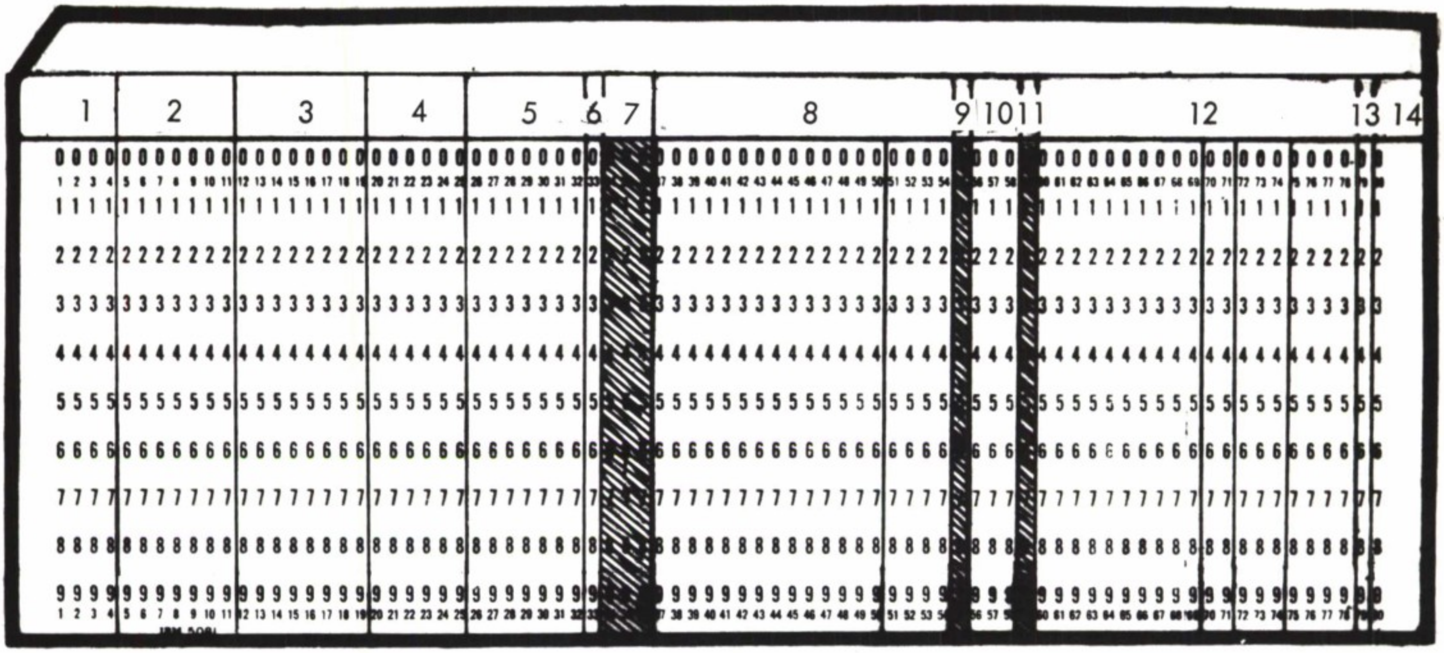
2.1.5.1 Sensor Cards

A sensor card must be provided for every different sensor number which appears on the included observation cards. The presence of sensor data is flagged in column 31 of the JDC card (Section 2.1.2). ESPOD assumes the new SPADATS sensor card format (1 January 1964), as shown in Figure 2-62.

Sensor cards do not require any punching to identify sigma types. The sigma type code digit for each sensor is stored in a table within ESPOD. If it is desired on any one run to vary the sigma type associated with the sensor, an STYPE card for the sensor must be entered. Any such change is retained until the next cold start.

The estimated standard deviations for each sigma type are stored in the SIGMA table within ESPOD. There are 60 different sets of sigmas identified by code types from 01 to 60. If it is desired on any one run to change the four values: σ_R, σ_A (σ_α), σ_E (σ_δ), $\sigma_{\dot{R}}$ in any set, a SIGMA card respecifying the four values by type must be entered. As in the STYPE change, the respecified values will be retained until the next cold start.

Credence dependent weights are obtained by multiplying the tabular sigmas by a function of the credence. This combined with the proper initial sigma set will produce closely the standard deviations tabulated by credence for the FPS-49 radars.

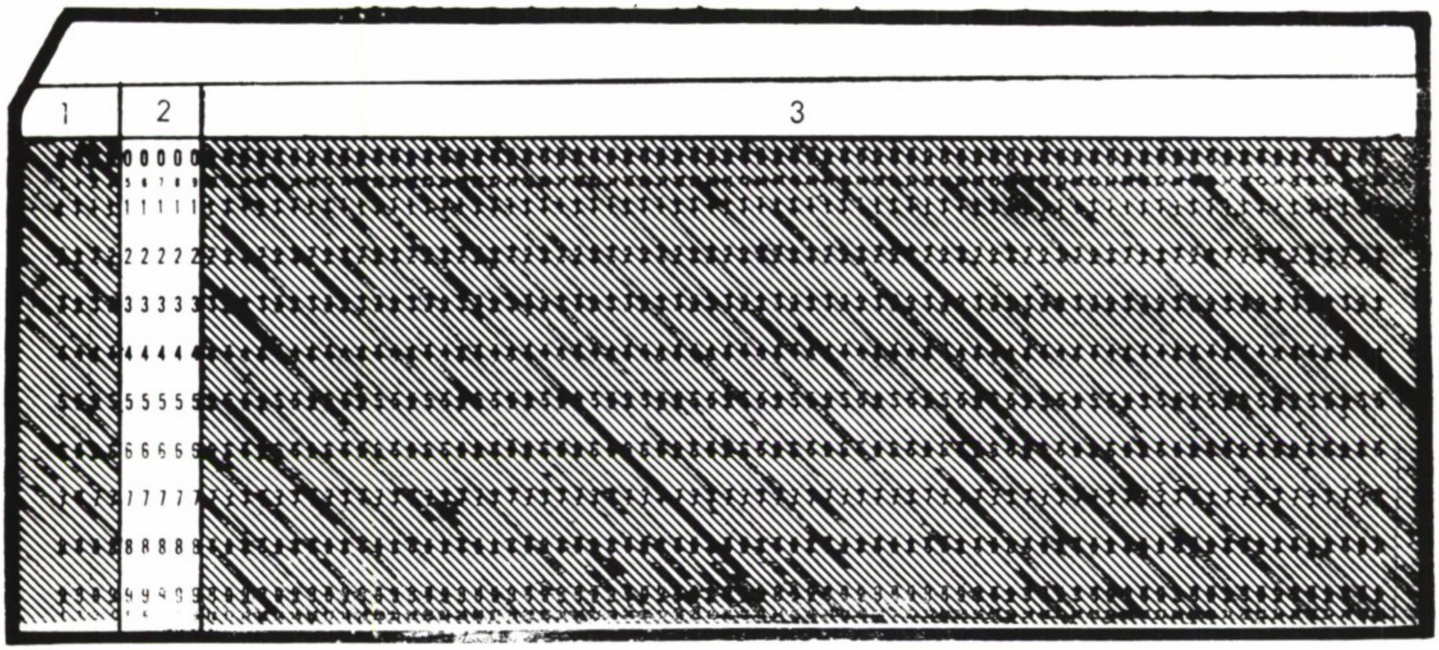


Field	Column	Description
1	1-4	New sensor number
2	5-11	ϕ^{o}(+N)—latitude (decimal assumed between columns 7-8)
3	12-19	λ^{o}(+W)—longitude (decimal assumed between columns 15-16)
4	20-25	H(meters)—altitude
5	26-32	Datum plane
6	33	Classification { u = unclassified c = classified
7	34-36	Not used
8	37-50	Location (name)
8	51-54	Temp (if the sensor is a temporary one)
9	55	Not used
10	56-58	Old sensor number
11	59	Not used
12	60-69	Remarks
12	70-71	WSRN or Minitrack station number
12	75-78	SAO station number
13	79	*indicates in "S" file
14	80	"S" to indicate sensor card

Figure 2-62. Sensor Card Format

2.1.5.2 End of Sensor Data

Following sensor cards, it is mandatory to insert an ENDSN card. The format is shown in Figure 2-63.



Field	Column	Content
1	1-4	Not used
2	5-9	ENDSN
3	10-80	Not used

Figure 2-63. ENDSN Card Format

2.2 DECK SETUP

This section explains the selection and input order of input cards for ESPOD. The first part of the section is an input diagnostic summary, which is essentially a tabulation of the program response to omitted and included input cards. This is followed by a classification of input cards by type that are mandatory, conditional mandatory, and optional. Sample ESPOD load sheets are included as a part of the discussion of their format and content. This section is concluded with a discussion of the input card sequence (decks).

2.2.1 Input Diagnostic Summary

Table 2-III. Program Response to Omitted and Included Input Cards

Input	No Card Present in Deck	Card Present in Deck
70ΔSCHTP	Run will not start Mandatory input	Must be first card in first deck Run starts normally
Job No.	B2 system exit Mandatory B2 scheduled run input	Job No. printed as input
RUN ESPOD, DATA	Run will not start Mandatory B2 system input Control from Flexowriter in manual	Reads preliminary data
JDC	Diagnostic exit Mandatory input	Run proceeds as indicated by JDC card input
REM	Run proceeds	Remarks printed on output
ICTYP	Diagnostic exit, if IC0ND cards present	Run proceeds
IC0ND	Automatic reference to SEAI tape for elements and epoch	Initial conditions taken as input
ITIME	Diagnostic exit if ICTYP = 1., 2., or 3.	Epoch indicated is input; not required for ICTYP = 4.
7-Card Elements	Same as IC0ND	Reads into program and is automatically transformed to Cartesian coordinates
DNREV	No update will be made when 7-card elements are input	For given flags, the program will: Flag — Option 1. Update to a specific time 2. Updates to N revolutions past epoch 3. Updates to a specified revolution -1. Updates to time of last observation, when using 7-card elements

Table 2-III. Program Response to Omitted and Included Input Cards (Continued)

Input	No Card Present in Deck	Card Present in Deck
CAT1	Assumes a nominal set of bounds and a 6 x 6 fit if CAT2 also absent. If CAT2 card present, all initial conditions are constrained and CAT2 variables are solved.	Solves for CAT1 variables flagged
CAT2	Assumes nominal bounds and 6 x 6 fit if CAT1 absent also. If CAT1 card present, solves for CAT1 variables and no CAT2 variables.	Solves for sensor data and location variables indicated
BNDS	If CAT1 or CAT2 card present, assumes nominal bounds. If no CAT1 or CAT2 cards, assumes nominal bounds and a 6 x 6 fit.	CAT1 and CAT2 variables bounded as input; must be a bound input for each variable flagged or variable will not be allowed to change.
BISES	No bias estimates input Program runs normally	Initial CAT2 variable bias estimate input; must have 1:1 correspondence with non-zero CAT2 variables flagged.
NITER	Assume a 5 iteration fit is desired	Allows the number of iterations input with this card as a maximum. The program may stop sooner if convergence occurs.
TSTEP	Assumes an initial step size of numerical integration of one minute	Changes the initial step size to specified value
DELET	No observations will be deleted from either the solution or the residuals calculation	The number of observations deleted will be those from a_1 through b_1, a_2 through b_2, etc. To delete a single observation, input the same observation identification number for both a_1, b_1, or a_2, b_2, etc.
TMAX	Observations which are more than ten days from epoch are rejected	Rejection of observations in days from epoch as specified on card

Table 2-III. Program Response to Omitted and Included Input Cards (Continued)

Input	No Card Present in Deck	Card Present in Deck
SIGMA	Assumes a standard set which will remain unless changed	Changes a particular data (R, A, E, $\dot{R}$, α, δ) sigma for a particular sigma type (01, 02, · · · , 60)
STYPE	Assumes standard data sigmas, average surface refractivity for each station, and a nominal gross outliers criterion	Changes, for the given, run, the stations data sigma, surface refractivity, and/or the gross outliers criterion
DRAG	Assumes drag free atmospheric model	Enters atmospheric, drag models, $C_DA/2m$, and K specified on card
APF10	Not required unless a dynamic atmosphere is flagged; zeroes will be assumed when card is absent.	If a single input for day of epoch, will be used as an average value; if daily values desired, and a short set is input, last value will apply to all subsequent days.
Z0NAL SECTR TESSR	Will assume a standard set is desired as a nominal model (Potential Model 1).	Enters parameters as indicated by a flag in the proper column of each card
RADPR	No radiation pressure perturbations	Uses radiation pressure model, with vehicle parameters as specified
SMAT	No *a priori* "S" matrix input; program runs normally.	An *a priori* "S" matrix is input to use data previously entered into the solution
UPMAT	If this is an ESP0DEPH run only (no ESP0DDC), no *a priori* covariance matrix update is performed; program runs normally. An update can be made after a DC run without this card if ESP0DEPH and a covariance matrix update is flagged on the JDC.	If this is an ESP0DEPH run only (no ESP0DDC), the *a priori* covariance matrix punched in UPMAT is input and updated. If ESP0DDC is present, cards are ignored.

Table 2-III. Program Response to Omitted and Included Input Cards (Continued)

Input	No Card Present in Deck	Card Present in Deck
DAC	No ESP0DEPH run, unless DELTT or PRDCT card(s) present	Trajectory points predicted for specific times on DAC cards input
PRDCT	No ESP0DEPH run, unless DELTT or DAC card(s) present	Trajectory points predicted for specific times input
DELTT	No ESP0DEPH run, unless a PRDCT or DAC card(s) present	Trajectory points printed as input for Δt increments over interval T minutes from epoch
99 CARD	No changes to program constants	Changes a given constant specified by a core location identification to the number input

Table 2-IV. ESPOD Inputs

Mandatory Inputs

B2 System Cards	70Δ SCHTP JOB No. RUN ESP0D, DATA	
	JDC	
either	ICTYP IC0ND ITIME	or ICTYP 7-Card elements or SEAI Tape
	Insert any conditional mandatory inputs	
	Insert any optional inputs	
	ENDPR	
	OBSERVATION CARDS (IF ANY) END0B	SRADU
	SENSOR CARDS (IF ANY) ENDSN	SEAI
	ENDAT	
B2 System	ENDDATA END0FJ0B ENDSCHED	

Conditional Mandatory Inputs

CAT1	If other than nominal 6 x 6 fit (drag par.)
CAT2	Station biases
BNDS	If CAT1 or CAT2 present
DRAG	For drag involvement
APF10	For dynamic atmosphere
for ESP0DEPH runs	
either	DAC
or	PRDCT
or	DELTT
DNREV	If update of epoch required

Optional Inputs

REM	Remarks
Initial Conditions:	
BISES	Bias estimate of CAT2
SMAT	a priori A^TA
UPMAT	a priori covariance matrix
Editing:	
DELET	Deletion of residuals
STYPE	Change in station sigma, refractivity, and/or gross outliers
SIGMA	Change of station sigmas for a particular sensor
TMAX	For integration maximum ≠ 10 days
Integration Control:	
TSTEP	Initial step-size ≠ minute
Convergence Control:	
NITER	Maximum iterations ≠ 5
Models:	
Z0NAL SECTR TESSR	For expanded potential model
RADPR	Inclusion of radiation pressure
99-CARD	Constants change

Table 2-V. Input Diagnostic

INPUTS	MANDATORY			OPTIONAL		
	Card Input	ESP0D Nominal	SPADATS Tape Files	Overriding Card Input	Options Called by Cards	Optional Input Data on Cards
B2 SYSTEM START						
70ΔSCHTP 11 8 2	X					
JOB NO	X					
Remarks Card(s)					X	
RUN ESP0D, DATA	X					
ESP0DDC and ESP0DEPH						
JDC	X	N. A.				
Either						
ICTYP	X	N. A.				
IC0ND	X	N. A.				
ITIME	X	N. A.				
or						
ICTYP	X	N. A.				
7-card el	X	N. A.				
DNREV	X	N. A.		X		
or						
NO ICTYP			SEAI			
DNREV		Time of last obs.		X		
DRAG		None			X	
APF10		N. A.			X	
TSTEP		1 min		X		
RADPR		None			X	
Z0NAL		J_2, J_3, J_4		X		
SECTR		None			X	
TESSR		None			X	
ESP0DDC						
CAT1		ADBARV		X		
CAT2		None			X	
BNDS		Nominal Bounds		X		
BISES		N. A.				X
SMAT		N. A.				X
NITER		5 iterations		X		
DELET		N. A.			X	
TMAX		10 days		X		
SIGMA		SIGMA TABLE		X		
STYPE		SENSOR TABLE		X		
ESP0DEPH only						
Either						
DAC	X					
or						
PRDCT	X					
or						
DELTT	X					
UPMAT		N. A.				X
GENERAL						
REM					X	
99		N. A.		X		
ENDPR	X	N. A.				
ESP0DDC - SPADATS File Data Only						
0BS CARDS		N. A.	SRADU			
END0B	X	N. A.				
SEN CARDS		N. A.	SEAI			
ENDSN	X	N. A.				
GENERAL, FOLLOWING LAST CASE						
ENDAT	X	N. A.				
B2 SYSTEM FINISH						
ENDDATA	X					
END0FJ0B 11 8 2	X					
ENDSCHED 11 8 2	X					

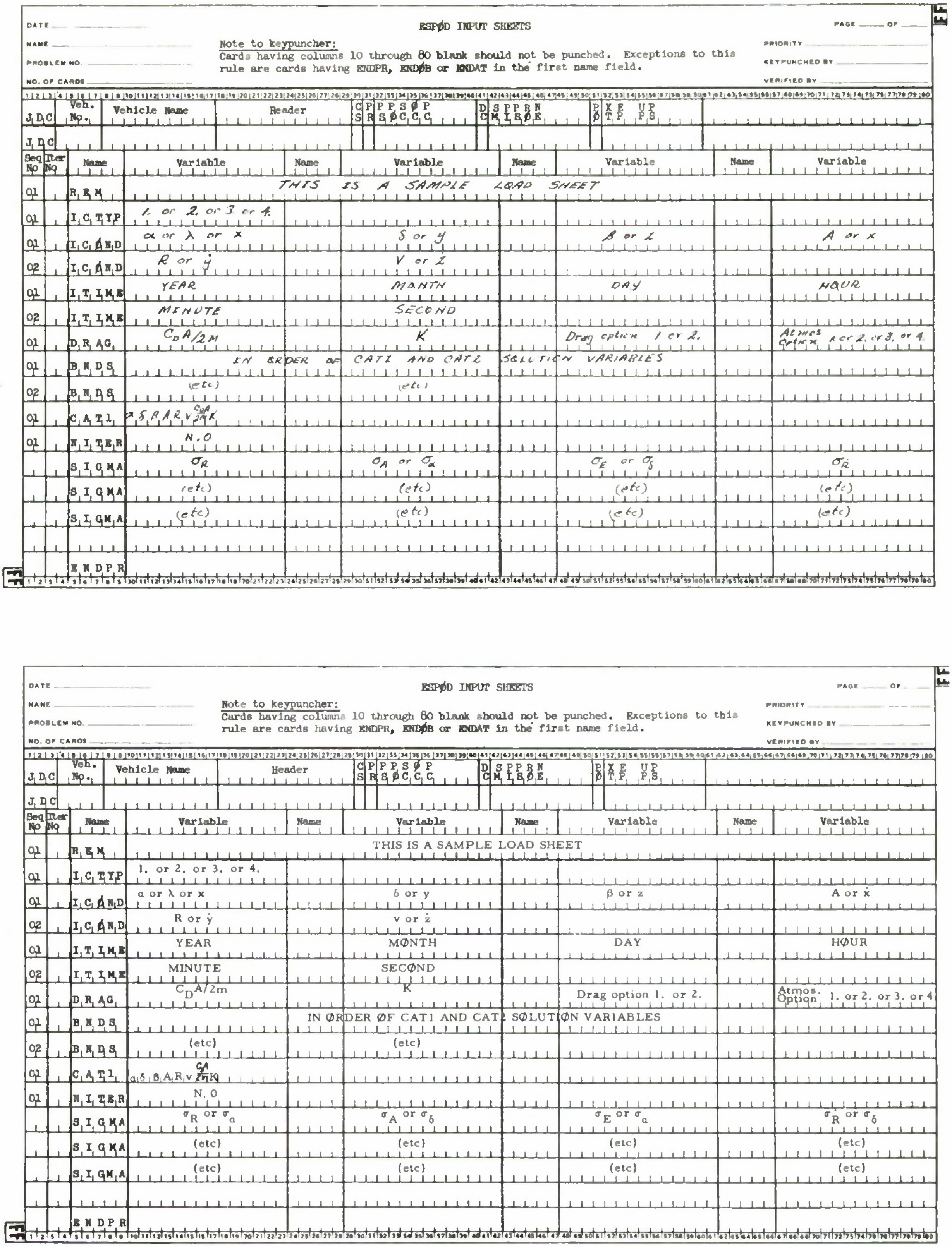
2.2.3 Load Sheets

ESPOD Load Sheets have been prepared to facilitate the task of punching input cards. Sample load sheets with the variable field content indicated have been included in the section.

The load sheet has abbreviations for the flagged columns, i. e., columns 30 to 56. They are listed below.

Column	Abbreviation	Interpretation
30	CS	Cold start
31	PR	Preprocessing necessary
32	PS	Print sensors
33	PØ	Print observations
34	SC	Sensor cards present
35	ØC	Observation cards present
36	PC	Print program constants
37-40	Not used	
41	DC	Differential correction
42	SM	S-Matrix input
43	PI	Punch $A^T A$ inverse
44	PS	Punch $A^T A$
45	RØ	Residual observations
46	NE	Use new elements
47-50	Not used	
51	PØ	Postprocessing required, i. e., execute ESPØDEPH
52	XT	DAC cards present this run
53	EP	Generate ephemeris
54	Not used	
55	UP	Perform matrix update
56	PS	Punch inverse of update covariance matrix

The actual column content is given in Section 2. 1. 2.



DATE

NAME

PROBLEM NO.

NO. OF CARDS

ESPØD INPUT SHEETS

PAGE ___ OF ___

PRIORITY

KEYPUNCHED BY

VERIFIED BY

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

J D C	Veh. No.	Vehicle Name	Reader	C S	P R	P P S Ø P S Ø C C C	D C	S P P R N M I S Ø E	P Ø	X E UP T P PS	
J D C											

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS A SAMPLE LOAD SHEET						
01		ICTYP	1. or 2. or 3 or 4.						
01		ICØND	α or λ or x		δ or y		β or z		A or x
02		ICØND	R or $\dot{y}$		V or z				
01		ITIME	YEAR		MØNTH		DAY		HØUR
02		ITIME	MINUTE		SECØND				
01		DRAG	$C_DA/2M$		K		Drag option 1 or 2.		Atmos Option 1 or 2. or 3. or 4
01		BNDS	IN ØRDER ØF CAT1 AND CAT2 SØLUTIØN VARIABLES						
02		BNDS	(etc)		(etc)				
01		CAT1	$\alpha\ \delta\ \beta\ A\ R\ v\ \frac{C_DA}{2m}\ K$						
01		NITER	N.0						
		SIGMA	σ_R		σ_A or σ_α		σ_E or σ_δ		$\sigma_{\dot{R}}$
		SIGMA	(etc)		(etc)		(etc)		(etc)
		SIGMA	(etc)		(etc)		(etc)		(etc)
		ENDPR							

DATE

NAME

PROBLEM NO.

NO. OF CARDS

ESPØD INPUT SHEETS

PAGE ___ OF ___

PRIORITY

KEYPUNCHED BY

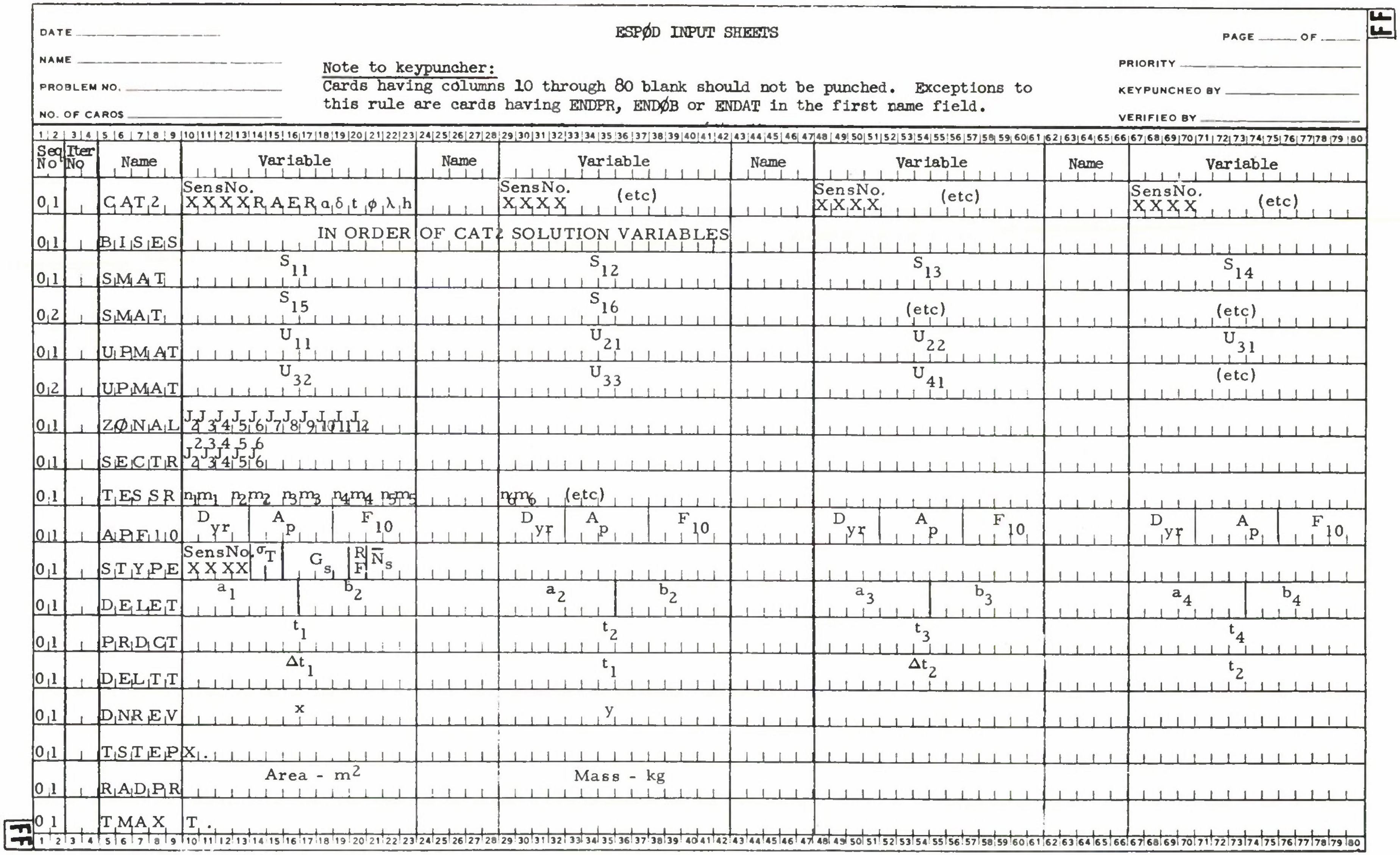
VERIFIED BY

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

J D C	Veh. No.	Vehicle Name	Header	C S	P R	P P S Ø P S Ø C C C	D C	S P P R N M I S Ø E	P Ø	X E UP T P PS	
J D C											

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS A SAMPLE LOAD SHEET						
01		ICTYP	1. or 2. or 3. or 4.						
01		ICØND	α or λ or x		δ or y		β or z		A or $\dot{x}$
02		ICØND	R or $\dot{y}$		v or $\dot{z}$				
01		ITIME	YEAR		MØNTH		DAY		HØUR
02		ITIME	MINUTE		SECØND				
01		DRAG	$C_DA/2m$		K		Drag option 1. or 2.		Atmos. Option 1. or 2. or 3. or 4
01		BNDS	IN ØRDER ØF CAT1 AND CAT2 SØLUTIØN VARIABLES						
02		BNDS	(etc)		(etc)				
01		CAT1	$\alpha\ \delta\ \beta\ A\ R\ v\ \frac{C_DA}{2m}\ K$						
01		NITER	N. 0						
		SIGMA	σ_R or σ_α		σ_A or σ_δ		σ_E or σ_α		$\sigma_{\dot{R}}$ or σ_δ
		SIGMA	(etc)		(etc)		(etc)		(etc)
		SIGMA	(etc)		(etc)		(etc)		(etc)
		ENDPR							

Figure 2-64. Sample Load Sheets



DATE ________ ESPØD INPUT SHEETS PAGE ____ OF ____

NAME ________

PROBLEM NO. ________

NO. OF CARDS ________

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

PRIORITY ________

KEYPUNCHED BY ________

VERIFIED BY ________

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		CAT2	SensNo. XXXXRAER α δ t ϕ λ h		SensNo. XXXX (etc)		SensNo. XXXX (etc)		SensNo. XXXX (etc)
01		BISES	IN ORDER	OF CAT2	SOLUTION VARIABLES				
01		SMAT	S_{11}		S_{12}		S_{13}		S_{14}
02		SMAT	S_{15}		S_{16}		(etc)		(etc)
01		UPMAT	U_{11}		U_{21}		U_{22}		U_{31}
02		UPMAT	U_{32}		U_{33}		U_{41}		(etc)
01		ZØNAL	$J_2 J_3 J_4 J_5 J_6 J_7 J_8 J_9 J_{10} J_{11} J_{12}$						
01		SECTR	$J_2^2 J_3^3 J_4^4 J_5^5 J_6^6$						
01		TESSR	n_1m_1 n_2m_2 n_3m_3 n_4m_4 n_5m_5		n_6m_6 (etc)				
01		APF10	D_{yr} | A_p | F_{10}		D_{yr} | A_p | F_{10}		D_{yr} | A_p | F_{10}		D_{yr} | A_p | F_{10}
01		STYPE	SensNo. XXXX | σ_T | G_s | R/F | $\bar{N}_s$						
01		DELET	a_1 | b_2		a_2 | b_2		a_3 | b_3		a_4 | b_4
01		PRDCT	t_1		t_2		t_3		t_4
01		DELTT	Δt_1		t_1		Δt_2		t_2
01		DNREV	x		y				
01		TSTEP	X.						
01		RADPR	Area - m^2		Mass - kg				
01		TMAX	T.						

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FF

Figure 2-65. Sample Load Sheet

2.2.4 Sample Input Decks

The ESPØD input deck, Figure 2-66 illustrates the data arrangement for an orbit determination run. The deck setup for a run involving ESPØDEPH only is the same except that observation cards and sensor cards are not present.

The input deck as shown is the order in which the various input categories, referred to as subdecks, are arranged. The content of the preliminary data subdeck determines the nature of the ESPØD run. Various possible versions of this subdeck will now be considered.

Reference to Sections 2.2.2 and 2.2.3 will help ascertain the functions of the subdecks. The content of the associated JDC card will be given with each preliminary subdeck, since it is the control card for the program. The contents of the first 29 columns of the JDC card have been omitted from the card content description as it is not relevant to the discussion. The End of Preliminary Data Card (ENDPR) was excluded from the sample decks which follow for the same reason.

Case 1

The simplest differential correction run consists of a JDC card only. File elements and sensor data are obtained from the SEAI tape, and observations obtained from the SRADU tape. In this case, the nominal epoch is the last time of observation. A DNREV card could override this epoch selection. Since no solution vector is specified, a nominal 6 x 6 fit (first six variables of CAT1) with nominal bounds is solved. This is a drag free model with a nominal (Model 1) potential model. There is a maximum of five (5) iterations and observations which are more than ten days from epoch are rejected. These nominal values could be changed with a NITER card and a TMAX card, respectively.

The output from this run (see Section 4.0 for detailed discussion of output formats) consists of station number and name, observation time (from epoch), numbered residual, a summary table of the mean and RMS residuals for each station, the delta correction to each variable, the old value of the variable (initial estimate), the new value, the uncertainty, the bound, the current RMS, predicted RMS, best RMS so far, the covariance matrix, the correlation matrix and a message to indicate whether the solution is converging.

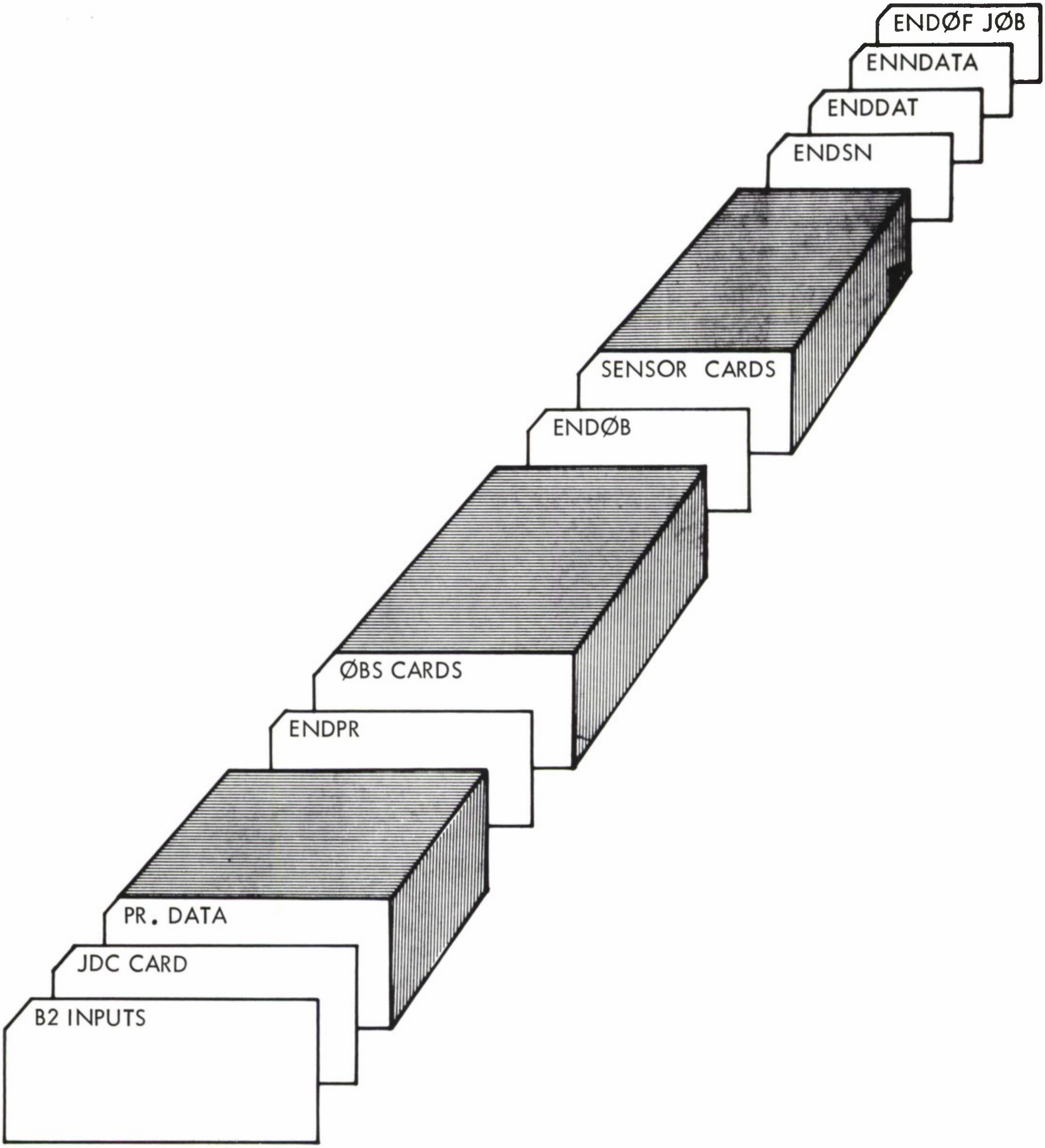
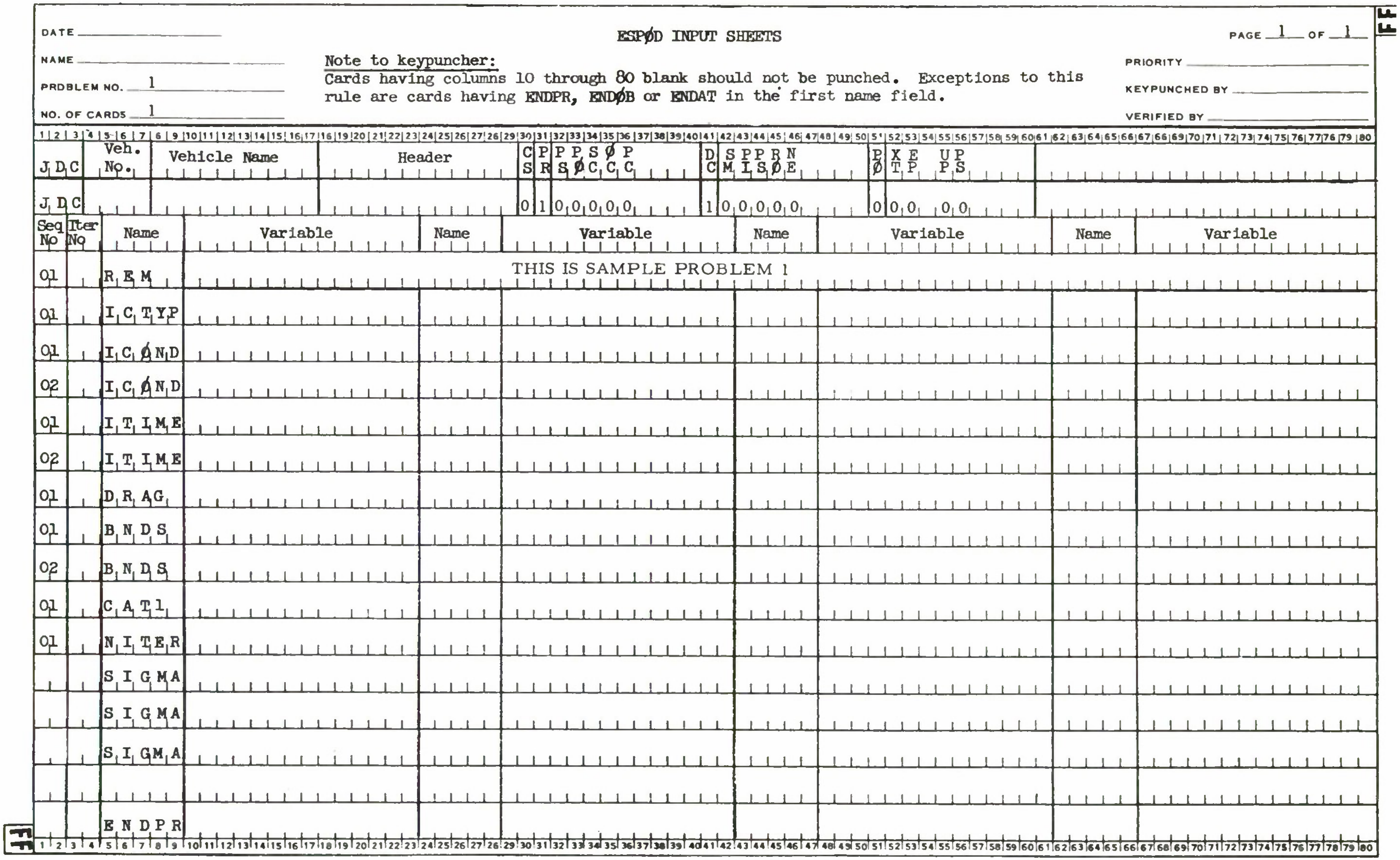


Figure 2-66. ESP0D Input Deck



DATE ____
NAME ____
PROBLEM NO. 1
NO. OF CARDS 1

ESPØD INPUT SHEETS

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

PAGE 1 OF 1
PRIORITY ____
KEYPUNCHED BY ____
VERIFIED BY ____

J D C	Veh. No.	Vehicle Name	Header	C S	P R	P S	P Ø	S C	Ø C	P C	D C	S M	P I	P S	R Ø	N E	P Ø	X T	E P	U P	P S	
J D C				0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS SAMPLE PROBLEM 1						
01		ICTYP							
01		ICØND							
02		ICØND							
01		ITIME							
02		ITIME							
01		DRAG							
01		BNDS							
02		BNDS							
01		CAT1							
01		NITER							
		SIGMA							
		SIGMA							
		SIGMA							
		ENDPR							

Figure 2-67. Load Sheet for Problem 1

The critical columns of the JDC card for this particular run are **31, 34, 35,** and **41**. The load sheet for this case follows, consisting of a JDC card only.

Case 2

The simplest card input subdeck for an ESPØDEPH run consists of two cards. The run consists of an ephemeris prediction only, using file elements and epoch.

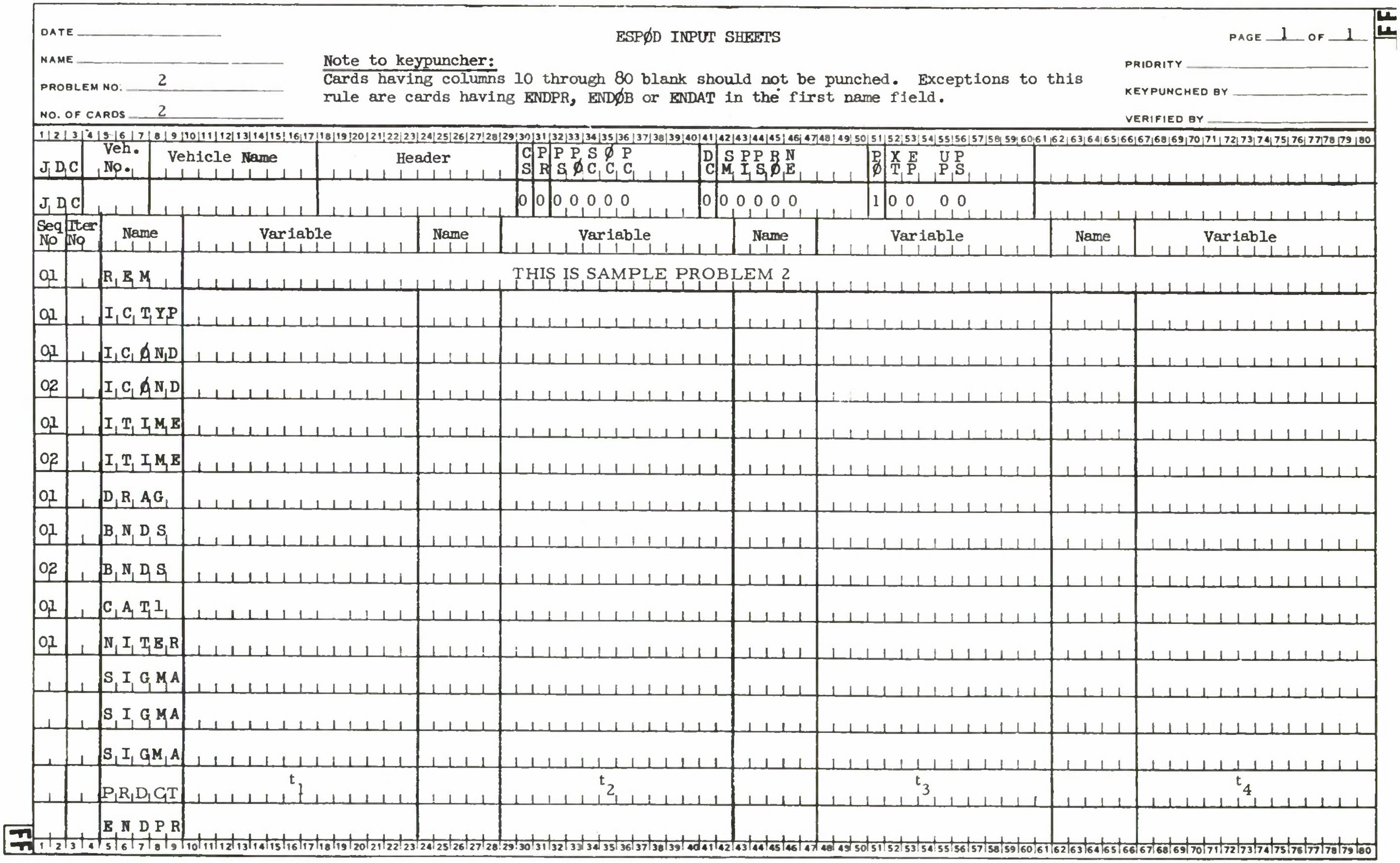
	Tapes
1. JDC Card	1. SEAI
2. PRDCT Card	2. SRADU

Since there is no specification of initial conditions on cards, the initial conditions will be read off the SEAI tape, in the SPADATS mean elements format. The epoch revolution number is specified in the SPADATS mean elements, and this is the epoch which is used in this case. Note that the radiation pressure model and the atmospheric models will not be included, and only a nominal potential model (J_2, J_3, J_4) is used in the ephemeris prediction.

A variation of this case would be to include a DNREV card for the purpose of updating the file elements to a desired epoch.

The ESPØDEPH output for each time specified is: vehicle position and velocity in polar and Cartesian form, the classical orbital elements, vehicle altitude, geodetic latitude, longitude, argument of latitude, period, perigee and apogee altitudes, time from epoch to the next crossing of the ascending node, and a set of indeterminancy free elements. If column 53 of the JDC card is punched, the special binary ephemeris tape containing x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$ versus time is generated.

The load sheet for this run, consisting of two cards, is shown in Figure 2-68.



DATE

NAME

PROBLEM NO. 2

NO. OF CARDS 2

ESPØD INPUT SHEETS

PAGE 1 OF 1

PRIORITY

KEYPUNCHED BY

VERIFIED BY

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

J D C	Veh. No.	Vehicle Name	Header	C S	P R	P S	P Ø	S C	Ø C	P C	D C	S M	P I	P S	R Ø	N E	P Ø	X T	E P	U P	P S
J D C				0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS SAMPLE PROBLEM 2						
01		ICTYP							
01		ICØND							
02		ICØND							
01		ITIME							
02		ITIME							
01		DRAG							
01		BNDS							
02		BNDS							
01		CAT1							
01		NITER							
		SIGMA							
		SIGMA							
		SIGMA							
		PRDCT	t_1		t_2		t_3		t_4
		ENDPR							

Figure 2-68. Load Sheet for Problem 2

Case 3

The input sequence of this case is given below.

1. JDC
2. ICTYP
3. IC0ND
4. ITIME
5. DRAG
6. APF10
7. CAT2
8. BISES
9. STYPE
10. SIGMA

Tapes Needed

1) SEAI
2) SRADU

This is preliminary subdeck setup (except for the JDC card) for a differential correction run. The initial conditions are specified on cards and the solution vector consists of Category 2 variables only. The presence of a CAT2 card without a CAT1 card suppresses the nominal 6 x 6 solution vector. The BISES card contains the initial bias estimates of the CAT2 variables. The only non-nominal perturbation in this integration model is the dynamic atmosphere, which requires APF10 cards. The STYPE card is used to change sensor characteristics and the SIGMA card changes standard deviations in the SIGMA table. (The load sheets for this case are shown in Figures 2-69 and 2-70.

Card 1: JDC	
Card 2-3: IC0ND	Specifies the initial conditions in Cartesian coordinates
Card 4-5: ITIME	Defines time of epoch
Card 6: ICTYP	The "3." Specified type 3 elements; i. e., Cartesian.
Card 7: DRAG	The first two variable fields contain the drag parameter and the drag variation respectively. The third variable field (content: 2) calls for secular drag variation; and the fourth variable field (content: 4) flags the COESA Dynamic Atmosphere.

Card 8: SIGMA	This card is used to change the standard deviations of sensor type 17, indicated in the first two columns of the card. The four variable fields contain the new standard deviations for this sensor type (for this run only).
Cards 9-10: APF10	These cards contain the A_p (geomagnetic planetary amplitude) and F_{10} (10.7 centimeter solar flux) coefficients for the days covering the period of integration. (8 days)
Card 11: CAT2	The first four columns of the variable field identify the sensor (0329). The "1"s call the variables to be solved for. For Sensor No. 0329 they are: range bias, azimuth bias, elevation bias, range rate bias, latitude bias, and longitude bias. In the second variable field, the solution variables for Sensor No. 0330 are: azimuth bias, elevation bias, range rate bias, and time bias.
Cards 12-14: BISES	These three cards contain the bias estimates for the Category 2 variables. As indicated on the load sheet, the bias estimates correspond one-to-one with Category 2 variables.
Card 15: STYPE	This card is used to change data in the STYPE table; that is, the sigma type, the gross outliers criterion, the refraction flag, and the mean surface value of refractivity. The new parameters are valid on this run only.

Case 4

This case is a combined ESP0DDC and ESP0DEPH run, and contains most of the options. The input preliminary cards are:

1. JDC
2. REM
3. ICTYP
4. SPADATS - 7 element
5. DNREV
6. DRAG
7. APF10
8. RADPR
9. Z0NAL
10. SECTR
11. TESSR
13. CAT1
14. CAT2
15. BNDS
16. BISES
17. NITER
18. DELET
19. TMAX
20. SIGMA
21. STYPE
22. PRDCT
23. 99 cards

DATE

NAME

PROBLEM NO. 3

NO. OF CARDS 15

ESPØD INPUT SHEETS

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

PAGE 1 OF 2

PRIORITY

KEYPUNCHED BY

VERIFIED BY

JDC	Veh. No.	Vehicle Name	Header	CS	PR	PPSØC	SØCCC	DC	SPPRN MISØE	PØ	XETP	UPPS
JDC				0	1	0,0,0,0,0		1	0,0,0,0,0	0	0,0	0,0

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS SAMPLE PRØBLEM 3						
01		ICTYP	3.						
01		ICØND	x		y		z		$\dot{x}$
02		ICØND	$\dot{y}$		$\dot{z}$				
01		ITIME	YEAR		MØNTH		DAY		HØUR
02		ITIME	MINUTE		SECØND				
01		DRAG	$C_D A/2m$		K		2.		4.
01		BNDS							
02		BNDS							
01		CAT1							
01		NITER							
17		SIGMA	σ_R		σ_A		σ_E		σ_R
		SIGMA							
		SIGMA							
		ENDPR							

Figure 2-69. Load Sheet 1 for Problem 3

DATE ________

NAME ________

PROBLEM NO. 3

NO. OF CARDS 15

ESPØD INPUT SHEETS

PAGE 2 OF 2

PRIORITY ________

KEYPUNCHED BY ________

VERIFIED BY ________

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		APF10	D_{yr} A_p F_{10}		D_{yr} A_p F_{10}		D_{yr} A_p F_{10}		D_{yr} A_p F_{10}
02		APF10	D_{yr} A_p F_{10}		D_{yr} A_p F_{10}		D_{yr} A_p F_{10}		D_{yr} A_p F_{10}
01		CAT2	03291111000110		033001110010000				
01		BISES	R_b (EST)		A_b (EST)		E_b (EST)		$\dot{R}_b$ (EST)
02		BISES	ϕ_b (EST)		λ_b (EST)		A_b (EST)		E_b (EST)
03		BISES	$\dot{R}_b$ (EST)		t_b (EST)				
01		STYPE	032917 G_s R F $\overline{N}_s$						

Figure 2-70. Load Sheet 2 for Problem 3

The initial conditions are specified on the SPADATS mean element cards (7), with the epoch, as specified with these elements, to be updated to a desired epoch with a DNREV card. As in the previous case, a dynamic atmosphere requiring A_p and F_{10} data is selected.

The initial integration time step is changed as well as the maximum number of iterations in the differential correction process. The most sophisticated potential model as well as the inclusion of radiation pressure complete this perturbation model. The solution vector consists of both CAT1 and CAT2 variables. As in the previous case, initial estimates of the Category 2 variables are included. New bounds for this case have been introduced. Data editing in the form of residual selection and rejection of observations too far removed in time from epoch is included. Data in the sigma and STYPE tables are changed for this run.

The ephemeris generation is specified on a PRDCT card, although it could be specified on DAC or DELTT cards. The load sheets for this run are shown in Figures 2-71 and 2-72.

Card 1: JDC	Columns 41 and 51 call for the differential correction package and ESPØDEPH. Column 36 indicates that the program constants are to be printed. In column 46, the "newest elements" are selected to generate the updated times in ESPØDEPH. These are the elements whose residuals have not been calculated. Column 53 calls for the generation of the special binary ephemeris tape.
Card 2: REM	The remarks card need not follow the JDC card.
Card 3: ICTYP	The content (4) indicates that type 4 elements are read in as initial conditions (SPADATS mean elements).
Card 4: DRAG	Same as Case 3
Card 5-6: BNDS	These two cards contain the bounds for the Categroy 1 and Category 2 variables respectively.
Card 7: CAT1	The Category 1 variables with a "1" indicate inclusion in the solution vector. They are: right ascension, declination, flight path angle (β), azimuth, $C_DA/2m$, and K.

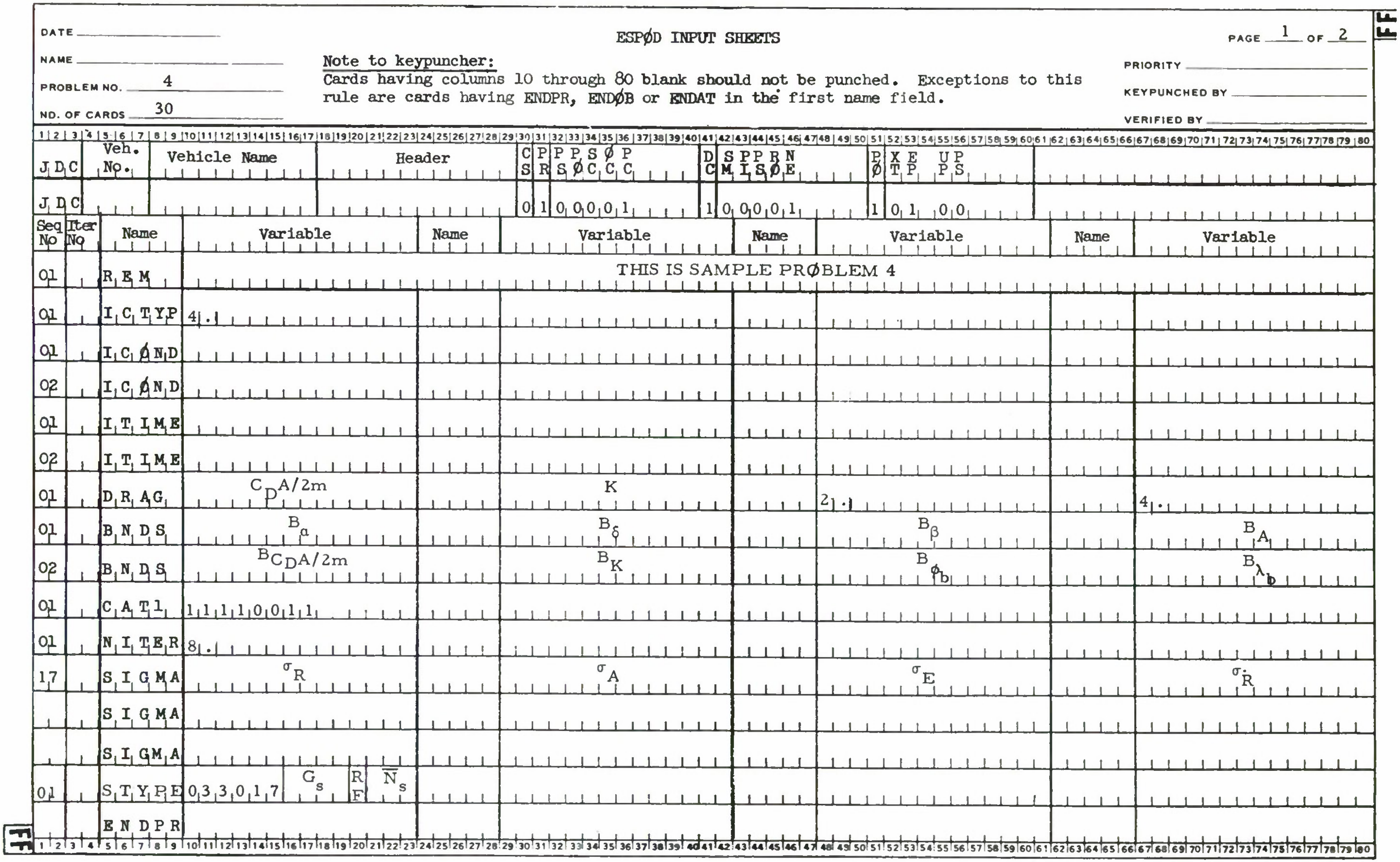
Card 8: NITER	This permits the maximum iterations in the differential correction process to be 8. The nominal value is 5 iterations.
Card 9: SIGMA	The first two columns indicate the sensor type (17), and the variable fields contain the new standard deviations for that sensor type.
Card 10: STYPE	This card can change the remaining sensor characteristics of sensor type 17; that is, gross outliers criterion, refraction flag, and mean surface value of refractivity.
Cards 11-12: APF10	These two cards contain the A_p and F_{10} coefficients for the period of integration.
Card 13: DNREV	The content (-1.0) is a flag to update the epoch (when using SPADATS mean elements) to the last time of observation.
Card 14: RADPR	This calls the radiation pressure option. The variable fields contain the effective area of the vehicle in square meters, and its mass in kilograms.
Card 15: ZØNAL	These four cards specify the fourth potential model as described in Section 2.1.3.7.3
Card 16: SECTR	
Card 17: TESSR	
Card 18: 99 card	
Card 19: CAT2	The Categroy 2 variables selected are the latitude and longitude biases for sensor No. 0330. Hence, the solution vector of this run is an 8 x 8 system.
Card 20: BISES	This card contains the bias estimates of the Category 2 variables, in the order given. That is, the first variable field contains the latitude bias and the second field, the longitude bias.

Card 21: DELET	This card specifies the first and last residual, in each V-field, of a list of residuals to be deleted. The identification numbers are obtained from the residuals listing output after running at least once with this case.
Card 22: TMAX	This card permits the rejection of observations which are more than 8 days from epoch. The nominal value is ten days.
Card 23: PRDCT	This card specifies the update times at which the vehicle position and velocity are calculated and printed. These times could have been specified on DAC or DELTT cards.
Cards 24-30:	SPADATS mean elements. See Section 2. 1. 3. 1. 1 for format.

2. 2. 5 Stacked Cases

It is possible to stack cases for a single run. For each case to be run, an adequate set of case description cards (b, c, d, e) are prepared. Cards for input are in seven categories as listed below:

1) Job start in B2 system schedule mode
2) ESP0D job description card, JDC
3) Preliminary data
4) Observation cards, if any
5) Sensor cards, if any
6) ESP0D end of data (ENDAT)
7) Job finish in B2 system schedule mode



DATE

NAME

PROBLEM NO. 4

NO. OF CARDS 30

ESPØD INPUT SHEETS

PAGE 1 OF 2

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

PRIORITY

KEYPUNCHED BY

VERIFIED BY

JDC	Veh. No.	Vehicle Name	Header	C S	P R	P P S Ø P S Ø C C C	D C	S P P R N M I S Ø E	P Ø	X E T P	U P P S
JDC				0	1	0 0 0 0 1	1	0 0 0 0 1	1	0 1	0 0

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		REM	THIS IS SAMPLE PRØBLEM 4						
01		ICTYP	4.						
01		ICØND							
02		ICØND							
01		ITIME							
02		ITIME							
01		DRAG	$C_DA/2m$		K		2.		4.
01		BNDS	B_α		B_δ		B_β		B_A
02		BNDS	$B_{C_DA/2m}$		B_K		B_{ϕ_b}		B_{λ_b}
01		CAT1	11110011						
01		NITER	8.						
17		SIGMA	σ_R		σ_A		σ_E		$\sigma_{\dot{R}}$
		SIGMA							
		SIGMA							
01		STYPE	033017 G_s $R F$ $\overline{N}_s$						
		ENDPR							

Figure 2-71. Load Sheet 1 for Problem 4

ESPØD INPUT SHEETS

DATE
NAME
PROBLEM NO. 4
NO. OF CARDS 30

Note to keypuncher:
Cards having columns 10 through 80 blank should not be punched. Exceptions to this rule are cards having ENDPR, ENDØB or ENDAT in the first name field.

PAGE 2 OF 2
PRIORITY
KEYPUNCHED BY
VERIFIED BY

Seq No	Iter No	Name	Variable	Name	Variable	Name	Variable	Name	Variable
01		APF10	184. A_p F_{10}		185. A_p F_{10}		186. A_p F_{10}		187. A_p F_{10}
02		APF10	188. A_p F_{10}		189. A_p F_{10}		190. A_p F_{10}		191. A_p F_{10}
01		DNREV	-1.0						
01		RADPR	Area - M^2		Mass - K				
01		ZØNAL	11111111						
01		SECTR	111						
01		TESSR	31 32 41 42 43						
99		00159	1082.48 -06	00160	-2.562 -06	00161	-1.84 -06		
01		CAT2	03300000000110						
01		BISES	ϕ_b		λ_b				
01		DELET	a_1 b_1		a_2 b_2		a_3 b_3		a_4 b_4
01		PRDCT	t_1		t_2		t_3		t_4
01		TMAX	8.						
			ALSO, 7-SPADATS MEAN	ELEMENTS CARDS					

Figure 2-72. Load Sheet 2 for Problem 4

The case description cards are arranged in multiple consecutive sets between the B2 system Job start and Job finish cards (see Section 2.1.1). For example, the card arrangement for three cases would be:

a

b_1 c_1 d_1 e_1
b_2 c_2 d_2 e_2
b_3 c_3 d_3 e_3

f

g

When running with File Data, the observation and sensor data are obtained from the SRADU and SEAI tapes, respectively; this would eliminate the d and e cards from the above sequence.

3. OPERATIONAL INSTRUCTIONS

ESPOD may be executed in two operational modes in the B2 system; the manual mode and the schedule mode as discussed below.

3.1 MANUAL MODE

Table 3-I lists the required and optional tapes for the manual mode.

Table 3-I. Tape Setup for Manual Mode

Logical Tape Number	Setup	Tape Description
⓪	Input	Prestored input data
1	System	B2 master system tape
4	SEAI	Master SEAI (sensor, elements, acquisition, and information sites)
6	SRADU	Observation tape
⑦	Scratch	ESPOD writes blocks of CØMMØN data and observations on this tape
◇8		Planetary ephemeris tape
◇⑩	Scratch	Special binary ephemeris tape ($\vec{R}$, $\vec{V}$ versus time) generated by ESPØDEPH on option
⑪	OUTPUT	Off line output tape
◇15		Prestored octal change cards (TOGGLE 45, ON, if octals present)

○ Write ring required

◇ May be left out if proper conditions are met

When the B2 System has been initiated, giving control to the flexowriter, the following is typed out:

MANUAL   Typed in by operator

When the manual mode is indicated as ready,

ESPØD   Typed in by operator

The computer system will locate the ESPØD segment on the B2 system tape and transfer control to it. The following will then by typed by the System on the flexowriter:

START ESPØD

START ESPØDDC   (if selected)

START ESPØDEPH   (if selected)

START ESPØD   (for next case)

.

.

.

.

NEXT FUNCTIØN

When NEXT FUNCTIØN is typed out, the orbit determination has been completed and the output is on LØG Tape 11. Printed output is in DS-0; wrap up output is in DS-1.

3.2 SCHEDULE MODE

The schedule mode requires no operator intervention; all necessary inputs for system operation are on the schedule tape. The tape setup for the schedule mode is given below.

Table 3-II. Tape Setup for Schedule Mode

Logical Tape Number	Setup	Tape Description
⓪	Scratch	Data is transferred to this tape
1	System	B2 master system tape
2	Schedule	Job tape (input)
◇3	SEAI	Backup tape for logical tape NO. 4
4	SEAI	Master SEAI tape. ESPØD uses only the sensors and elements from this tape
6	SRADU	Observation tape
⑦	Scratch	ESPØD writes blocks of CØMMØN DATA and observations on this tape
◇8		Planetary ephemeris tape
◇⑩	Scratch	Special binary ephemeris tape ($\vec{R}$, $\vec{V}$ versus Time) generated by ESPØDEPH on option
⑪	Output	Off-line output tape
◇15		Prestored Octal change cards (Toggle 45, ON)

○ Write ring required

◇ May be left out if proper conditions are met

Toggle Settings:

Toggle 24, ON

Toggle 45, ON, if octals are present (Tape 15).

The input deck must be in the order as specified in Section 2.2.5 (input decks, stacked cases). The SCHEDULE tape is interrogated by the B2 system and ESPØD is called in after data has been transferred to Tape 0. If it is a cold-start, then Tape LØG 7 is not read, but is written before calling the next section of the orbit determination package. If it is a conditioned start, ESPØD reads Tape LØG 7, expecting to find CØMMØN storage already recorded there.

DS-0 prints all normal ESPØDEPH output. DS-1 prints card image of card prepared by ESPØDEPH for GIPAR, and DS-2 punches all cards.

3.3 COLD AND CONDITIONED START

Column 30 of the JDC card indicates whether the current run is started from a cold start, a conditioned start, or a conditional start. The distinction between the cold start and either the conditioned or conditional start is that with the latter cases the observations are recovered from a LØG 7 tape which was generated on a previous cold-start run. This eliminates the necessity of reprocessing observation cards when the only change to the input deck is in the JDC options or the preliminary data. The conditional start is a suboption of a conditioned start.

3.3.1 Cold Start

The following procedure describes the method of input processing from a cold start. First, the JDC card is read and interpreted and followed by the preliminary data. The program then interrogates the JDC card to determine if it is an ESPØDEPH run only. If this is so, ESPØDEPH is called into core from the B2 Master Tape and control is transferred to it. However, if ESPØDDC is to be executed, the observation data is read (from the SRADU tape or observation cards), time sorted and written on the data tape. Sensor data (from the SEAI tape or on cards), if any, is processed and a tape is generated of the data in CØMMØN storage. ESPØDDC is then called from the B2 Master Tape and control is given to it. After execution of the differential corrector package, the JDC card is again interrogated and ESPØDEPH is executed, if called.

3.3.2 Conditioned Start

The conditioned start options (column 30 of JDC card = 1 or 2) permit the running conditions to be obtained from a tape record generated in the last iteration of some preceding differential correction. The tape left on Tape LØG 7 after a differential correction contains the data necessary for this type of continuation. The uses of the conditioned start are:

a) Restarting an iteration after machine failure or an interruption, without reprocessing the preliminary data, the observations, and sensor data

b) Extending the previous differential correction with more iterations, with modifications to the solution vector or to the force models

c) Performing a prediction with the results of a previous differential correction

As indicated above, it is possible to modify some of the preliminary data associated with the previous differential correction. In a conditioned start, a new JDC card, which calls for a conditioned start (column 30) with new preliminary data, if any, is input. The foregoing restrictions apply:

a) The object must remain the same

b) The initial conditions may be changed but this nullifies any benefit from a previous differential correction run

c) The solution vector may be changed; if drag is added, and a drag model was not previously included, it must be provided with the new preliminary data

d) The force model may be changed

e) New observations may not be added

f) New sensor data may not be added

g) Sensor type data and standard deviations may be modified (STYPE and SIGMA cards)

3.3.3 Conditional Start

The conditional start is a suboption of the conditioned start. It is provided principally to prevent running a prediction using initial conditions which, because of the circumstances of their formation, may be worse than the best available. In the conditional start mode, the run will not proceed if two conditions were present when the correction terminated: a) convergence was not obtained on the final iteration; and b) the next to last iteration was a diverging step. ESPØDEPH will not run on a conditional start if it follows immediately after an ESPØDDC run which was not converging. In this case, no prediction will be performed.

3.4 ERROR RETURNS AND RECOVERY

Section 4.1 of this document lists the on-line messages and Section 4.2.9, the off-line messages. When an incorrect card is input, the program continues to read until it finds the next JDC card, or exits if it is the last case. An exception to this rule occurs when there are no observations on the SRADU Tape for the vehicle in question. The program then exercises the STOP-GO option until the operator types STOP or GO as instructed on the Flexowriter. The same rule applies when the SEAI Tape does not contain the initial conditions for the vehicle.

3.5 INTERFACE CONSIDERATIONS

3.5.1 Core Interface

ESPOD stores the predicted Cartesian position coordinates (X, Y Z in Earth radii) and the associated time in days and fractions of days for the times specified on DAC cards. These parameters are stored in core, beginning in location 15100. These parameters are not left in core if the ESPØDEPH times are specified on DELTT or PRDCT cards (up to four sets of data can be stored).

3.5.2 Special Binary Ephemeris Tape

ESPOD generates an ephemeris tape (Tape LØG 10) of X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$ versus time on option (column 53 of JDC card). This tape may be used as input to other system programs (for use with XYZLA). The Binary Ephemeris Tape format is described in Section 3.7.5 of ESD-TDR-64-395 "ESPOD Mathematical and Subroutine Description."

4. OUTPUT DESCRIPTION

ESPOD produces output in the form of on-line messages, punched cards, magnetic tape and off-line printout. This section explains the format, the parameters produced, and in the case of optional output, how to obtain it. Each kind of output will be discussed in turn, and samples are given to clarify the description.

4.1 ON-LINE MESSAGES

On-line messages may be typed by the Flexowriter during an ESPOD run. They are error diagnostics which direct the operator to the source of a program stoppage.

The messages below are arranged alphabetically to aid the operator in using this document.

CONDITIONAL REQUIREMENTS NOT MET - PROCEEDING TO NEXT CASE

> This message appears when CLDSTR = 2 and CONVR $\neq$ 0. The program then finds the next JDC card and starts to read more data, or exits if this is the last case.

DATA NAME (   ) NOT FOUND

> This message indicates that an illegal card name was used, and the program proceeds reading cards

ERROR. NO OBS ON SRADU FOR SATELLITE NO.__________.
TYPE GO TO REREAD TAPE, STOP FOR NEXT CASE.

> When this message is typed, the program exercises the STOP-GO option until the operator types GO or STOP as instructed on the Flexowriter.

OBS OVERFLOW CORE, NOT IN REVERSE SORT, ERROR.

> When this message is typed, the program finds the next JDC card and starts to read more data, or exits if this is the last case.

SENSOR DATA OVERFLOWS COMMON, ERROR

> When this message is typed, the program finds the next JDC card and starts to read more data, or exits if this is the last case.

TAPE 04 BAD---MOUNT BACKUP
ELEMENTS FOR SATT.__________NOT ON SEAI.
TYPE---GO TO REREAD SEAI, STOP FOR NEXT CASE.

> When this message is typed, the program exercises the STOP-GO option until the operator types GO or STOP as instructed on the Flexowriter.

TAPE 04 BAD---MOUNT BACKUP
TYPE---GO RETRY TAPE, STOP NEXT CASE.

This message indicates that the program will exercise the STOP-GO option while the backup tape is being mounted, and will do so until the operator types GO or STOP as instructed on the Flexowriter.

TAPE ON LOG 7 NOT CORRECT. I. D. IS __________.
TYPE---GO TO RETRY TAPE, STOP FOR NEXT CASE.

This message indicates that the program will exercise the STOP-GO option until the operator changes the tape and/or types GO or STOP as instructed on the Flexowriter.

4. 2 STANDARD OUTPUT

ESPOD's standard output is an off-line printout. This information contained in the run is indexed in Figure 4-1, which directs attention to more detailed descriptions of particular output sections.

4. 2. 1 Input Listing

This page lists the input cards which were entered for the run. The columns in the listing correspond exactly with the columns punched on the input cards. See Section 2.0 for the input card formats.

These data are a quick and convenient check for proper input to the run. Figure 4-2 shows a sample input listing page.

4. 2. 2 Run Header Data

The Job Description Card (JDC), run identification data, program control and reference data, and initial conditions comprise the run header data. See Section 2.0 for input quantity descriptions.

These data identify the run, labeling the various input quantities and presenting standard coordinate initial conditions. Figure 4-3 shows a sample header data page. Each line is described as follows:

Page Print Line No.	Line Description
1	An identification obtained from JDC columns 20-29; run number, programmer's name, etc.
2	Vehicle number from JDC columns 4-7, vehicle name from columns 8-19.

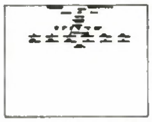
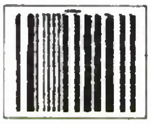
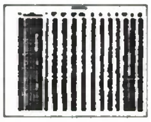
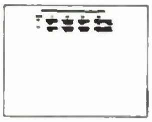
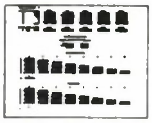
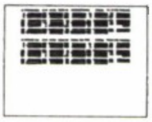
SAMPLE RUN	DATA	NO. PAGES	SECTION
	INPUT LISTING	1	4.2.1
	RUN HEADER DATA	1	4.2.2
	OBSERVATION TYPE	1 OR MORE	4.2.3
	SENSOR LOCATIONS	1	4.2.4
	RESIDUALS PRINT	1 OR MORE	4.2.5
	ESTIMATES OF MEAN AND STANDARD DEVIATIONS	1	4.2.6
	CURVE FIT INTERATION SUMMARY	1	4.2.7
	TRAJECTORY PRINT	1 OR MORE	4.2.8

Figure 4-1. ESPOD Standard Run Output

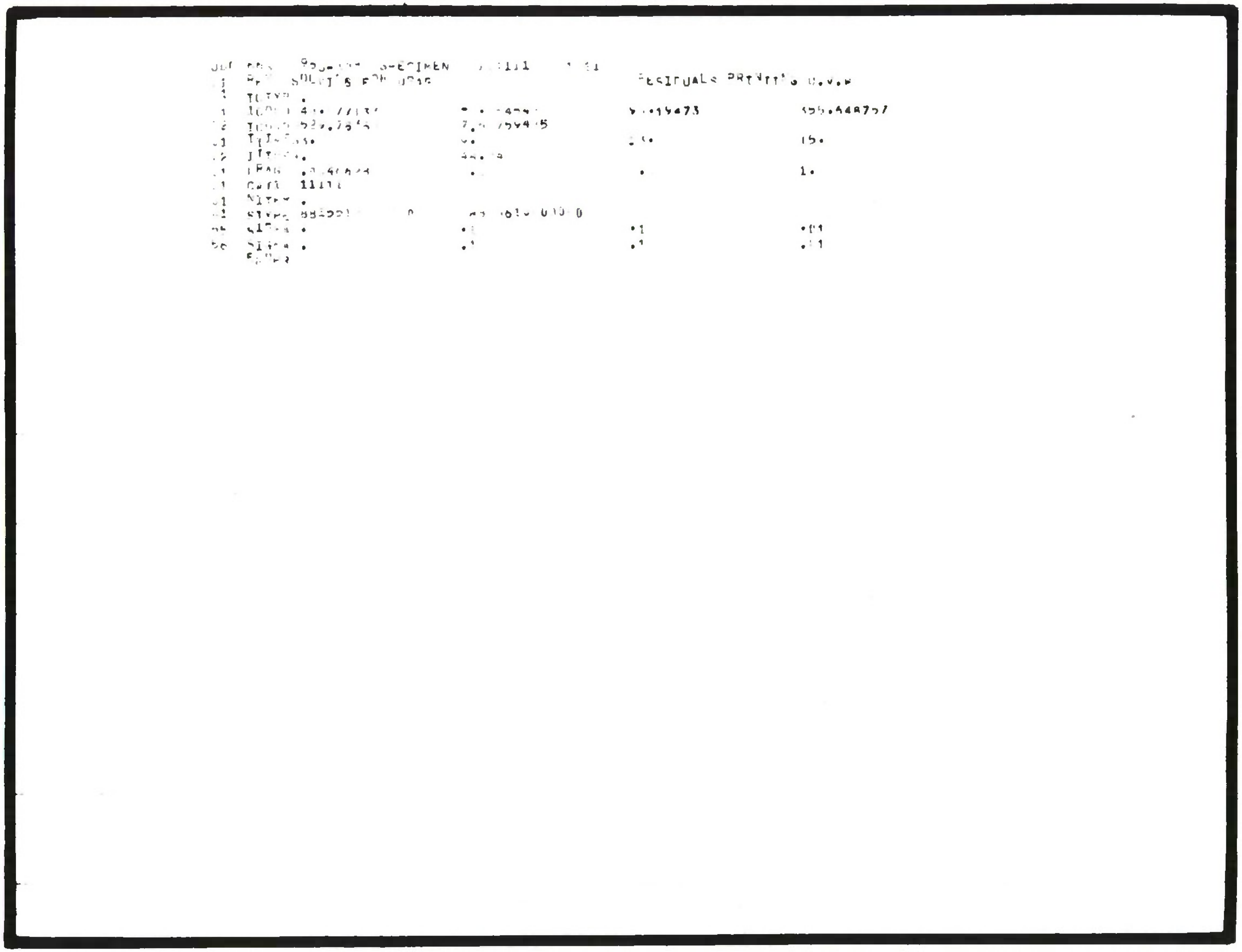
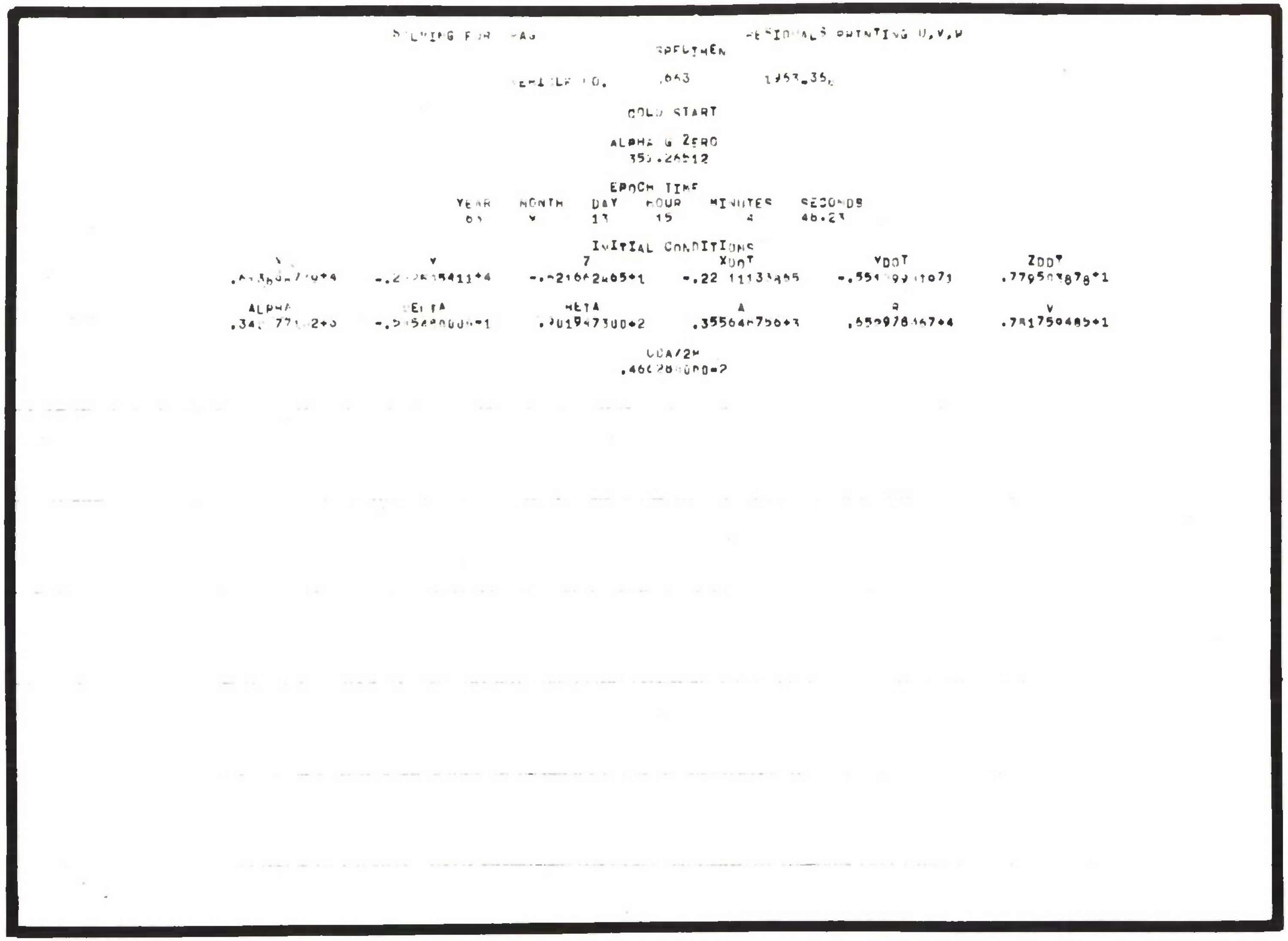


Figure 4-2. Sample ESPOD Input Listing Page



```
SOLVING FOR [illegible]                    RESIDUALS PRINTING U,V,W
                                SPECIMEN

              VEHICLE NO.     .6[illegible]3          1963_35

                                COLD START

                               ALPHA G ZERO
                                35[illegible].26512

                                EPOCH TIME
            YEAR    MONTH    DAY    HOUR    MINUTES    SECONDS
             6[illegible]      [illegible]       13      15        4        46.23

                            INITIAL CONDITIONS
     X              Y              Z              XDOT            YDOT            ZDOT
.[illegible]+4   -.2[illegible]5411+4   -.[illegible]21642465+1   -.22 1113[illegible]85   -.551[illegible]99[illegible]1071   .7795[illegible]878+1

   ALPHA          DELTA          BETA             A               R               V
.34[illegible]77[illegible]2+3   -.5[illegible]54[illegible]000[illegible]-1   .[illegible]01947300+2   .35564[illegible]756+3   .55[illegible]978[illegible]67+4   .781750485+1

                                 CDA/2M
                                .46[illegible]28[illegible]0D0-2
```

Figure 4-3. Sample ESPOD Header Data Page

Page Print Line No.	Line Description
3	COLD START or NON-COLD START: By flag in JDC column 30; 0 = cold start, 1 = non-cold start.
4	ALPHA G ZERO: The right ascension of the Greenwich meridian at midnight on the day of epoch.
5	Numerical value of Alpha G Zero, in degrees.
6, 7, 8	Epoch time of the run.
9	INITIAL CONDITIONS: First estimate of conditions at epoch.
10, 11	Symbols and numerical values of initial conditions in geocentric inertial Cartesian coordinates, units are kilometers and kilometers/second.
12, 13	Symbols and numerical values of initial conditions in geocentric inertial spherical polar coordinates, units are degrees, kilometers, and kilometers/second.

The following are printed only if a drag parameter value has been input:

14	CDA/2M: atmospheric drag parameter.
15	Numerical value input for $C_DA/2m$, units are meters^2/kilogram.

4.2.3 Observation Type

This page lists the time-ordered observations input for this run. Figure 4-4 shows a sample observation type page. The column symbols and their descriptions are:

Column Symbol	Description
ID	Observing station's identification number, corresponds to a number under SENSOR LOCATIONS.
T-TO	Time of the observation in minutes from the epoch (TO).
YR MN DAY HR MIN SEC	Greenwich time at which the observation was obtained: Year, month, day, hour, minute, and decimal seconds.

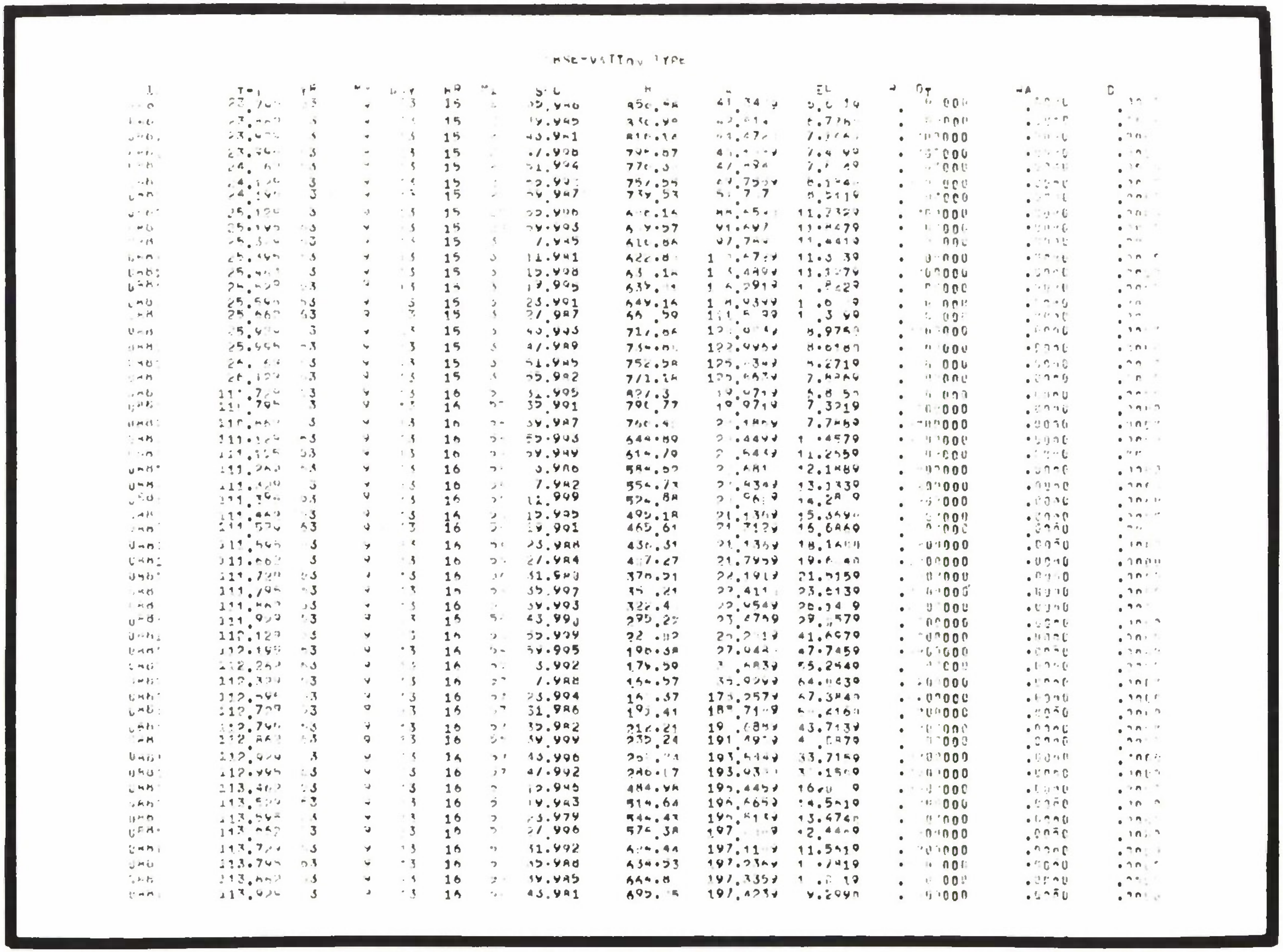


Figure 4-4. Sample ESPOD Observation Type Page

Column Symbol	Description
R	Range observation, in kilometers.
A	Azimuth observation, in degrees positive clockwise from true north.
EL	Elevation observation, in degrees from the horizon.
R DOT	Range rate observation, in kilometers/second.
HA	Hour angle observation, in degrees.*
D	Declination observation, in degrees.*

The numerical values for the observations are listed in the above columns on one or more pages. All quantities are positive unless prefixed by a minus sign. Columns for which the particular sensor does not report data automatically contain zeroes.

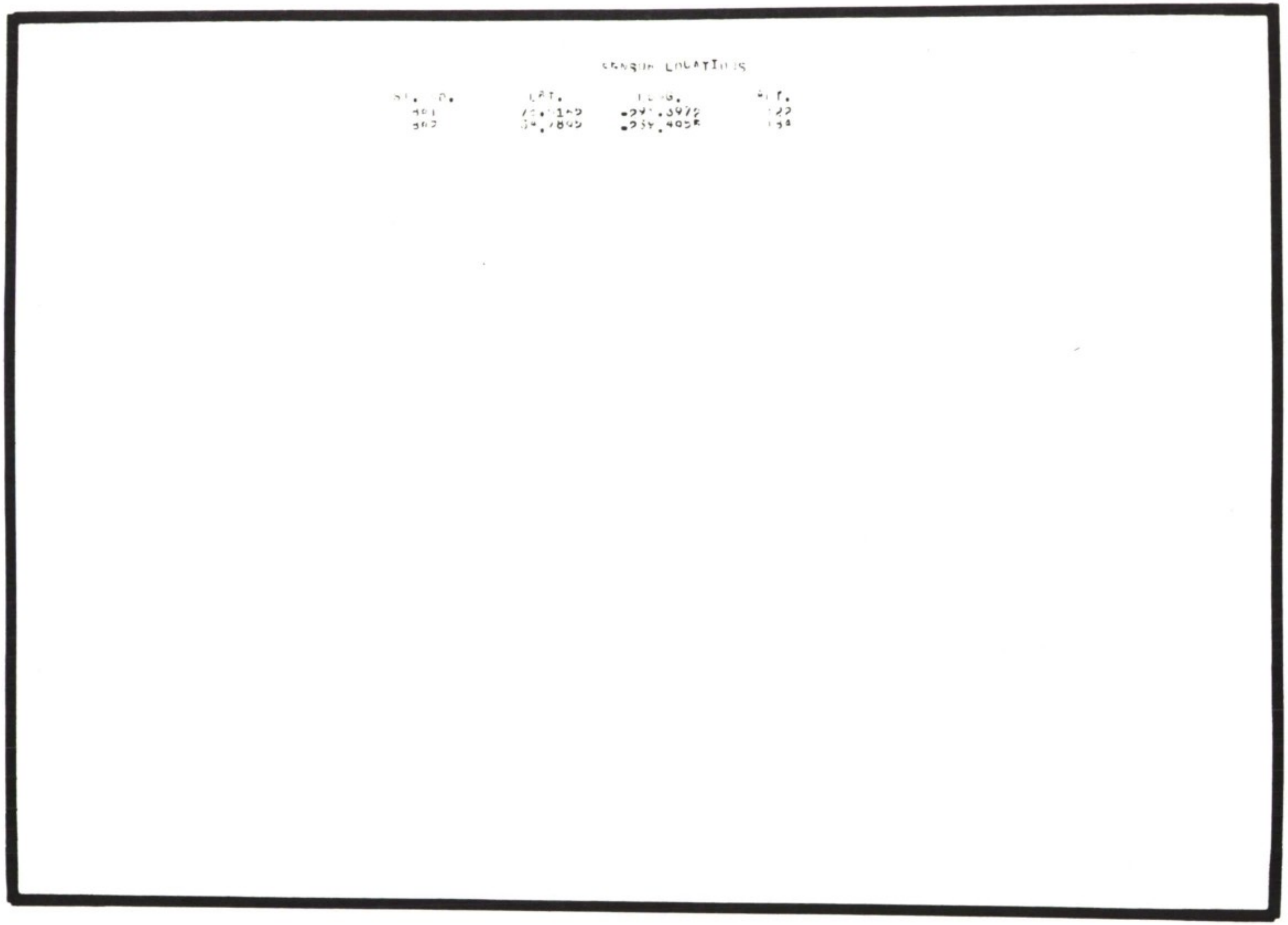
4.2.4 Sensor Locations

This page shows the locations of the sensors for which observations have been input for this particular run. Figure 4-5 shows a sample page print of the sensor locations. The following listing describes the lines on this page:

Page Print Line No.	Line Description
1	SENSOR LOCATIONS: The identification and geodetic location of stations furnishing observations, referenced to the WGS 1960 spheroid.
2	Column identifications ST. NO. Observing station's identification number LAT. North latitude of observing station, in degrees LONG. West longitude of observing station, in degrees ALT. Altitude of observing station above mean sea level, in meters
3 to Page End	Numerical values in the columns indicated in line 17.

---

*Zeroes if the station reports angular observations in azimuth and elevation, and vice versa.



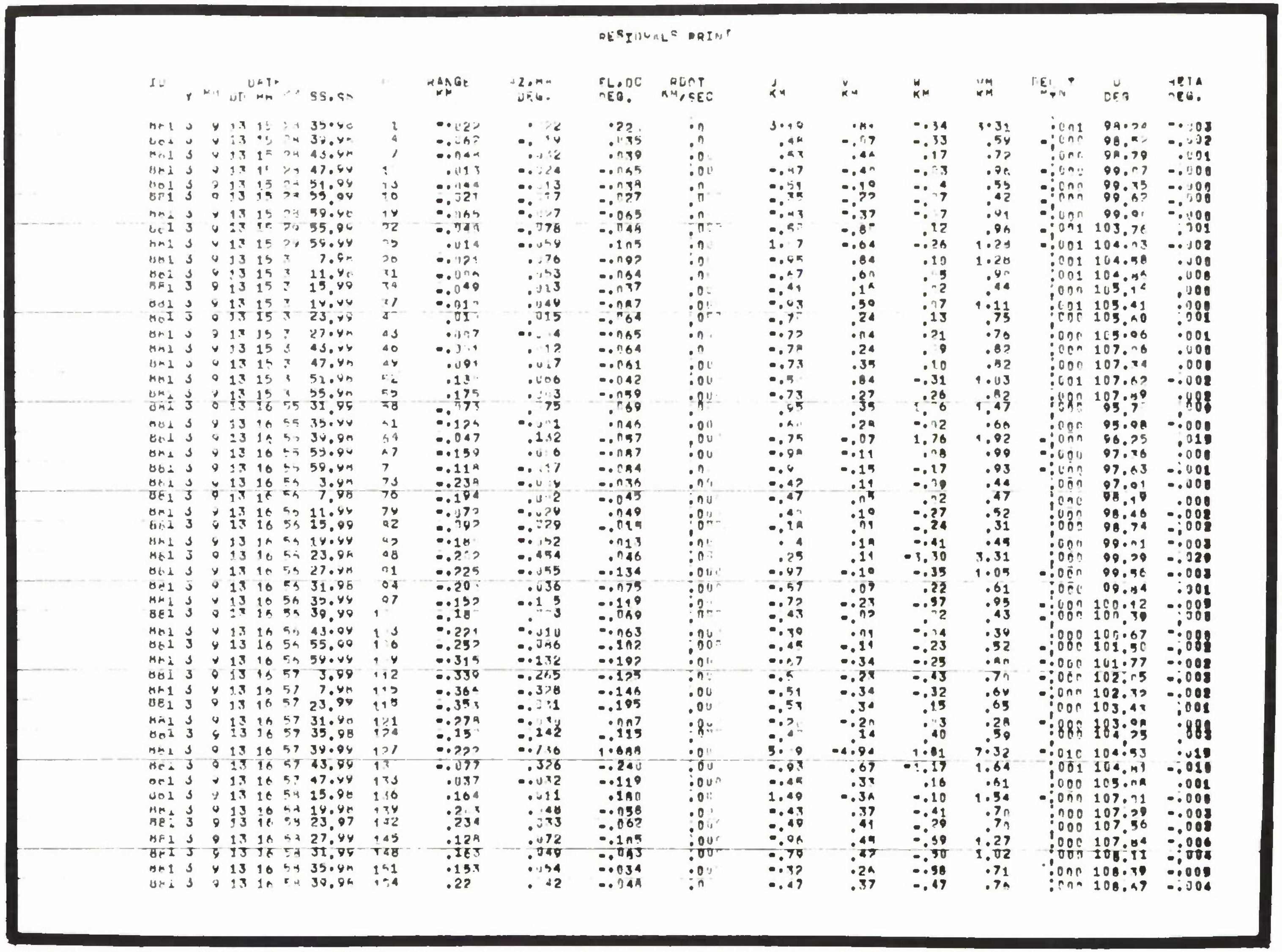
```
                         SENSOR LOCATIONS

ST. NO.          LAT.          LONG.          ALT.
  401          72.0142      -291.3972         122
  402          34.7809      -234.4058         134
```

Figure 4-5. Sample ESPOD Sensor Locations Page

4.2.5 Residuals Print

The residuals printed are defined as the difference between the measured observations and the computed observations: measured - computed = residual. The computed observations are based on the initial conditions before the first iteration and on the revised initial conditions after each successive iteration. The residuals are time-ordered like the observation type listing just described, and correspond exactly in time with their associated measured observations. Figure 4-6 shows a sample residuals print page. The column symbols and their descriptions are:

Column Symbol	Description
ID	Observing station's identification number; corresponds to a number under SENSOR LOCATIONS.
DATE Y MM DD HH MM SS. SS	Time associated with the measured observation differenced to obtain this residual. Symbol indicates allowable number of digits which can be shown, i. e., Y = year and last digit only. Successively, others are month, day, hour, minute, and decimal seconds.
N	Serial number assigned to each residual for identification purposes. It is constant through the run.
RANGE KM	Range residual in kilometers
AZ, HA DEG	Azimuth or hour angle residual, whichever type of observation this sensor measures, in degrees.
EL, DC DEG	Elevation or declination residual, whichever type of observation this sensor measures, in degrees.
RDOT KM/SEC	Range rate residual, in kilometers/second.
U KM	Up component of the position residual, collinear with and positive in the same direction as the radius vector, in kilometers.
V KM	Down component of the position residual, orthogonal to the radius vector, in the orbit plane, positive in the direction of motion, in kilometers.
W KM	Cross component of the position residual, normal to the orbit plane and positive in the direction of the angular momentum vector to complete a right-handed coordinate system, in kilometers.



```
                                          RESIDUALS PRINT

ID         DATE                 N    RANGE    AZ,HA     EL,DC    RDOT     U      V      W      VM    DELT     U      BETA
   Y MO DD HH MM SS.SS              KM       DEG.      DEG.    KM/SEC   KM     KM     KM     KM    MIN     DEG     DEG.

BB1 3  9 13 15 24 35.96      1   -.022     .022      .22      .0     3.19    .84   -.34   3.31   .001   98.24  -.003
BB1 3  9 13 15 24 39.98      4   -.062    -.019      .035     .0      .48   -.07   -.33    .59  -.000   98.52  -.002
BB1 3  9 13 15 24 43.98      7   -.044     .032      .039     .00     .53    .44    .17    .72   .000   98.79   .001
BB1 3  9 13 15 24 47.99     10    .013    -.024     -.065     .00    -.47   -.40   -.23    .96  -.000   99.07  -.000
BB1 3  9 13 15 24 51.99     13   -.044    -.013     -.039     .0     -.51   -.19   -.4     .55  -.000   99.35  -.000
BB1 3  9 13 15 24 55.99     16   -.021    -.017     -.027     .0     -.35   -.22   -.7     .42  -.000   99.62  -.000
BB1 3  9 13 15 24 59.98     19   -.065    -.027     -.065     .0     -.43   -.37   -.7     .91  -.000   99.90  -.000
BB1 3  9 13 15 29 55.99     22   -.048    -.078     -.048     .00    -.57   -.87    .12    .96  -.001  103.76   .001
BB1 3  9 13 15 29 59.99     25    .014    -.059      .105     .0     1.07   -.64   -.26   1.24  -.001  104.03  -.002
BB1 3  9 13 15 3   7.98     28   -.021     .076     -.092     .0     -.95    .84    .10   1.28   .001  104.58   .000
BB1 3  9 13 15 3  11.98     31   -.006     .053     -.064     .0     -.67    .60    .5     .90   .001  104.86   .000
BB1 3  9 13 15 3  15.99     34   -.049     .013     -.037     .0     -.41    .16    .2     .44   .000  105.14   .000
BB1 3  9 13 15 3  19.99     37   -.012     .049     -.087     .00    -.93    .59    .07   1.11   .001  105.41   .000
BB1 3  9 13 15 3  23.99     40    .017     .015     -.064     .00    -.77    .24    .13    .75   .000  105.60   .001
BB1 3  9 13 15 3  27.98     43    .007    -.004     -.065     .0     -.72    .04    .21    .76   .000  105.96   .001
BB1 3  9 13 15 3  43.99     46   -.031     .012     -.064     .0     -.78    .24    .9     .82   .000  107.06   .000
BB1 3  9 13 15 3  47.98     49    .091     .017     -.061     .00    -.73    .35    .10    .82   .000  107.34   .000
BB1 3  9 13 15 3  51.98     52    .13      .006     -.042     .00    -.5     .84   -.31   1.03   .001  107.62  -.002
BB1 3  9 13 15 3  55.98     55    .175     .003     -.059     .00    -.73    .27    .26    .82   .000  107.89   .002
BB1 3  9 13 16 55 31.99     58   -.173     .75       .069     .0      .95    .35   1.6    1.47   .000   95.7    .000
BB1 3  9 13 16 55 35.99     61   -.125    -.001      .046     .00     .60    .28   -.02    .66   .000   95.98  -.000
BB1 3  9 13 16 55 39.98     64   -.047     .132     -.057     .00    -.75   -.07   1.76   1.92  -.000   96.25   .019
BB1 3  9 13 16 55 55.99     67   -.159     .016     -.087     .00    -.98   -.11    .08    .99  -.000   97.36   .000
BB1 3  9 13 16 55 59.98     7    -.118    -.017     -.084     .0     -.9    -.15   -.17    .93  -.000   97.63  -.001
BB1 3  9 13 16 56  3.98     73   -.238    -.019     -.036     .00    -.42    .11   -.39    .44   .000   97.91  -.000
BB1 3  9 13 16 56  7.98     76   -.194     .012     -.045     .00    -.47    .05    .02    .47   .000   98.19   .000
BB1 3  9 13 16 56 11.99     79   -.072    -.029      .049     .00     .42    .19   -.27    .52   .000   98.46  -.002
BB1 3  9 13 16 56 15.99     82   -.092    -.229     -.015     .00    -.18    .01   -.24    .31   .000   98.74  -.002
BB1 3  9 13 16 56 19.99     85   -.18     -.152      .013     .00     .4     .18   -.41    .45   .000   99.01  -.003
BB1 3  9 13 16 56 23.98     88   -.252    -.454      .046     .00     .25    .11  -1.30   3.31   .000   99.29  -.020
BB1 3  9 13 16 56 27.98     91   -.225    -.055     -.134     .000   -.97   -.19   -.35   1.05  -.000   99.56  -.003
BB1 3  9 13 16 56 31.98     94   -.20      .036     -.075     .000   -.57    .07    .22    .61   .000   99.84   .001
BB1 3  9 13 16 56 35.99     97   -.152    -.105     -.119     .0     -.72   -.23   -.57    .95  -.000  100.12  -.009
BB1 3  9 13 16 56 39.99    100   -.18      .003     -.069     .00    -.43   -.02    .2     .43  -.000  100.39   .000
BB1 3  9 13 16 56 43.99    103   -.221    -.010     -.063     .00    -.39    .01   -.14    .39   .000  100.67  -.000
BB1 3  9 13 16 56 55.99    106   -.252    -.046     -.102     .00    -.45   -.11   -.23    .52  -.000  101.50  -.002
BB1 3  9 13 16 56 59.99    109   -.315    -.132     -.192     .00    -.67   -.34   -.25    .80  -.000  101.77  -.002
BB1 3  9 13 16 57  3.99    112   -.339    -.265     -.125     .00    -.5    -.23   -.43    .70  -.000  102.05  -.003
BB1 3  9 13 16 57  7.98    115   -.364    -.328     -.146     .00    -.51   -.34   -.32    .69  -.000  102.32  -.002
BB1 3  9 13 16 57 23.99    118   -.353    -.331     -.195     .00    -.53    .34    .15    .65   .000  103.43   .001
BB1 3  9 13 16 57 31.98    121   -.278    -.039      .007     .00    -.20   -.20    .3     .28  -.000  103.98   .000
BB1 3  9 13 16 57 35.98    124   -.15     -.142     -.115     .0     -.4     .14    .40    .59   .000  104.25   .003
BB1 3  9 13 16 57 39.99    127   -.222    -.736     1.688     .00    5.19  -4.94   1.81   7.32  -.010  104.53   .019
BB1 3  9 13 16 57 43.99    130   -.077     .326     -.240     .00    -.93    .67  -1.17   1.64   .001  104.81  -.018
BB1 3  9 13 16 57 47.99    133    .037    -.032     -.119     .000   -.45    .33    .16    .61   .000  105.08   .001
BB1 3  9 13 16 58 15.98    136    .164     .011      .180     .00    1.49   -.36   -.10   1.54  -.000  107.01  -.000
BB1 3  9 13 16 58 19.98    139    .243     .048     -.058     .00    -.43    .37   -.41    .70   .000  107.29  -.003
BB1 3  9 13 16 58 23.97    142    .234     .033     -.062     .00    -.49    .41   -.29    .70   .000  107.56  -.003
BB1 3  9 13 16 58 27.99    145    .128     .072     -.105     .00    -.96    .45   -.59   1.27   .000  107.84  -.006
BB1 3  9 13 16 58 31.99    148    .163     .049     -.043     .00    -.79    .47   -.30   1.02   .000  108.11  -.004
BB1 3  9 13 16 58 35.98    151    .153     .054     -.034     .00    -.32    .26   -.58    .71   .000  108.39  -.009
BB1 3  9 13 16 58 39.96    154    .22      .042     -.048     .0     -.47    .37   -.47    .76   .000  108.47  -.004
```

Figure 4-6. Sample ESPOD Residuals Page

Column Symbol	Description
VM KM	Magnitude of the position residual or displacement vector, in kilometers.
DEL T MIN	Time separation of computed and measured positions, assuming Keplerian mean motion, in minutes.
U DEG	The argument of latitude (angle from the ascending mode to the radius vector in the orbit plane) at this time, in degrees.
BETA DEG	Residual angle between the measured position vector and the computed orbit plane.

The numerical values for the residuals are listed in the above columns on one or more pages. A symbol or letter following a numerical value indicates that residual has been deleted from further calculation on a given criterion, which is one of the following:

Symbol	Criterion
*	Observation deleted by a DELETE input (removed by analyst's choice).
G	Observation deleted as a gross outlier. See Section 2.2.3.5 for further details.
K	Observation deleted from this iteration by KRMS test. The nominal value for K may be changed as described in Section 2.2.3.11.

If observations are input from a station for which the location has not been input, a note will appear in place of the residuals for this sensor as follows:

STATION (ST. ID.) NOT IN MASTER SENSOR LIST

Note that the program cannot compute a position vector without knowing the station location, and hence cannot calculate the residual.

4.2.6 Estimates of Mean and Standard Deviations

To aid the analyst in determining where systematic error solution is required, or in deleting data, estimates of mean and standard deviations by sensor and type are printed. Figure 4-7 shows a sample page containing these data. A given station's data are arranged into columns of three lines each. The column symbols and their descriptions are:

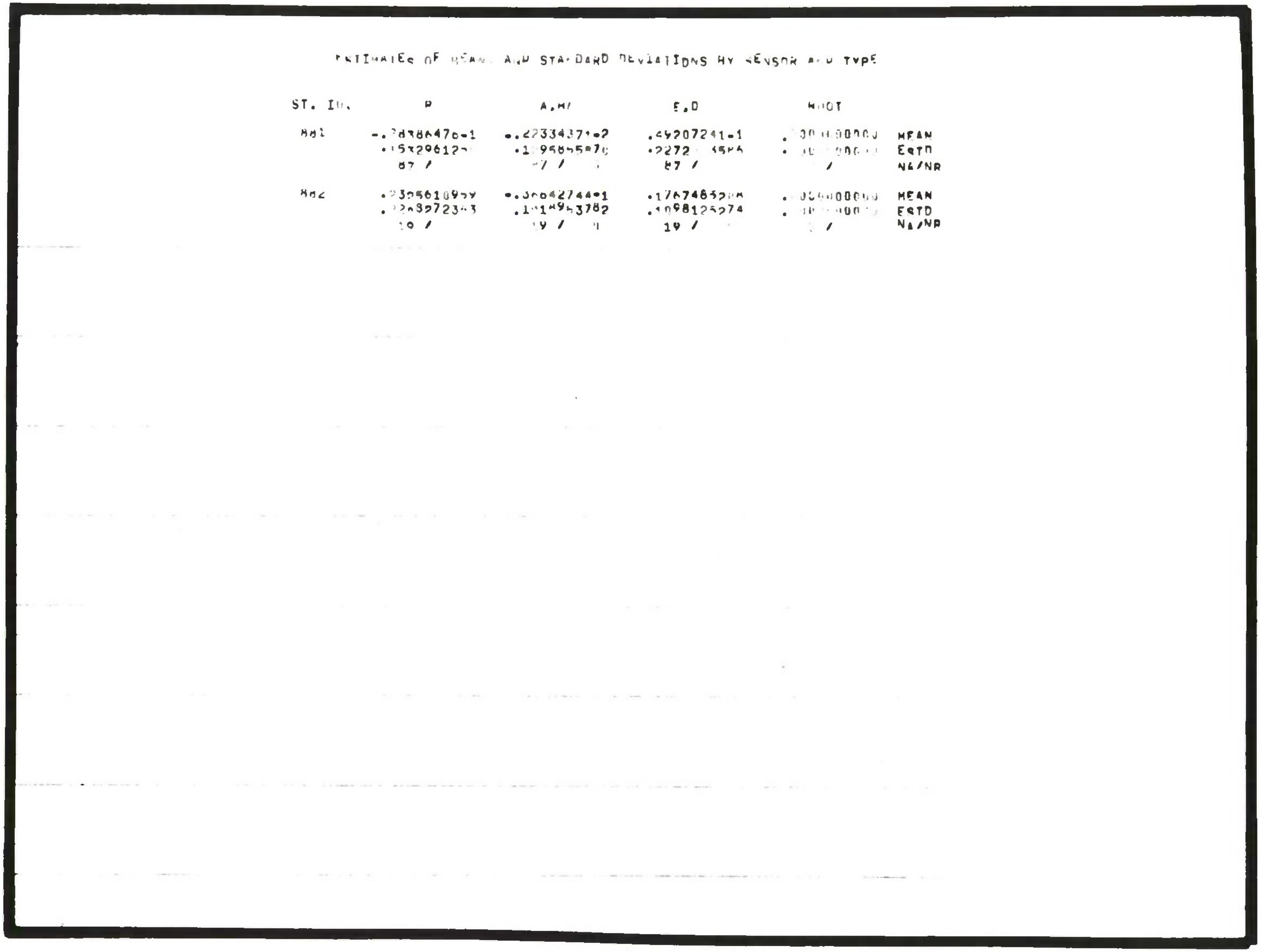
Column Symbol	Description
ST. ID	Observing station's identification number, corresponds to a number under SENSOR LOCATIONS.
R	Numerical values associated with range, in kilometers.
A,HA	Numerical values associated with azimuth or hour angle, in degrees.
E, D	Numerical values associated with elevation or declination, in degrees.
RDOT	Numerical values associated with range rate, in kilometers per second.

The last column on the right identifies the data on each line as follows:

MEAN	The arithmetic mean or average values of the residuals for each type of data observed by the given station.
ESTD	The estimated standard deviation (one sigma) for each type of data observed by the given station.*
NA/NR	The number of observations accepted/the number of observations rejected, for each type of data observed by the given station.

---

*Note: The estimated standard deviation is calculated about the computed mean value and not about an assumed mean of zero.



```
            ESTIMATES OF MEAN AND STANDARD DEVIATIONS BY SENSOR AND TYPE

ST. ID.        R             A,H/            E,D            RDOT

881      -.28386470-1    -.22334371-2    .49207241-1    .[illegible]     MEAN
          .153296127      .1[illegible]95855870      .2272[illegible]95P6    .[illegible]     ESTD
          87 /            87 /            87 /              /            NA/NR

882       .2305610959    -.36642744-1    .1767485208    .[illegible]     MEAN
          .2263972343     .1014953782    .1098125274    .[illegible]     ESTD
          19 /            19 /            19 /              /            NA/NR
```

Figure 4-7. Sample ESPOD Estimates of Mean and Standard Deviations Page

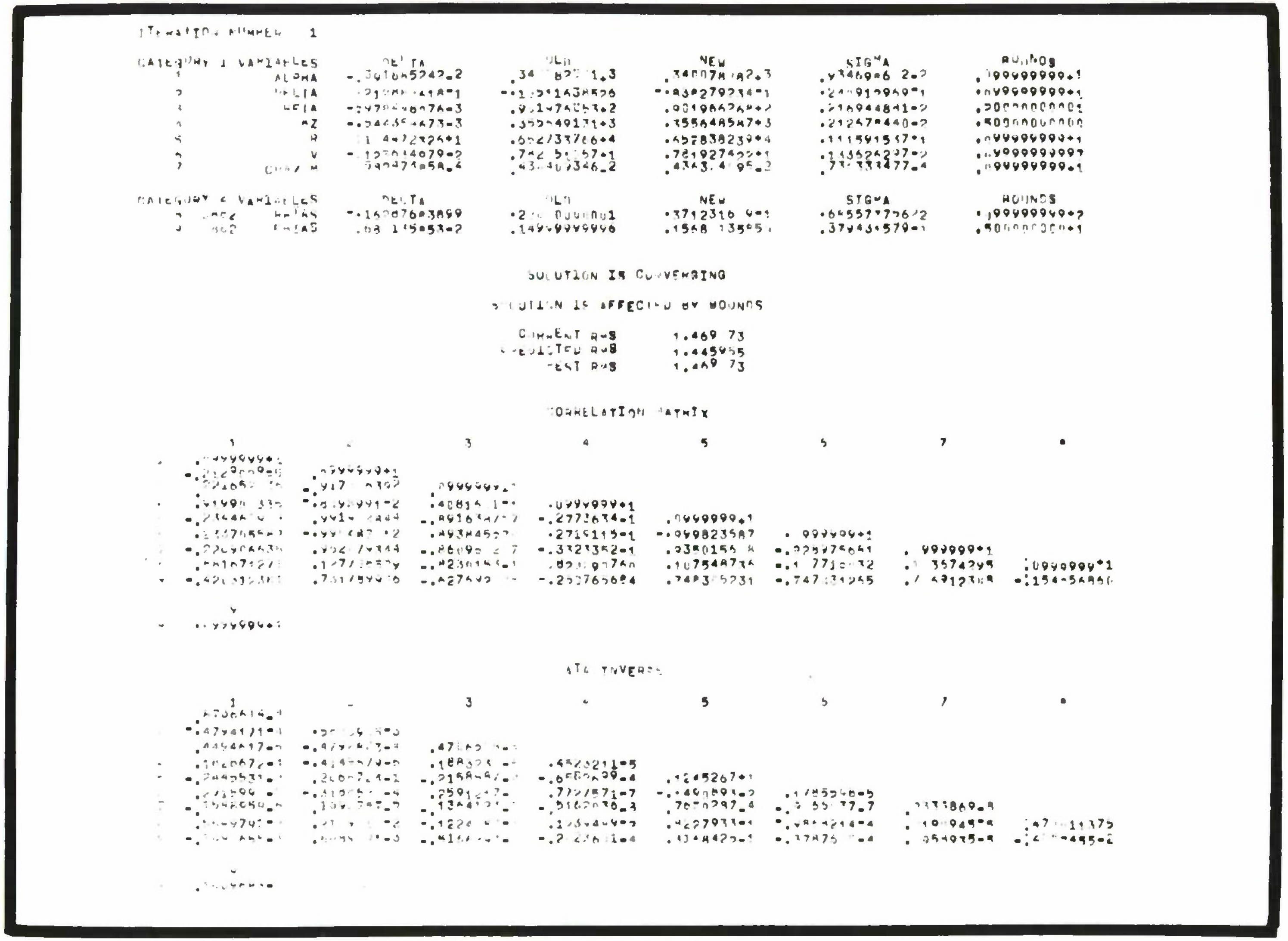
4.2.7 Curve Fit Iteration Summary

This page shows the results and convergence status for a given iteration. If the solution is converging, correlation and covariance lower triangular matrices are printed. Figure 4-8 shows a sample curve fit summary page. The first line on the page identifies the iteration number in this particular run. The following describes the tabulated solution vector data, arranged in columns as shown below:

Column Symbol	Description
CATEGORY 1 VARIABLES	These are the orbital and drag parameters, identified by a number and a name as follows:

1	ALPHA	Right ascension (degrees)
2	DELTA	Declination (degrees)
3	BETA	Flight path angle from local vertical (degrees)
4	AZ	Azimuth to inertial velocity vector, clockwise from true north (degrees)
5	R	Radius vector from geocenter (kilometers)
6	V	Velocity vector magnitude (kilometers/sec)
7	CDA/2M	Drag parameter (meters^2 per kilograms)
8	K	Drag variation (secular option: meters^2 per kilogram per day; periodic option: meters^2 per kilogram)

DELTA	The corrections applied by the program to each variable.
OLD	Numerical values for the variables from the previous iteration.
NEW	Numerical values for the variables from this iteration (NEW = OLD + DELTA).
SIGMA	The uncertainty in each variable, computed from the covariance matrix.
BOUNDS	The constraints applied to the changes which the program is allowed make to the variables.



```
ITERATION NUMBER   1

CATEGORY 1 VARIABLES        DELTA          OLD            NEW            SIGMA          BOUNDS
   1           ALPHA
   2           DELTA
   3           BETA
   4              AZ
   5               R
   6               V
   7          CHAR M

CATEGORY 2 VARIABLES        DELTA          OLD            NEW            SIGMA          BOUNDS

                        SOLUTION IS CONVERGING

                    SOLUTION IS AFFECTED BY BOUNDS

                          CURRENT RMS        1.469 73
                        PREDICTED RMS        1.445955
                             TEST RMS        1.469 73

                          CORRELATION MATRIX

         1          2          3          4          5          6          7          8

                              ATA INVERSE

         1          2          3          4          5          6          7          8
```

Figure 4-8. Sample ESPOD Curve Fit Summary Page

If Category 2 variables (station and data biases) are being solved for, a data tabulation much like that just described will be listed next. Its columns are as follows:

Column Symbol	Description
CATEGORY 2 VARIABLES	These variables will be numbered from the next digit following the last Category 1 variable number to 50. Each number will be followed by a station identification number, as used in SENSOR LOCATIONS, and the name of the variable which can be any of the following: R Range (kilometers) A, HA Azimuth or hour angle (degrees) E, D Elevation or declination (degrees) R DOT Range rate (kilometers per second) LAT Station north latitude (degrees) LONG Station east longitude (degrees) ALT Station altitude (meters) T Time (seconds)
DELTA OLD NEW SIGMA BOUNDS	Same as for Category 1 variables.

The following line states "SOLUTION IS (IS NOT) CONVERGING." The solution is converging if the current RMS of the residuals is smaller than the best RMS to this point in the run.

This message is followed immediately by "SOLUTION IS (IS NOT) AFFECTED BY BOUNDS." The program first forms an unbounded solution, and if it satisfies the condition $\sum\left(\frac{\text{DELTA}_i}{\text{BOUNDS}_i}\right)^2 < 1$, "SOLUTION IS NOT AFFECTED BY BOUNDS" is printed. If the condition is not satisfied, the system of equations is solved until the condition is satisfied, and "SOLUTION IS AFFECTED BY BOUNDS" is printed.

Next are listed the current RMS of the residuals, the RMS predicted for the next iteration (based on the DELTA's and $(A^TA)^{-1}$), and the best RMS so far in the curve fit run.

A correlation matrix in lower triangular form is printed next if the solution is converging. Its rows and columns are numbered to correspond to the Category 1 variables as they are numbered in the solution vector data tabulation previously described.

Following the correlation matrix is the $(A^TA)^{-1}$ matrix or covariance matrix, also in lower triangular form. It is printed only if the solution is converging. If it were printed and the solution were not converging, the information in the matrix would be false, because the solution would be based on the previous $(A^TA)^{-1}$ in the last converging iteration and $\frac{K\,(BOUNDS)}{8}$, the most rightly constrained solution which the program can produce.

The next item will appear on the final iteration only, and will be one of the following:

SOLUTION HAS CONVERGED

MAXIMUM ITERATIONS EXCEEDED

BOUNDS/8 FAILED

This indicates the criterion on which the run has been terminated.

4.2.8 Trajectory Printout

The last page(s) of the run consist of blocks of trajectory and related data, updated to times from the epoch which were specified by input. Figure 4-9 shows a sample trajectory printout page. Each item in the block is preceded by an identifying symbol. The first line of each block contains the date and Greenwich mean time for the data, time in minutes from epoch, and time in days from January 0 of the year of the epoch. The following list describes the parameters associated with each identifying symbol:

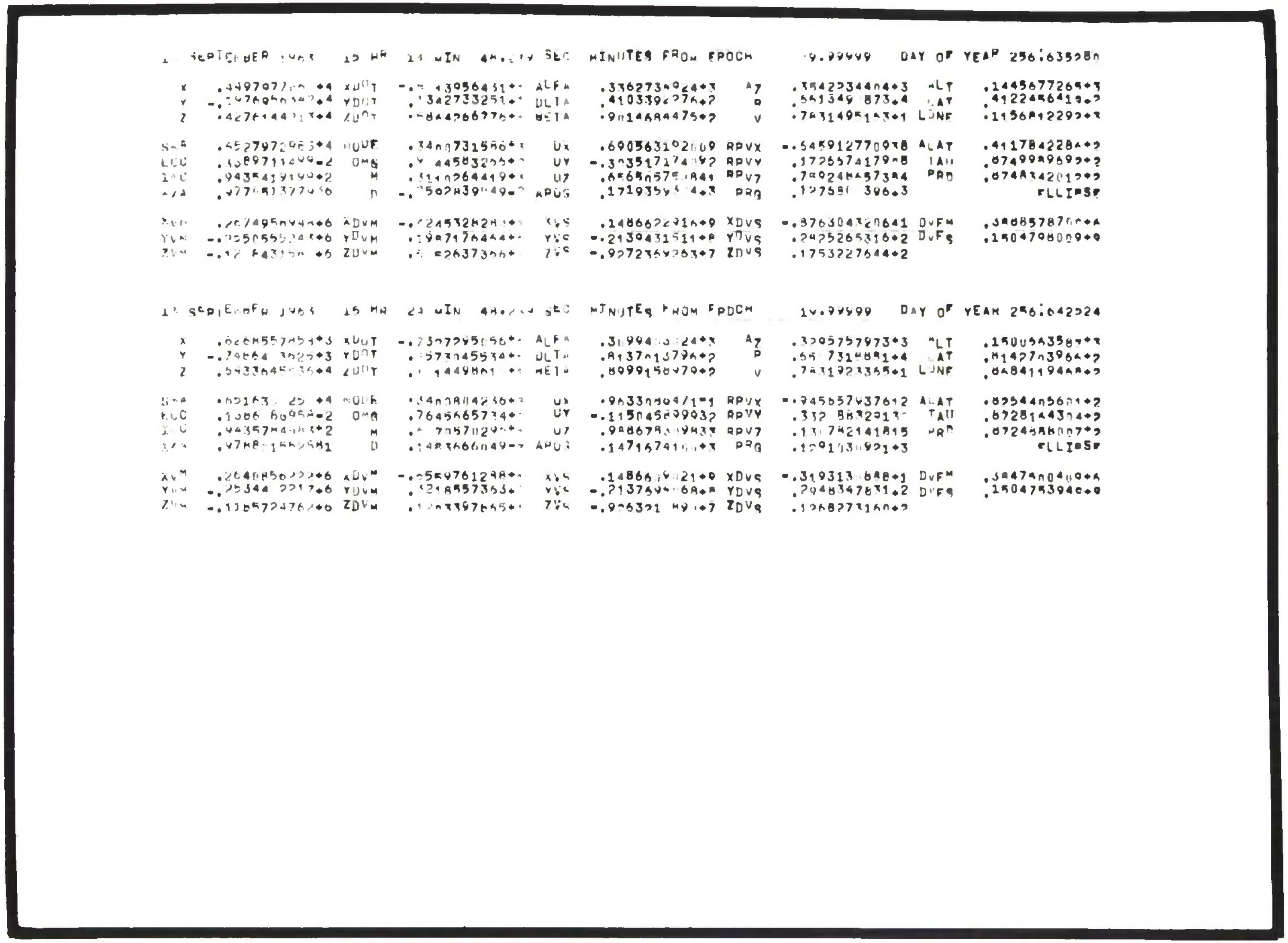


Figure 4-9. Sample ESPOD Trajectory Printout Page

Symbol	Description
X Y Z $\dot{X}$ $\dot{Y}$ $\dot{Z}$	Components of the position and velocity vector in geocentric inertial Cartesian coordinates. It is a right-handed orthogonal system where the X axis is in the direction of the vernal equinox and the Z axis is in the direction of true north. Units are kilometers and kilometers/second. Coordinates are true of $0^{\mathrm{h}}.0$ day of epoch.
ALFA	Right ascension, in degrees
DLTA	Declination, in degrees
BETA	Flight path angle, in degrees, positive downward from the local vertical.
AZ	Azimuth of the velocity vector, in degrees, positive clockwise from true north.
R	Radius vector from the geocenter, in kilometers.
V	Magnitude of the velocity vector, in kilometers per second.
ALT	Height of the satellite above mean sea level, in kilometers.
LAT	Geodetic north latitude of the satellite, in degrees.
LONE	East longitude of the satellite, in degrees.
SMA	Semimajor axis, in kilometers.
ECC	Eccentricity of the orbit.
INC	Inclination of the orbit plane to the equator, in degrees, positive counterclockwise from the equatorial to the orbit plane at the ascending node.
NODE	Right ascension of the ascending node, in degrees.
OMG	Argument of perigee, in degrees, positive in the direction of motion from the ascending node.
M	Mean anomaly, in degrees, positive in the direction of motion from perigee.
UX UY UZ	Direction cosines of the position in Cartesian coordinates, with axes directed as in the XYZ system previously described.

Symbol	Description
RPVX RPVY RPVZ	Components in Cartesian coordinates of a vector in the orbit plane which is orthogonal to the position ($\underline{r}$) and angular momentum ($\underline{h}$) vectors.
ALAT	Argument of latitude, in degrees, equals the sum of the argument of perigee and the true anomaly.
TAU	Time until the next ascending nodal crossing, in minutes from epoch.
PRD	Osculating period of the orbit, in minutes.
1/A	Inverse of the semimajor axis, in earth radii (indeterminacy-free element).
D	Indeterminacy-free element = $\frac{R \cdot \dot{R}}{\sqrt{\mu}}$, in (earth radii)$^{1/2}$.
APOG	Altitude of apogee above a mean equator, in kilometers.
PRG	Altitude of perigee above a mean equator, in kilometers.
ELLIPSE HYPERBOLA	Prints one or the other to describe the orbit's conic form. If HYPERBOLA, many of the preceding values will be omitted.
XVM YVM ZVM XDVM YDVM ZDVM	Vehicle position and velocity relative to the moon, in a coordinate system defined like the geocentric inertial Cartesian system in this section, but translated to the selenocenter. These coordinates are true of $0\overset{h}{.}0$ day of epoch.
XVS YVS ZVS XDVS YDVS ZDVS	Vehicle position and velocity relative to the sun, in a coordinate system defined like the geocentric inertial Cartesian system in this section, but translated to the heliocenter. These coordinates are true of $0\overset{h}{.}0$ day of epoch.
DVFM	Distance from the vehicle to the selenocenter, in kilometers.
DVFS	Distance from the vehicle to the heliocenter, in kilometers.

The above parameters are repeated for as many updates as were requested in the input. These data complete the standard output from ESPOD.

4.2.9 Off-Line Messages

Off-line messages are given in the printed output to aid the analyst in diagnosing stoppages which occurred during a run. In many cases, the program will bypass the case in which an error halt occurred and go on to the next one. When the printed output is reviewed, the program will have indicated the case in which the error halt occurred with an off-line message.

To aid the operator in quickly finding the explanations for these messages, they are arranged alphabetically in the following list.

COLUMN 68 in CARD 7 IS ILLEGAL. CARD IMAGE BELOW

(Followed by the data actually punched on card 7)

> This message is printed when column 68 in element card 7 is not a 0, 1, or 2. The program then finds the next JDC card and continues reading input. If this is the last case, the program exits.

CONDITIONAL REQUIREMENTS NOT MET——PROCEEDING TO NEXT CASE.

> This message indicates that the cold start flag CLDSTR=2 and CONVR $\neq$ 0. The program finds the next JDC card and continues reading input. If this is the last case, the program exits.

DATA NAME(· · ·) NOT FOUND.

> An illegal card name has been used in place of (· · ·). The program finds the next JDC card and continues reading input, or exits, if this is the last case.

ELEMENTS FOR SATT.______________NOT ON SEAI.

> This message is printed off-line for the record and on-line for action. The accompanying on-line message is:
>
> Tape 04 bad - mount backup
> Elements for satt.______not in SEAI
> Type — GO to reread SEAI, STOP for next case.

* * *END OF FILE ENCOUNTERED READING THE EPHEMERIS TAPE

> This message records the reason for the program's halt on this case. It then finds the next JDC card, reads the input and continues or exits if this is the last case.

* * * EPHEMERIS TAPE ARGUMENT TOO LARGE · · ·
T = ._________SECONDS FROM 1950.0

This message indicates that the time for which data are requested is after 19 December 1969, which is the end of the ephemeris tape's data. The program proceeds to the next case or exits if this is the last case.

* * * EPHEMERIS TAPE ARGUMENT TOO SMALL · · ·
T = .__________SECONDS FROM 1950.0

This message indicates that the time for which data are requested is before 28 August 1960, which is the beginning of the ephemeris tape's data. The program proceeds to the next case or exits if this is the last one.

ERROR. NO OBS ON SRADU FOR SATELLITE NO.___________

This message records the reason for proceeding to the next case or exiting if this is the last one. The accompanying on-line comment for action is:

Error. No obs on SRADU for satellite no.______
Type GO to reread tape, STOP for next case.

ICOND[*]
ICTYP } CARD REQUIRED FOR THIS RUN
ITIME

This message indicates that an ICOND, ICTYP, or ITIME card was missing from the input deck. The program proceeds to the next case or exits if this is the last one.

ILLEGAL TESSERAL NM REQUESTED, THE PROGRAM IS IGNORING IT AND PROCEEDING

This message is printed if the value of a requested tesseral harmonic is greater than or equal to the degree. The program proceeds with the case as though the illegal input were never there.

JDC CARD NOT FOUND. ID WHICH TERMINATED RUN IS ____________.

While searching the input for a JDC card, the program found an identification name to be ENDAT, ZZZZZ, or EEEEE. The program exits.

---

[*] One of these will appear in the message.

* * *MAJOR PROGRAM ERROR · · · POSSIBLE INPUT AND/OR MACHINE ERROR

This message indicates that the total RMS on the first iteration has exceeded the maximum floating point number which the computer can handle. The program returns and reads input for the next case or exits if this is the last one.

NO JDC IN 400 CARDS

This message records the fact stated. The program exits when this message has been written for printing.

OBS OVERFLOW CORE, NOT IN REVERSE SORT, ERROR.

This message records the facts stated to indicate why the program proceeded to the next case or exited. Observations may be added until they overflow core if and only if they are in reverse sort. This message is typed on-line at the same time it is written for off-line printing.

PARTIAL (J) WITH RESPECT (I) ASKED FOR

This message indicates that a non-orbital parameter partial derivative has been requested which the program does not recognize, because the allowable numbers (J=6, I=10) have been exceeded. The program sets this illegal partial derivative equal to zero and proceeds.

REQUIRED SENSORS TABLE FULL. ITEM NOT SAVED IS____________*

This message is written for printing when the stated fact occurs.

SENSOR____________NOT IN MASTER SENSOR LIST

This message is printed when the program cannot find this sensor identification in the master list, and so cannot calculate a residual because it does not know the sensor location. The program continues through the observations until a different sensor identification is found which is the master list.

SENSOR DATA OVERFLOWS COMMON, ERROR

This message indicates that too large a system of sensors and non-orbital parameters was requested, and variable storage capacity has been exceeded. The program reads input for the next case or exits if this is the last case.

---

*Will be a sensor identification number. If the table overflows by more than one sensor, a separate message is printed for each. The program continues the computation as though the overflowing sensors were never input.

SUBERR EXIT OCCURRED, SUBERR J LOC, PROGRAM JMP LOC, A REGISTER, Q REGISTER

> This message records that the exit to the next case was instigated by the ERR0R subroutine. The contents of the A, Q, and JA registers are printed to aid in diagnosing the error. SUBERR J LOC is the address from which the ERROR subroutine was called, and the PROGRAM JMP LOC is the subroutine which called the error-incurring subroutine.

TAPE ON LOG 7 NOT CORRECT. I.D. IS________________.

> This message records the reason for exit to the next case, and is written for off-line printing at the same time as this on-line message:
>
> Tape on LOG 7 not correct. I.D. is__________.
>
> Type - GO to retry tape, STOP for next case.

THE FOLLOWING CARD(S) COULD NOT BE CONVERTED_________ERR LOCATION

> This message is printed when subroutine BCD0BS cannot read an observation card for any reason. The core address is given in the message where the subroutine tried to read the observation card, and the card is imaged as read on the line following the message. The program proceeds as though the illegal card were never present.

4.3 OPTIONAL OUTPUT

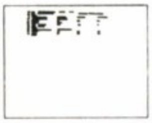
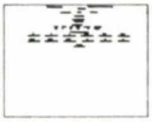
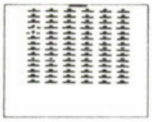
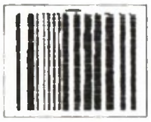
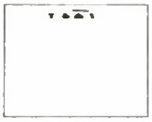
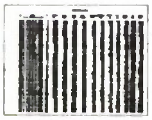
This section describes optional outputs and how to obtain them. These options are described in the same order in which they would be present on the printout. Figure 4-10 shows the ordering of the optional print and the section in which it is subsequently described.

4.3.1 Input Listing

Any flags input to produce optional output will be present in the input listing. Since it is simply an interpretation of the punched input cards or listing from the magnetic tape, there are no optional outputs for this page of the printout.

4.3.2 Run Header Data

There are no optional outputs for the run header data.

SAMPLE RUN	DATA	NO. PAGES	SECTION
	INPUT LISTING	1	4.3.1
	HEADER DATA	1	4.3.2
	PROGRAM CONSTANTS*	1	4.3.3
	SENSOR INFORMATION*	1	4.3.4
	OBSERVATION TYPE	1 OR MORE	4.3.5
	SENSOR LOCATIONS	1	4.3.6
	RESIDUALS PRINT*	1 OR MORE	4.3.7
	ESTIMATES OF MEAN AND STANDARD DEVIATIONS	1	4.3.8
	CURVE FIT INTERATION SUMMARY	1	4.3.9
	TRAJECTORY PRINT*	1 OR MORE	4.3.10

---

*OPTIONAL PRINT AVAILABLE

Figure 4-10. ESPOD Standard and Optional Run Output

4.3.3 Program Constants

The program constants may be printed by placing a 1 flag in JDC card column 36. These constants may be changed by making an appropriate input on a 99-card, as described in Section 5.0.

For a listing of the constants shown by this print option, see Section 5.0. Figure 4-11 shows a sample program constants print page.

4.3.4 Sensor Information

The flag which causes the program constants to be printed also results in the sensor information, which the program has in its master list, being printed. Figure 4-12 shows a sample sensor information print page. The column symbols and the information pertaining to each sensor are described in the following list:

Column Symbol	Description
SENSOR NO.	The sensor identification number which is used to reference a given sensor location or properties, when they are desired for use in the program.
SIGMA TYPE	The identification for the group of standard deviations associated with certain stations' data.
RANGE/RA(FR)	The standard deviation in range, or, if the sensor is a Baker-Nunn camera, the standard deviation in right ascension when it is a field-reduced observation.
AZ/DEC(FR)	The standard deviation in azimuth, or in the case of a Baker-Nunn camera sensor, the standard deviation in declination when the observation is field reduced.
EL/RA(PR)	The standard deviation in elevation, or in the case of a Baker-Nunn camera sensor, the standard deviation in right ascension when the observation is precision reduced.
RDT/DEC(PR)	The standard deviation in range rate, or in the case of a Baker-Nunn camera sensor, the standard deviation in declination when the observation is precision reduced.
GSUBS	The gross outlier editing criterion for the observations in terms of N sigma.

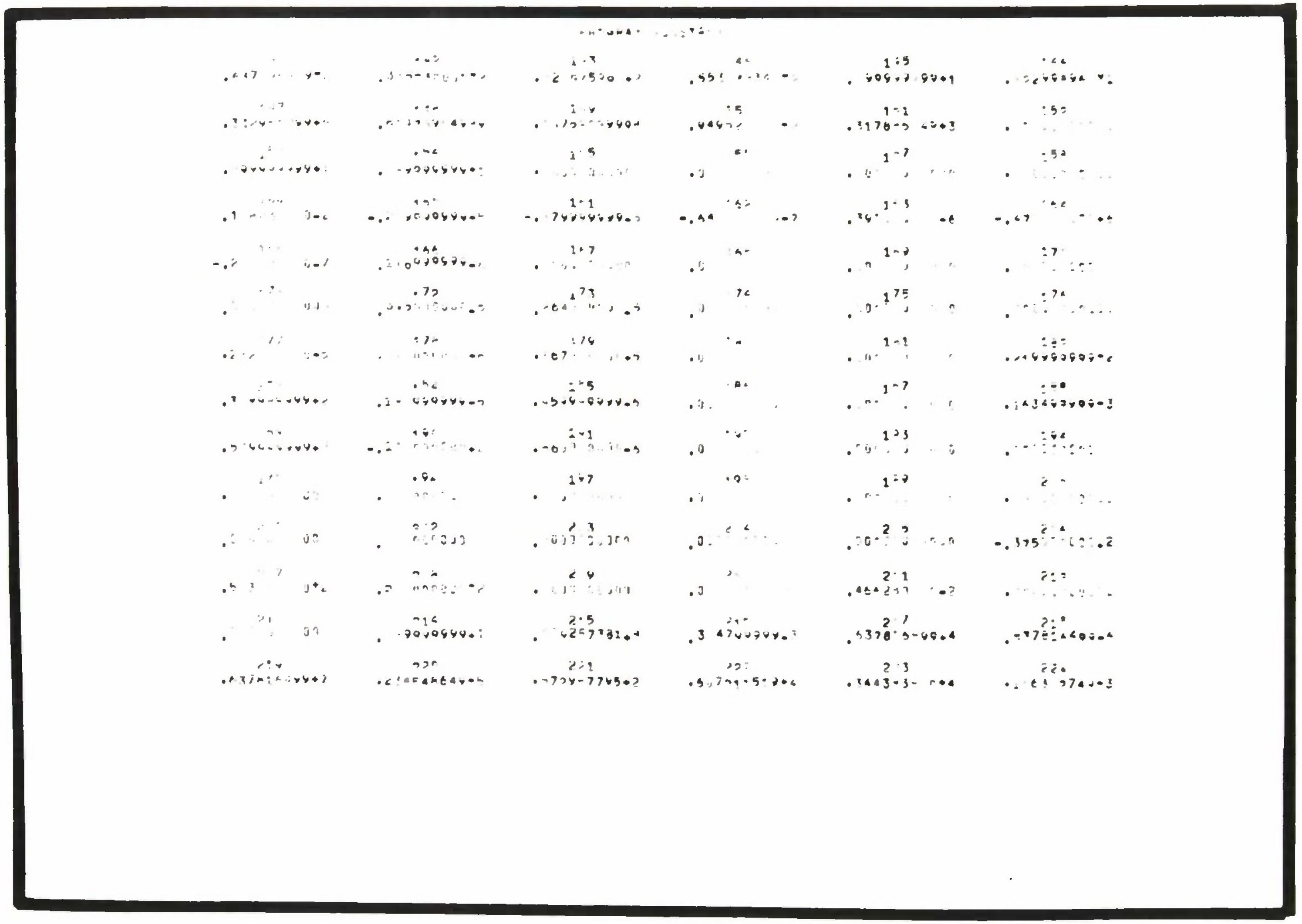
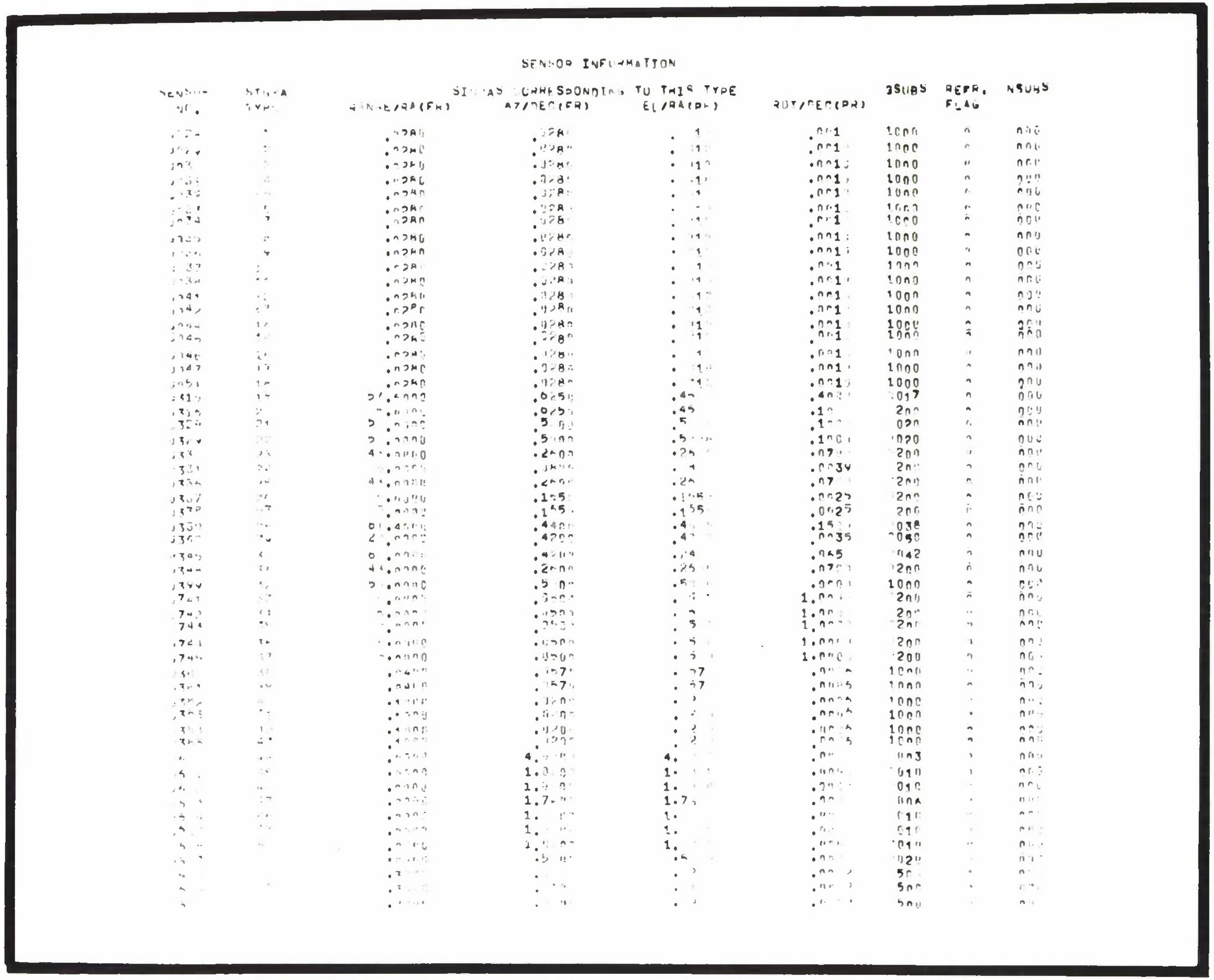


Figure 4-11. Sample ESPOD Program Constants Page



SENSOR INFORMATION

SENSOR NO. | SIGMA TYPE | SIGMAS CORRESPONDING TO THIS TYPE: RANGE/RA(FR) | AZ/DEC(FR) | EL/RA(PR) | ROT/DEC(PR) | DSUBS | REFR. FLAG | NSUBS

Figure 4-12. Sample ESPOD Sensor Information Page

Column Symbol	Description
REFR. FLAG	Applies the program's refraction correction to all observations from a given sensor if a "1" is input. If a "0" is input, no refraction correction is performed by the program.
NSUBS	The local index of refraction for the given station and the time of interest. Used in the refraction correction routine.

4.3.5 Observation Type

There are no optional outputs for the observation type, since it is simply a time-ordered listing of the observations input to the program.

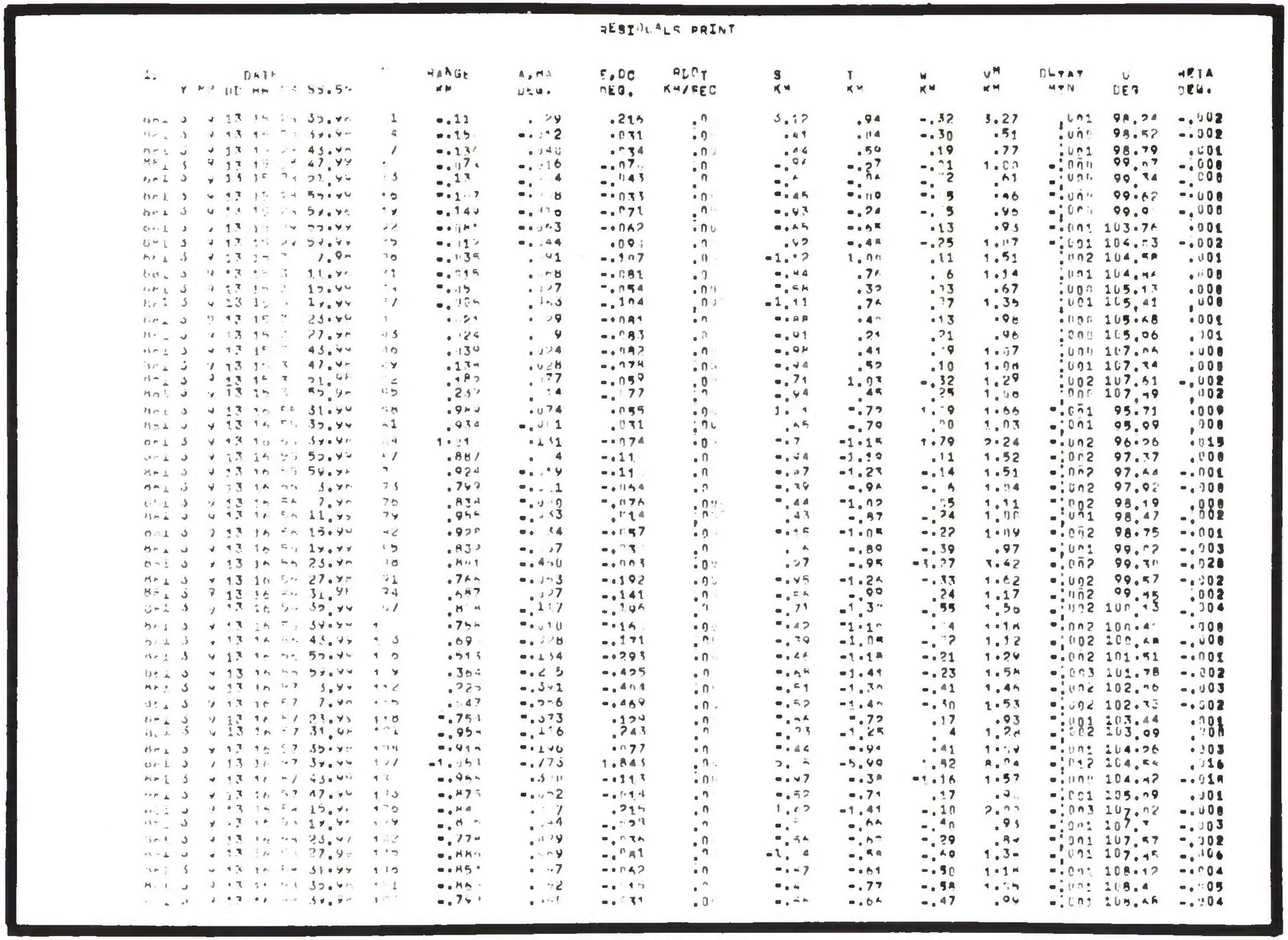
4.3.6 Sensor Locations

There are no print options for the sensor locations. It is simply a listing of input data for this run from the master sensor data table contained in the program.

4.3.7 Residuals Print

Two options are available on the residuals print which replace the columns which are headed with U, V and W on the standard output. By setting the DCFLG(5) = 1, the components of a vector describing the displacement of the observed with respect to the computed position are printed for each observation, in a normal, tangential and cross direction. Figure 4-13 shows a residuals page print with the STW option. The column symbols are described as follows:

Column Symbol	Description
S KM	Vector component orthogonal to the velocity vector and in the orbit plane, forming a right-handed system with T and W.
T KM	Vector component collinear with and in the same direction as the velocity vector.
W KM	Vector component normal to the orbit plane and in the same direction as the angular momentum vector.



```
RESIDUALS PRINT

ID        DATE              RANGE   A,MA    E,DC    RDOT     S     T     W     VM    DLTAT    U     HETA
   Y MO DE HR MN SS.SS      KM      DEG.    DEG.   KM/SEC   KM    KM    KM    KM    MIN     DEG   DEG.
```

Figure 4-13. Sample ESPOD Residuals (STW Option) Page

By setting DCFLG(5) = 2, the components of a vector describing the displacement of the observing station which would be required to reduce the residual to zero are computed. Figure 4-14 shows a residuals page print with this LLH option. The column symbols and their explanations are as follows:

Column Symbol	Description
ST. LAT DEG	Displacement component in geocentric latitude, in degrees, positive northward.
ST. LONE DEG	Displacement component in longitude, in degrees, positive eastward.
ST. HT KM	Displacement component in height, in kilometers above mean equatorial sea level.

4.3.8 Estimates of Means and Standard Deviations

There are no output print options for the page containing the estimates of mean and standard deviations.

4.3.9 Curve Fit Iteration Summary

There are no output print options for the page containing the curve fit iteration summary.

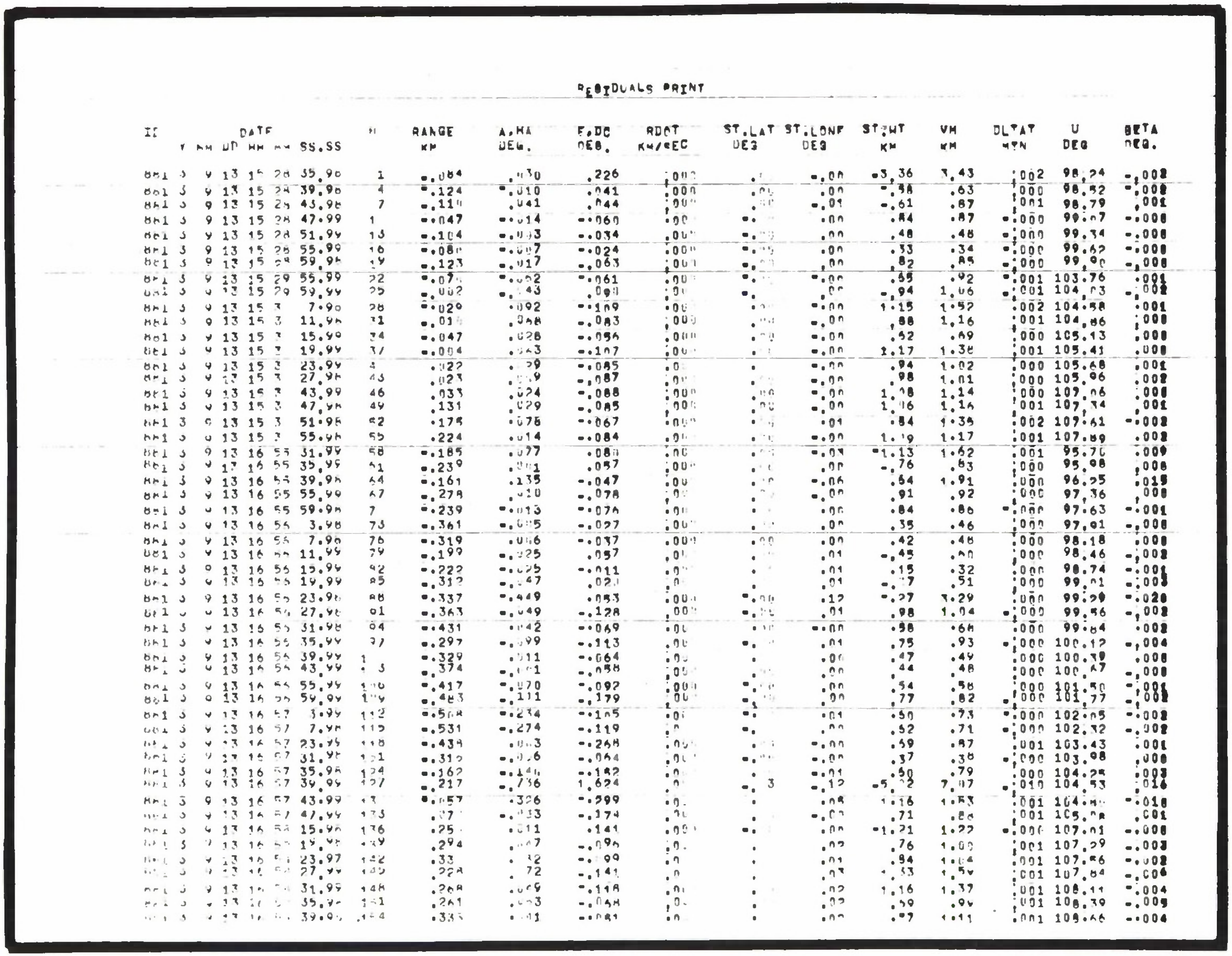
4.3.10 Trajectory Printout

In addition to the block of data printed for each trajectory update time, as described in Section 4.2.7, updated error matrices are available in a variety of coordinate systems. The variations are:

Orbit Plane Coordinates (UVW)
Spherical Polar Coordinates (ADBARV)
Cartesian Coordinates (XYZ)

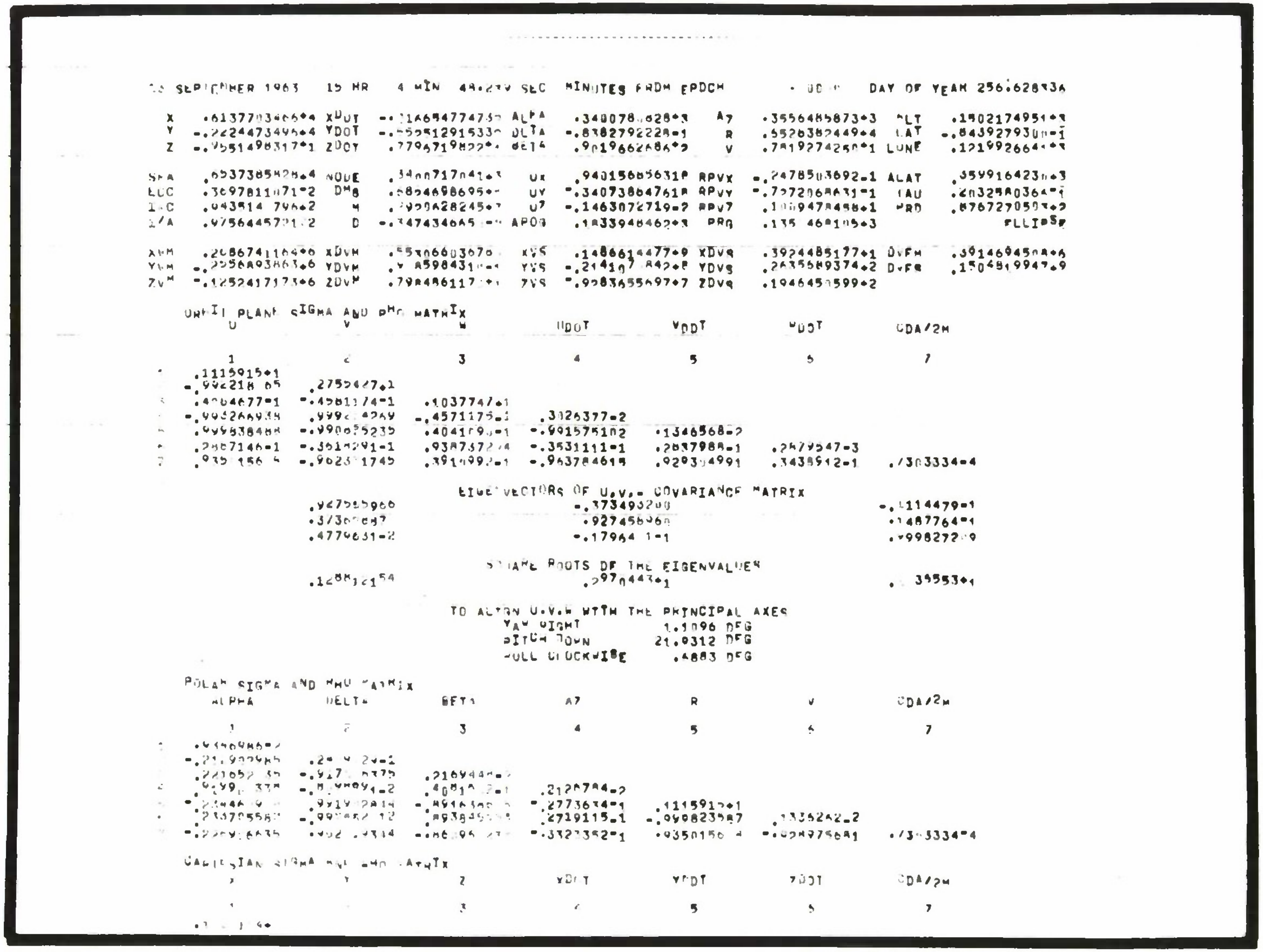
This print option is obtained by placing a "1" flag in column 55 of the JDC card. Figure 4-15 shows a sample page print of the updated error matrices option.

The optional updated matrices are "sigma and rho" symmetric matrices given in lower triangular form. The diagonal terms are the estimated standard deviation (σ) and the off diagonal terms are the correlation coefficients (ρ). The following list describes the parameters given in the columns of each optional updated matrix:



```
                                        RESIDUALS PRINT

II        DATE               N    RANGE    A.HA    E.DC    RDOT   ST.LAT ST.LONG  ST.HT    VH   DLTAT     U     BETA
   Y MM DD HH MM SS.SS             KM     DEG.    DEG.   KM/SEC   DEG     DEG      KM     KM    MIN     DEG    DEG.

881 3  9 13 15 28 35.96    1    -.084    .030    .226    .00     .      -.00   -3.36   3.43   .002   98.24  -.002
881 3  9 13 15 28 39.96    4    -.124   -.010    .041    .000    .00     .00    -.38    .63   .000   98.52  -.002
881 3  9 13 15 28 43.96    7    -.110    .041    .044    .00     .      -.01    -.61    .87   .001   98.79   .001
881 3  9 13 15 28 47.99   10    -.047   -.014   -.060    .00    -.       .00     .84    .87  -.000   99.07  -.008
881 3  9 13 15 28 51.99   13    -.104   -.003   -.034    .00    -.       .00     .48    .48  -.000   99.34  -.008
881 3  9 13 15 28 55.99   16    -.080   -.007   -.024    .00    -.       .00     .33    .34  -.000   99.62  -.008
881 3  9 13 15 28 59.96   19    -.123   -.017   -.063    .00    -.       .00     .82    .85  -.000   99.90  -.008
881 3  9 13 15 29 55.99   22    -.07    -.002   -.061    .00    -.      -.00     .65    .92  -.001  103.76   .001
881 3  9 13 15 29 59.99   25    -.002   -.043    .098    .00    -.       .00    -.94   1.06  -.001  104.03  -.002
881 3  9 13 15 3   7.90   28    -.029    .092   -.109    .00     .      -.00    1.15   1.52   .002  104.58   .001
881 3  9 13 15 3  11.96   31    -.01     .048   -.083    .00     .      -.00     .88   1.16   .001  104.86   .008
881 3  9 13 15 3  15.99   34    -.047    .028   -.056    .00     .      -.00     .62    .69   .000  105.13   .008
881 3  9 13 15 3  19.99   37    -.004    .043   -.107    .00     .      -.00    1.17   1.38   .001  105.41   .008
881 3  9 13 15 3  23.99   40     .022    .29    -.085    .0      .      -.00     .94   1.02   .000  105.68   .001
881 3  9 13 15 3  27.96   43     .023    .9     -.087    .00     .      -.00     .98   1.01   .000  105.96   .002
881 3  9 13 15 3  43.99   46     .033    .024   -.088    .00     .      -.00    1.08   1.14   .000  107.06   .008
881 3  9 13 15 3  47.96   49     .131    .029   -.085    .00     .      -.00    1.16   1.16   .001  107.34   .001
881 3  9 13 15 3  51.96   52     .175    .076   -.067    .00     .       .01     .84   1.35   .002  107.61  -.002
881 3  9 13 15 3  55.96   55     .224    .014   -.084    .0      .      -.00    1.19   1.17   .001  107.89   .002
881 3  9 13 16 55 31.99   58    -.185    .077    .080    .00     .      -.03   -1.13   1.62   .001   95.70   .009
881 3  9 13 16 55 35.95   61    -.239    .001    .057    .00     .       .00    -.76    .63   .000   95.98   .008
881 3  9 13 16 55 39.96   64    -.161    .135   -.047    .00     .      -.06     .64   1.91   .000   96.25   .015
881 3  9 13 16 55 55.99   67    -.278    .010   -.078    .0      .      -.00     .91    .92   .000   97.36   .008
881 3  9 13 16 55 59.96   70    -.239   -.013   -.076    .0      .       .00     .84    .86  -.000   97.63  -.001
881 3  9 13 16 56  3.98   73    -.361   -.005   -.027    .00     .       .00     .35    .46   .000   97.91  -.008
881 3  9 13 16 56  7.96   76    -.319    .006   -.037    .00     .00     .00     .42    .48   .000   98.18   .008
881 3  9 13 16 56 11.99   79    -.199   -.025    .057    .0      .       .01    -.45    .60   .000   98.46  -.002
881 3  9 13 16 56 15.99   82    -.222   -.025   -.011    .0      .       .01     .15    .32   .000   98.74  -.001
881 3  9 13 16 56 19.99   85    -.312   -.047    .02     .0      .       .01    -.17    .51   .000   99.01  -.003
881 3  9 13 16 56 23.96   88    -.337   -.449    .053    .00    -.00     .12    -.27   3.29   .000   99.29  -.020
881 3  9 13 16 56 27.96   91    -.363   -.049   -.128    .00    -.       .01     .98   1.04  -.000   99.56  -.002
881 3  9 13 16 56 31.98   94    -.431    .042   -.069    .0      .      -.00     .98    .66   .000   99.84   .002
881 3  9 13 16 56 35.99   97    -.297   -.099   -.113    .0     -.       .01     .75    .93  -.000  100.12  -.004
881 3  9 13 16 56 39.99  100    -.329    .011   -.064    .0      .       .00     .47    .49   .000  100.39   .008
881 3  9 13 16 56 43.99  103    -.374   -.01    -.058    .0      .       .00     .44    .48   .000  100.67  -.008
881 3  9 13 16 56 55.99  106    -.417   -.070   -.092    .00    -.       .00     .54    .58   .000  101.50  -.001
881 3  9 13 16 56 59.99  109    -.483   -.111   -.179    .00    -.       .00     .77    .82  -.000  101.77  -.002
881 3  9 13 16 57  3.99  112    -.508   -.234   -.105    .0     -.       .01     .50    .73  -.000  102.05  -.002
881 3  9 13 16 57  7.98  115    -.531   -.274   -.119    .0     -.       .00     .52    .71  -.000  102.32  -.002
881 3  9 13 16 57 23.95  118    -.439    .003   -.268    .0      .      -.00     .59    .87   .001  103.43   .001
881 3  9 13 16 57 31.98  121    -.31    -.006   -.064    .00    -.      -.00     .37    .38  -.000  103.98   .008
881 3  9 13 16 57 35.96  124    -.162   -.14    -.182    .0      .      -.01     .50    .79   .000  104.25   .003
881 3  9 13 16 57 39.99  127    -.217   -.736   1.624    .0     -.  3   -.12   -5.2    7.07  -.010  104.53   .016
881 3  9 13 16 57 43.99  130    -.057    .326   -.299    .0      .       .08    1.16   1.53   .001  104.8   -.016
881 3  9 13 16 57 47.99  133     .07    -.033   -.174    .0      .      -.0      .71    .86   .001  105.0    .001
881 3  9 13 16 58 15.96  136     .25     .011    .141    .00    -.       .00   -1.21   1.22  -.000  107.01  -.008
881 3  9 13 16 58 19.9   139     .294    .07    -.096    .0      .       .02     .76   1.00   .001  107.29  -.003
881 3  9 13 16 58 23.97  142     .33     .32    -.099    .0      .       .01     .94   1.04   .001  107.56  -.002
881 3  9 13 16 58 27.99  145     .228    .72    -.141    .0      .       .03    1.33   1.5    .001  107.84  -.006
881 3  9 13 16 58 31.99  148     .268    .069   -.118    .0      .       .02    1.16   1.37   .001  108.11  -.004
881 3  9 13 16 58 35.9   151     .261    .03    -.048    .0      .       .02     .59    .9    .001  108.39  -.005
881 3  9 13 16 58 39.9   154     .33     .01    -.081    .0      .       .0      .7    1.11   .001  108.66  -.004
```

Figure 4-14. Sample ESPOD Residuals (LLH Option) Page



```
13 SEPTEMBER 1963   15 HR   4 MIN  48.239 SEC  MINUTES FROM EPOCH      . 00 .     DAY OF YEAR 256.628936

  X   .6137703466+4 XDOT  -.1146547747357 ALPHA  .3400780628+3   AZ   .3556485873+3  ALT   .1502174951+3
  Y  -.2224473495+4 YDOT  -.5551291533- DLTA   -.8382792228-1   R    .5526382449+4  LAT  -.8439279300-1
  Z  -.9551498317+1 ZDOT   .7796719822+  BETA   .9019662686+2   V    .7819274250+1 LUNE   .1219926641+3

SMA   .6537385828+4 NODE   .3400717041+3    UX   .9401566563+  RPVX -.2478503692-1 ALAT   .3599164230+3
ECC   .3697811071-2 DMB    .6824469869+-    UY  -.3407386476+  RPVY -.7272068631-1  TAU   .2032580364-1
INC   .9435147966+2    M   .7999628245+7    UZ  -.1463072719-2 RPVZ  .1009478458+1  PRD   .8767270593+2
1/A   .9756445721-2    D  -.3474346645-- APOG   .1833948462+3  PRG   .135 468105+3              ELLIPSE

XVM   .2086741164+6 XDVM   .5306603670   XVS   .1486614477+9 XDVS   .3924485177+1 DVFM   .3914694508+6
YVM  -.2956893863+6 YDVM   .A5984310--   YVS  -.2141907 842+8 YDVS   .2635589374+2 DVFS   .1504819947+9
ZVM  -.1252417173+6 ZDVM   .7984861171+  ZVS  -.9983655697+7 ZDVS   .1946450599+2

    ORBIT PLANE SIGMA AND RHO MATRIX
        U             V             W            UDOT         VDOT         WDOT         CDA/2M

        1             2             3             4            5            6            7
 1   .1115915+1
 2  -.9942186 65  .2755427.1
 3   .4064677-1  -.4581174-1   .1037747+1
 4  -.9952669358  .9992 4269  -.4571175-1   .3026377-2
 5   .9996384868 -.9900575235  .4041090-1  -.9915751102  .1346568-2
 6   .2867146-1  -.3614291-1   .9387372/4  -.3531111-1   .2037988-1   .2679547-3
 7   .935 156 5  -.9623 1745   .3914992-1  -.9637846115  .9293 4991  .3438912-1   .7303334-4

                                EIGENVECTORS OF U,V,- COVARIANCE MATRIX
                 .9275559660                  -.3734932000                           -.1114479-1
                 .3730 0837                    .9274569600                            .1487764-1
                 .4779631-2                   -.17964 1-1                             .9998272 9

                                 SQUARE ROOTS OF THE EIGENVALUES
                 .1280121154                   .2970443+1                             . 39553+1

                             TO ALIGN U.V.W WITH THE PRINCIPAL AXES
                                  YAW RIGHT           1.1096 DEG
                                  PITCH DOWN         21.9312 DEG
                                  ROLL CLOCKWISE       .4883 DEG

    POLAR SIGMA AND RHO MATRIX
      ALPHA         DELTA          BETA           AZ            R             V           CDA/2M

        1             2             3             4            5            6            7
 1   .9460986-2
 2  -.21 9229865  .2  9 29-1
 3   .2216522 35 -.917  6375    .2169444-2
 4   .9299  338  -.8 9809 1-2   .4081  2-1   .2128784-2
 5  -.23446 9    .9919 2814   -.8916360 5  -.2773634-1   .1115917+1
 6   .2337055 6  -.99 852 12   .8938495 5   .2719115-1  -.0908235 87  .1336242-2
 7  -.2269 6635  .992 .9314   -.86 95 27   -.3323352-1   .9350156 4  -.0289756 1   .73 3334-4

    CARTESIAN SIGMA AND RHO MATRIX
        X             Y             Z            XDOT         YDOT         ZDOT         CDA/2M

        1             2             3             4            5            6            7
 1   .1  1 5+
```

Figure 4-15. Sample ESPOD Trajectory (Updated Error Matrices Option) Printout Page

ORBIT PLANE SIGMA AND RHO MATRIX

Column Symbol	Description
U 1	Position vector (up) component in the direction of the radius vector and collinear with it, in kilometers.
V 2	Position vector (down) component in the direction of motion and orthogonal to the radius vector in the orbit plane, in kilometers.
W 3	Position Vector (cross) component normal to the orbit plane in the direction of the angular momentum vector to complete a right-handed coordinate system, in kilometers.
UDOT 4	Velocity vector (up) component, defined like U, in kilometers per second.
VDOT 5	Velocity vector (down) component, defined like V, in kilometers per second.
WDOT 6	Velocity vector (cross) component, defined like W, in kilometers per second.
CDA/2M 7	Drag parameter, in meters^2 per kilogram.
or	
K 7	Drag variation parameter, in meters^2 per kilogram per day for the secular option and in meters^2 per kilogram for the periodic option.

Note: Any further headings and numbers will apply to nonorbital parameters which have been entered into the solution.

The following parameters provide information concerning the size, shape and orientation of the error ellipsoid about the position of the vehicle for a particular update time.

EIGENVECTORS OF U, V, W, COVARIANCE MATRIX

These are the normalized eigenvectors of the preceding U, V, W covariance matrix. They are direction cosine components with respect to the U, V, W axes for the orthogonal axes of the error ellipsoid defined by the covariance matrix.

SQUARE ROOTS OF THE EIGENVALUES

The square roots of the eigenvalues represent the lengths of the orthogonal semi-principal axes of the error ellipsoid. They correspond respectively to the normalized eigenvector columns immediately above. They are rotated from the U, V, W coordinate axes as described next.

TO ALIGN U, V, W WITH THE PRINCIPAL AXES

YAW RIGHT (* . . .) DEG
PITCH DOWN (* . . .) DEG
ROLL CLOCKWISE (* . . .) DEG

These are a series of ordered rotations which will reposition an observer, facing initially in the positive V direction, to a new orientation facing along the error ellipsoid's nearest principal axis.
(* . . .) indicates a numerical value for each direction of rotation.

POLAR SIGMA AND RHO MATRIX

Column Symbol	Description
ALPHA 1	Right ascension, in degrees
DELTA 2	Declination, in degrees
BETA 3	Flight path angle, in degrees, positive downward from the local vertical.
AZ 4	Azimuth of the velocity vector, in degrees, positive clockwise from true north.
R 5	Radius vector from the geocenter, in kilometers.
V 6	Magnitude of the velocity vector, in kilometers per second.

Note: Any further headings will apply to the drag parameter, the drag variation, and/or any nonorbital parameters which were entered into the solution.

CARTESIAN SIGMA AND RHO MATRIX

Column Symbol	Description
X 1	Position vector component from the geocenter in the direction of the vernal equinox, in kilometers.

CARTESIAN SIGMA AND RHO MATRIX (Continued)

Column Symbol	Description
Y 2	Position vector component from the geocenter orthogonal to X and Z to complete a right-handed coordinate system, in kilometers.
Z 3	Position vector component from the geocenter in the direction of true north, in kilometers.
XDOT 4 YDOT 5 ZDOT 6	Velocity vector components from the position defined by X, Y, Z and in the directions defined by X, Y, Z, respectively. In kilometers per second.

Note: Any further headings will apply to the drag parameter, the drag variation, and/or any non-orbital parameters which were entered into the solution.

4.4 PUNCHED CARD OUTPUT

ESPOD will produce punched card output in three formats. One format is used for the 7-card element set, another for ESPOD solution parameters, and a third for DAC data.

4.4.1 7-Card Element Set Output

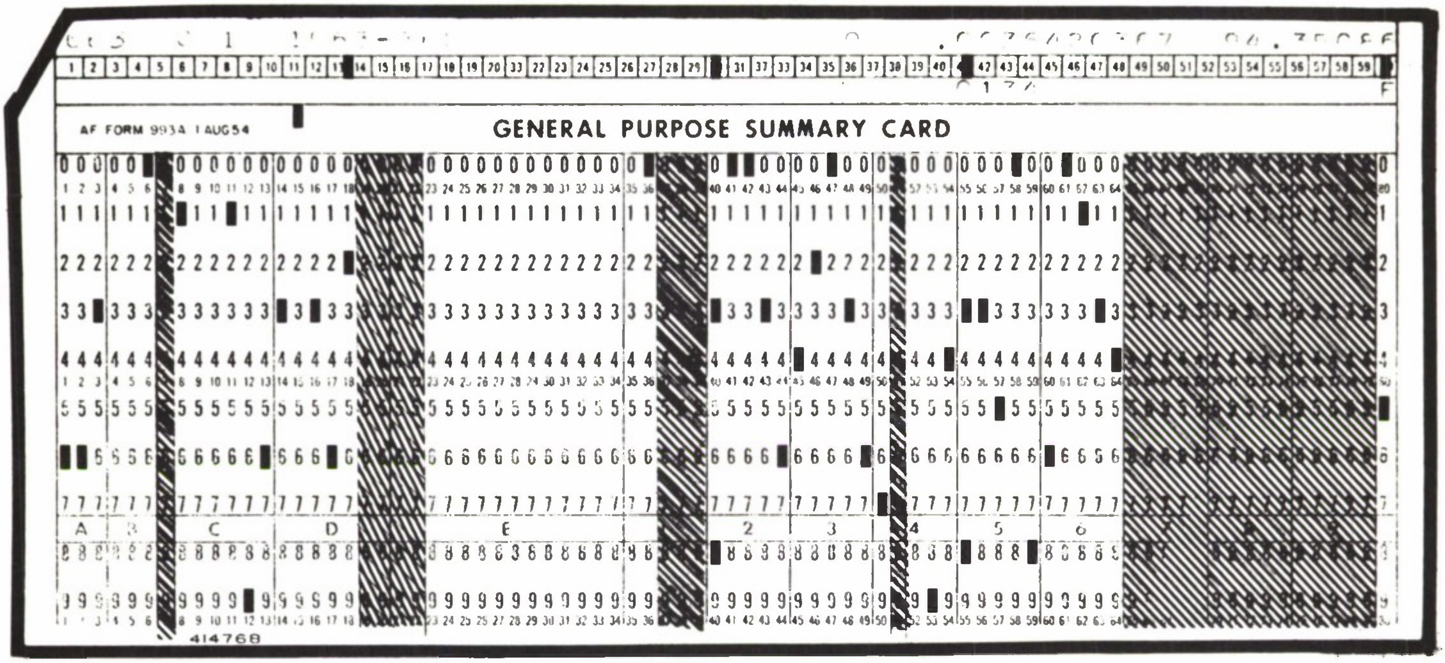
The 7-card element set is in the standard SPS element format, and will always be osculating elements. At the end of each differential correction run with ESPOD, the resulting best elements which have been tested in the program (labeled OLD on the printout) may be obtained by operating DATA SELECT 2 on the Universal Buffer Controller (UBC). If elements are wanted which have the last changes made by ESPOD, a 1 flag in JDC card Column 46 will cause the latest elements from the best iteration (labeled NEW on the printout) to be punched by operating DATA SELECT 2 on the UBC.

The card field assignments for the 7-card element set produced by ESPOD are given in Figures 4-16 through 4-22. All values are floating point, and although the decimal is indicated to be in a given column, it may be anywhere in the field without invalidating the format. The decimals are shown in the columns where they will appear in the ESPOD output.

Note that in all subsequent sample cards shown, areas which should not contain punches are cross-hatched. These samples may be used to test questionable cards quickly by placing them over the full-sized sample and noting if any punches fall in cross-hatched areas.

7 CARD ELEMENTS NO. 1

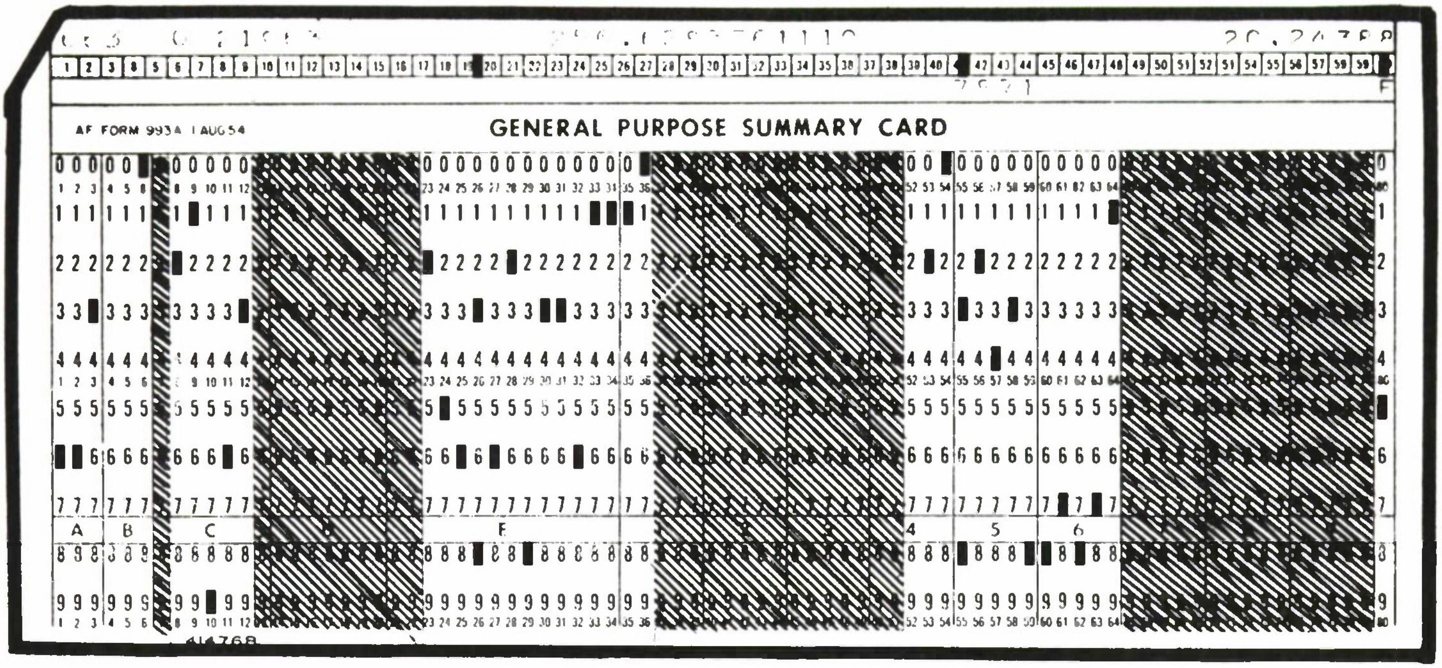
7 CARD ELEMENTS NO. 1



Card-Field	Columns	Data	Remarks
1-1	1-3	Satellite number	Right adjusted to Column 6
	4-6	Elements number	
	7	Not used	
1-2	8	Card number of set	Always 1
	9-18	Object name	
	19-22	Not used	
1-3	23-36	Epoch revolution = N_o	Right adjust
	37-39	Not used	
1-4	40	Decimal	
	41-50	Eccentricity = e	
	51	Not used	
1-5	52-54	Inclination = i	Whole degrees
	55	Decimal	
	56-64	Inclination	Decimal degrees
	65-79	Not used	
1-6	80	-	Always E

Figure 4-16. 7-Card Elements, Card 1

7 CARD ELEMENTS NO. 2

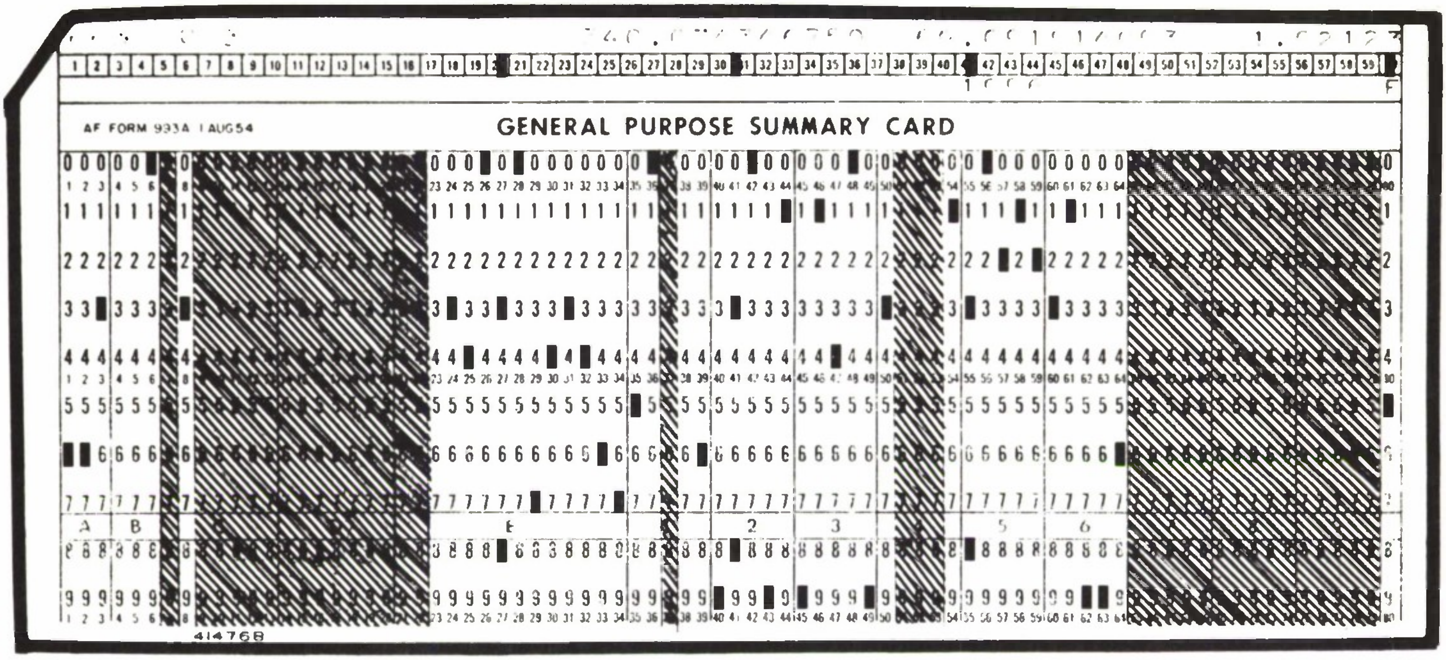


Card-Field	Columns	Data	Remarks
2-1	1-3	Satellite number	Right adjusted
	4-6	Elements number	to Column 6
	7	Not used	
2-2	8	Card number of set	Always 2
	9-12	Epoch year	
	13-22	Not used	
2-3	23-25	Epoch time = t_o	Whole days
	26	Decimal	
	27-36	Epoch time	Decimal days
	37-51	Not used	
2-4	52-54	Mean orbital longitude	Whole degrees
	55	Decimal	
	56-64	Mean orbital longitude	Decimal degrees
	65-79	Not used	
2-5	80	--	Always E

Figure 4-17. 7-Card Elements, Card 2

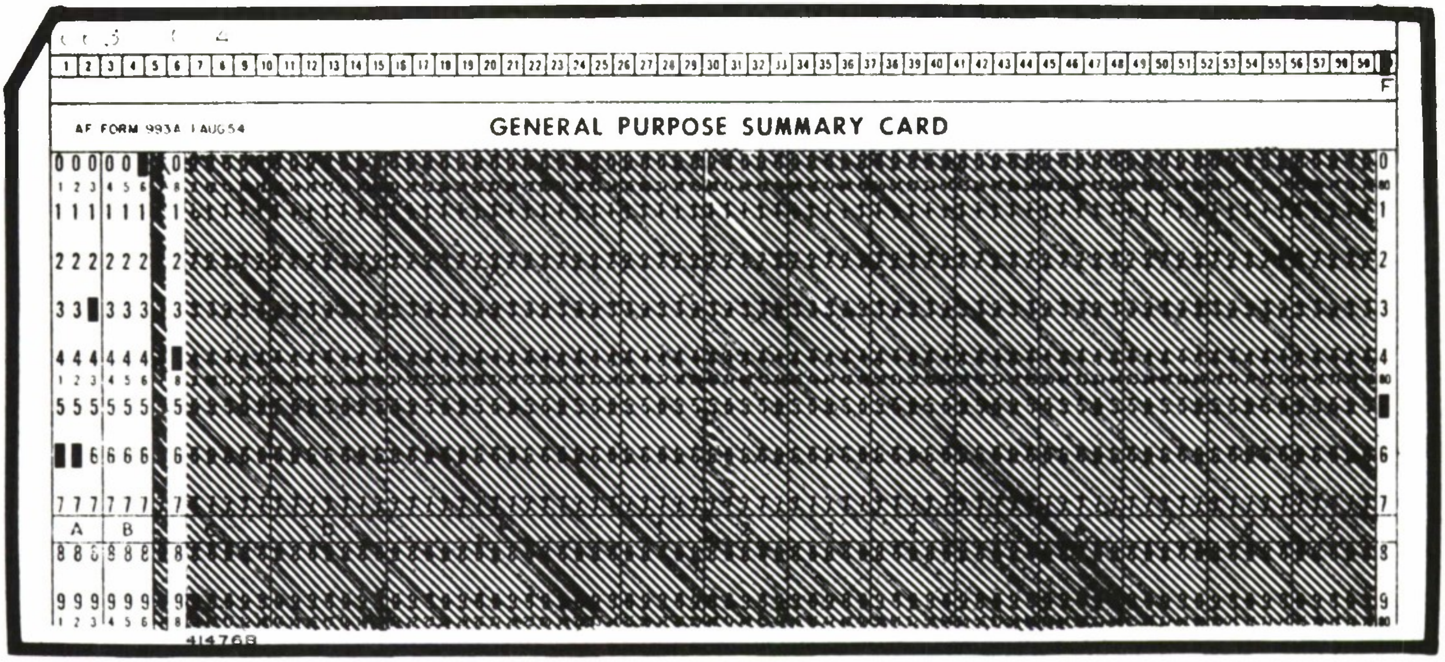
7 CARD ELEMENTS NO. 3

7 CARD ELEMENTS NO. 3



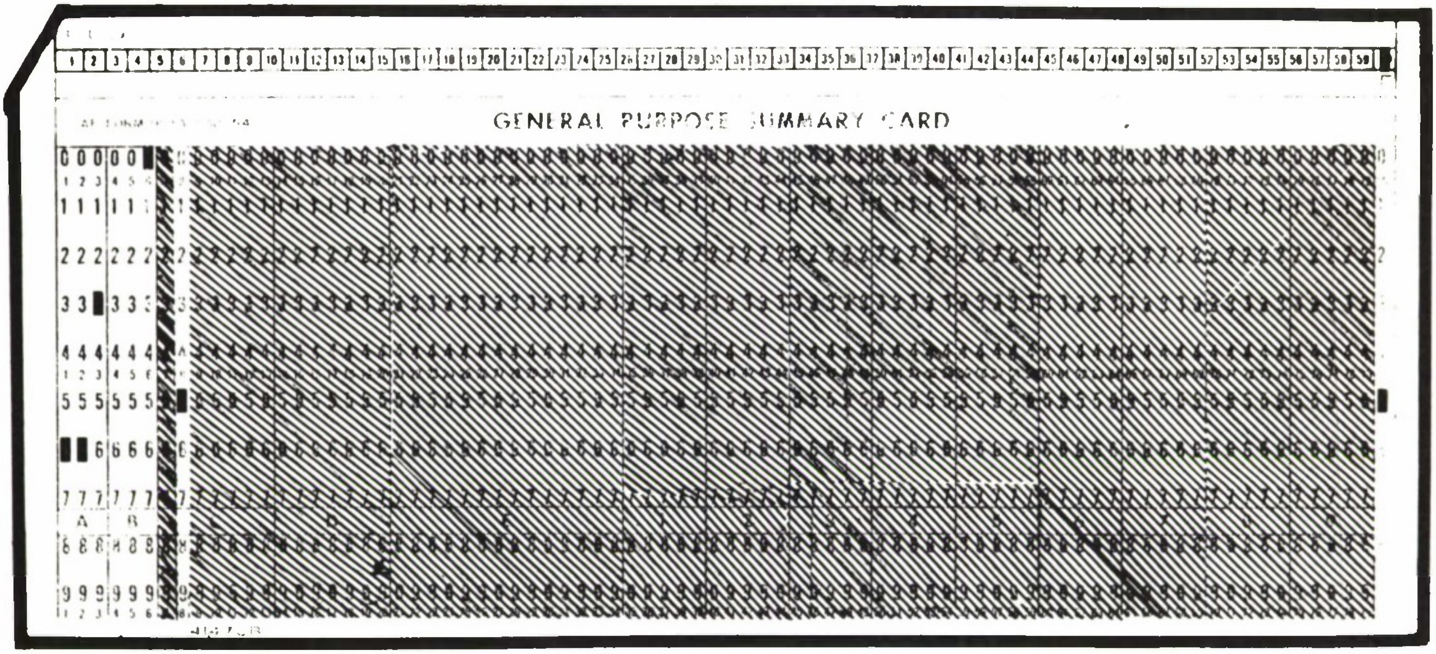
Card Field	Columns	Data	Remarks
3-1	1-3	Satellite number	Right adjusted to Column 6
	4-6	Elements number	
	7	Not used	
3-2	8	Card number of set	Always 3
	9-22	Not used	
	23-26	Right Ascension of Node at t_o	Whole degrees
	27	Decimal	
	28-36	Right Ascension of Node at t_o	Decimal degrees
	37	Not used	
3-3	38-40	Argument of Perigee at t_o	Whole degrees
	41	Decimal	
	42-50	Argument of Perigee at t_o	Decimal degrees
	51-53	Not used	
3-4	54	Perigee distance	Whole earth radii
	55	Decimal	
	56-64	Perigee distance	Decimal earth radii
	65-79	Not used	
3-5	80	--	Always E

Figure 4-18. 7-Card Elements, Card 3



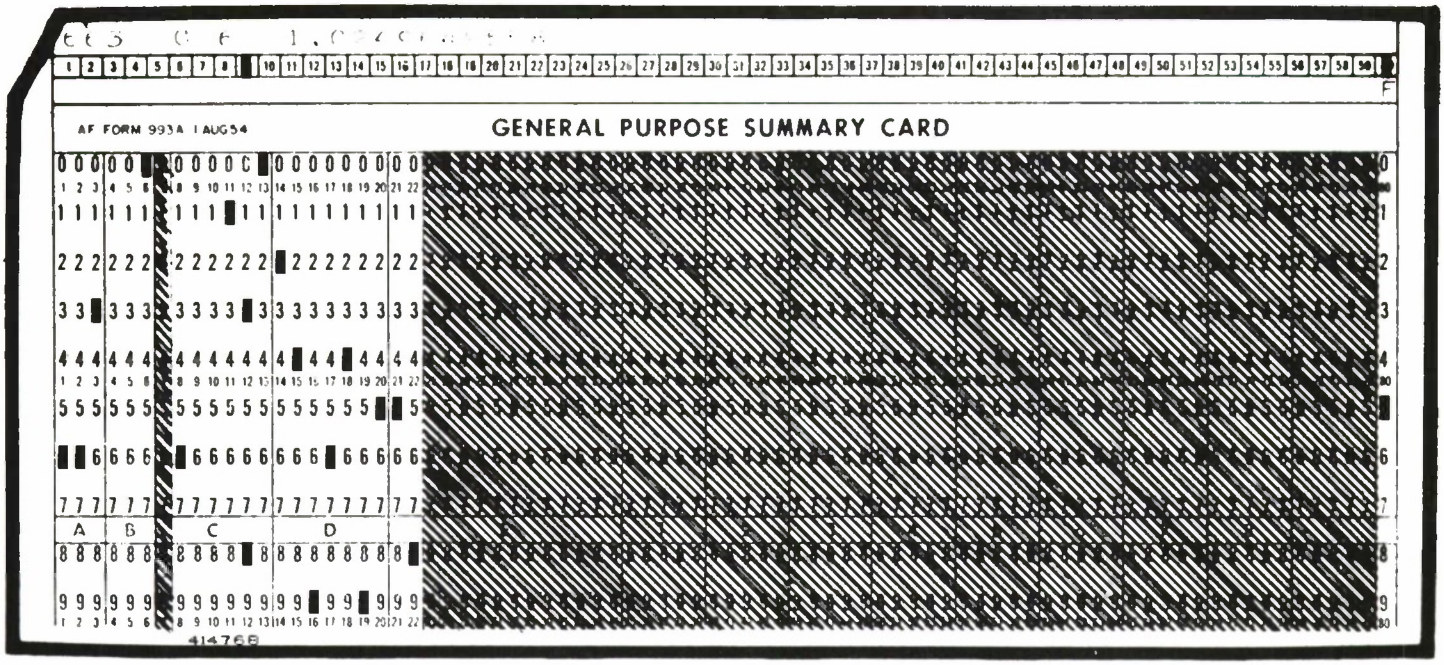
Card-Field	Columns	Data	Remarks
4-1	1-3	Satellite number	Right adjusted
	4-6	Elements number	to Column 6
	7	Not used	
4-2	8	Card number in set	Always 4
	9-79	Not used	
4-3	80	—	Always E

Figure 4-19. 7-Card Elements, Card 4



Card-Field	Columns	Data	Remarks
5-1	1-3	Satellite number	Right adjusted
	4-6	Elements number	to Column 6
	7	Not used	
5-2	8	Card number in set	Always 5
	9-79	Not used	
5-3	80	—	Always E

Figure 4-20. 7-Card Elements, Card 5


AF FORM 993A 1 AUG54

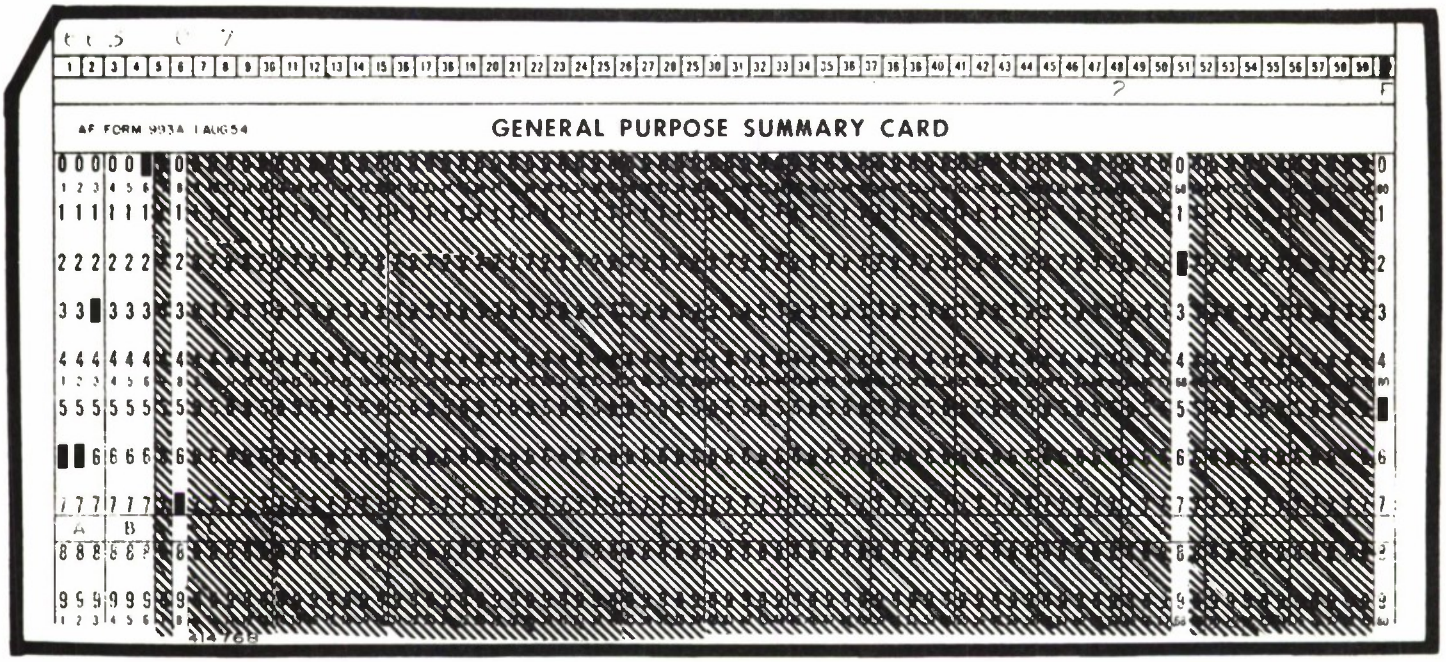
GENERAL PURPOSE SUMMARY CARD

Card-Field	Columns	Data	Remarks
6-1	1-3	Satellite number	Right adjusted to Column 6
	4-6	Elements number	
	7	Not used	
6-2	8	Card number in set	Always 6
	9-11	Semi-major axis = a	Whole earth radii
	12	Decimal	
	13-22	Semi-major axis	Decimal earth radii
	23-79	Not used	
6-3	80	--	Always E

Figure 4-21. 7-Card Elements, Card 6

7 CARD ELEMENTS NO. 7

7 CARD ELEMENTS NO. 7



Card-Field	Columns	Data	Remarks
7-1	1-3	Satellite number	Right adjusted to Column 6
	4-6	Elements number	
	7	Not used	
7-2	8	Card number in set	Always 7
	9-67	Not used	
7-3	68	Type of 7 card elements	Δ for pre K25 1 for K25 2 for osculating
	69-79	Not used	
7-4	80	--	Always E

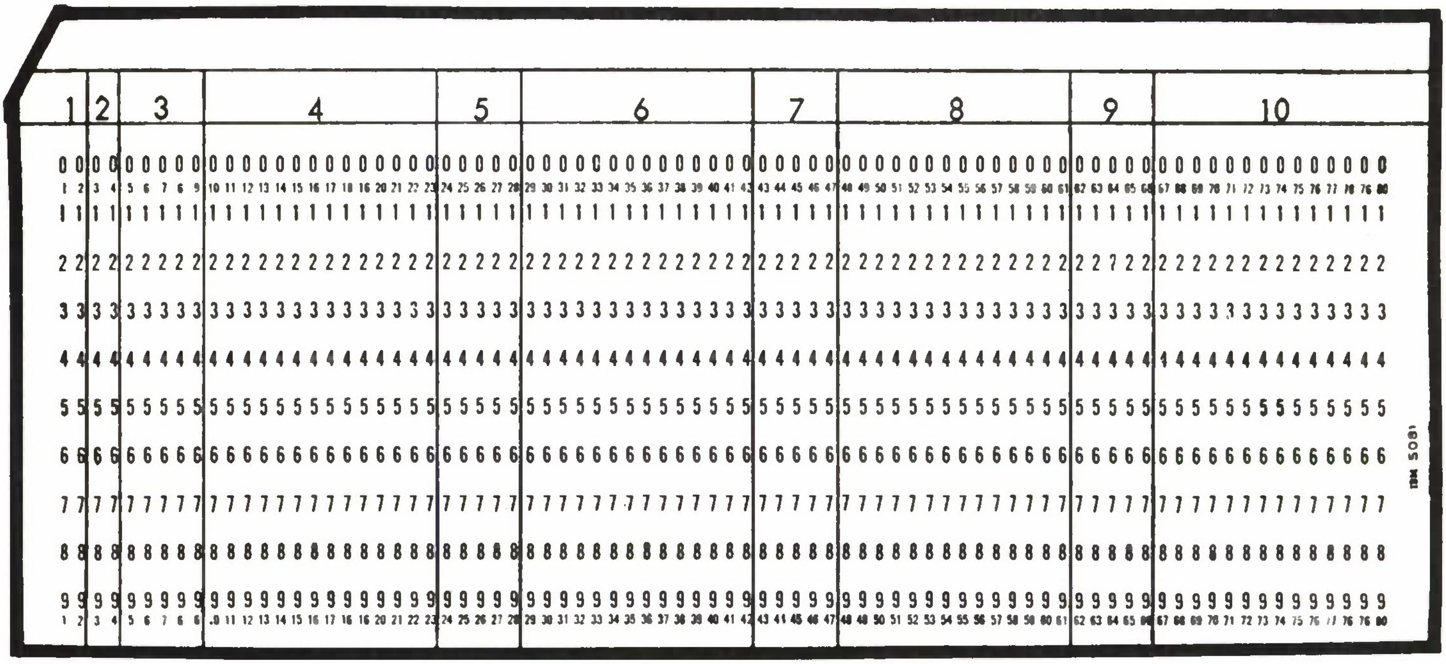
Figure 4-22. 7-Card Elements, Card 7

4.4.2 ESPOD Solution Parameters

A second category of punched card output available from ESPOD serves to record data from a run for convenient resubmission to the computer at a later time. Since these parameters correspond exactly to input cards described in Section 2, only a description of the card fields is given here. Parameters output in this format include ICØND, DRAG, BISES, BNDS, ICTYP, and ITIME.

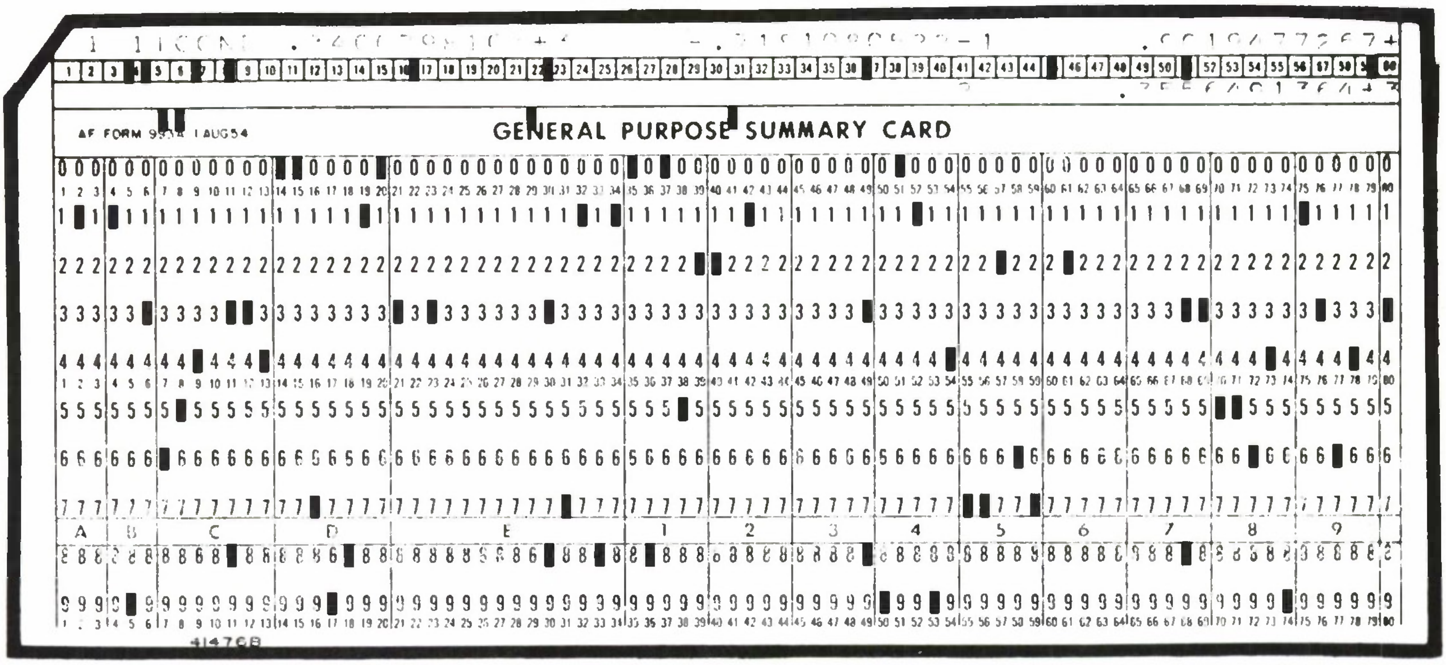
This punched output is identified by a header card for each iteration's output, so that the results of a given iteration may be selected for resubmission.

Card fields, and the field assignments are shown in Figure 4-23. Sample cards are shown in Figures 4-25, 4-25, and 4-26.



Field	Columns	Data	Description
1	1-2	Sequence No.	Identify successive cards starting with first card having identifier in Field 3.
		or	
		Special Identifier	Identifies 99 cards and DAC cards 08, 12
2	3-4	Iteration No.	Identify punched output from successive iterations
3	5-9	I-Field 1	Principal identifier for card
4	10-23	V-Field 1	Data
5	24-28	I-Field 2	
6	29-42	V-Field 2	
7	43-47	I-Field 3	
8	48-61	V-Field 3	
9	62-66	I-Field 4	
10	67-80	V-Field 4	

Figure 4-23. Solution Parameter Punched Card Output



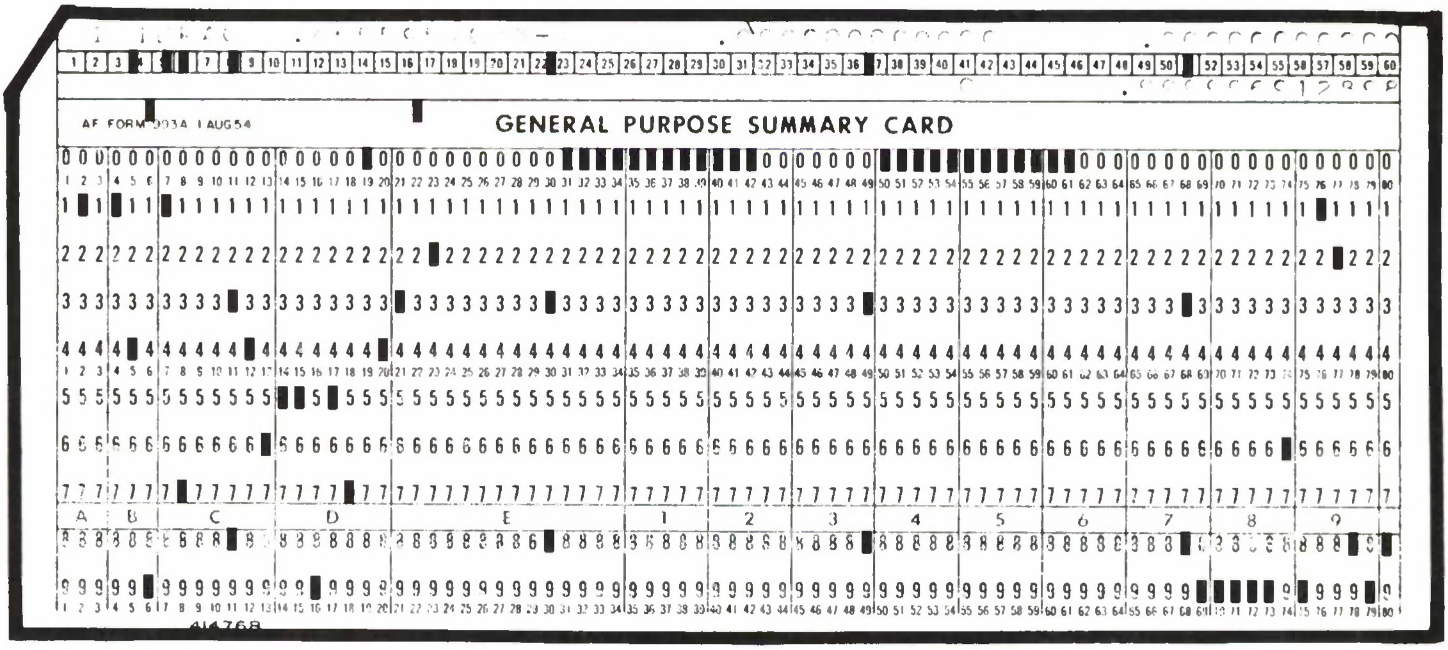


Figure 4-24. Sample Solution Parameter Cards, ICOND, DRAG

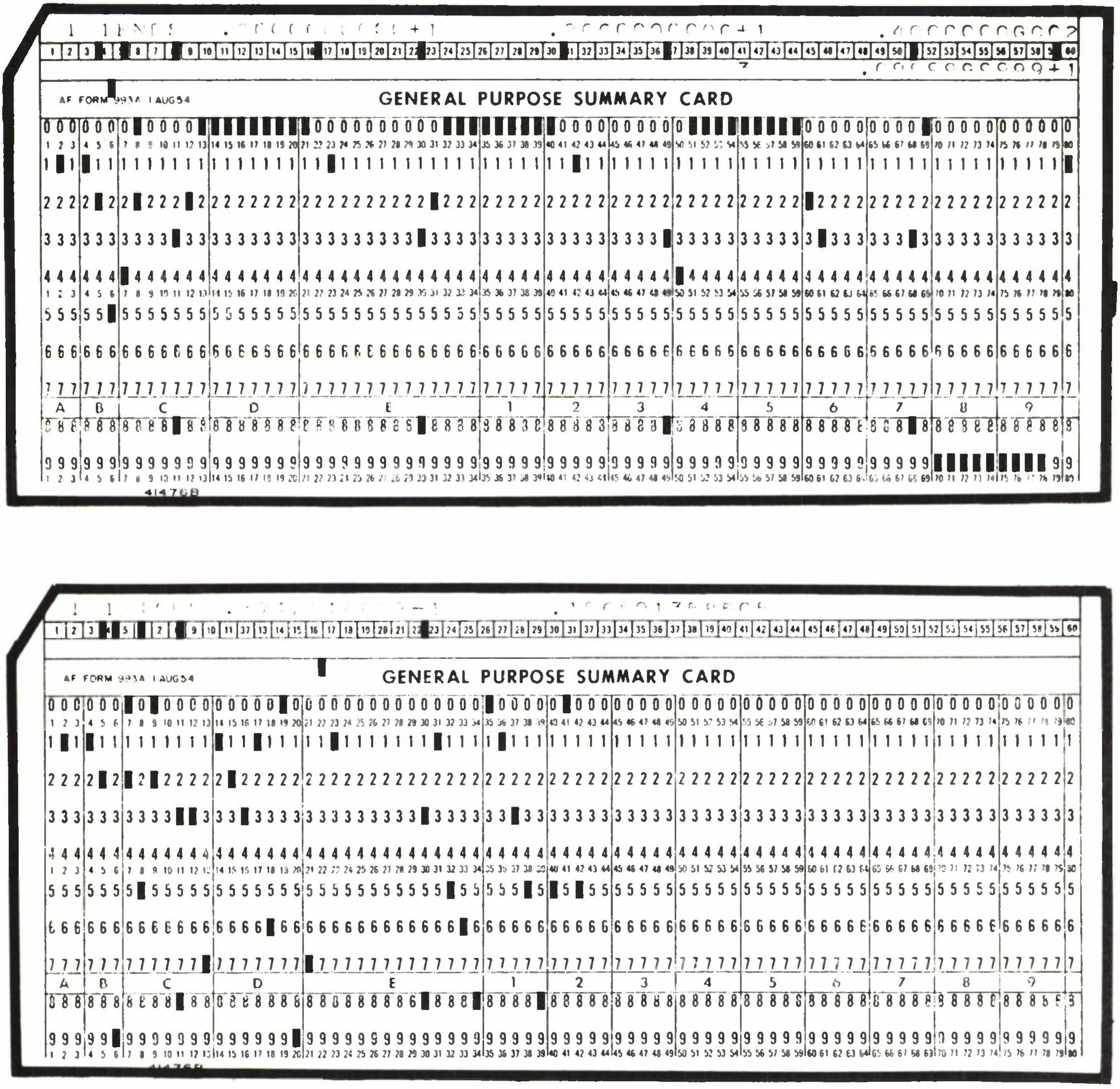


Figure 4-25. Sample Solution Parameter Cards, BNDS, BISES

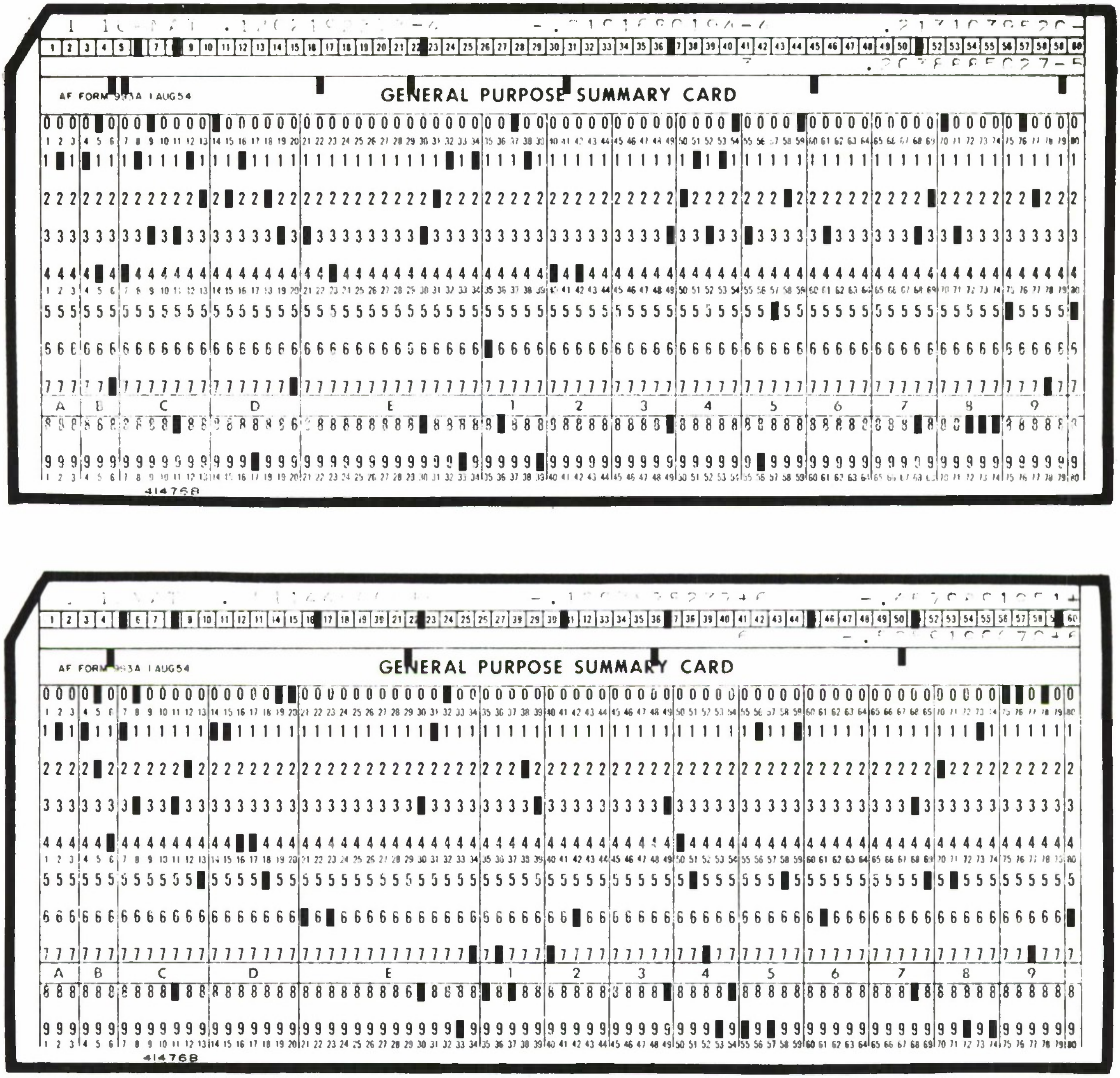


Figure 4-26. Sample Solution Parameter Cards, UPMAT, SMAT

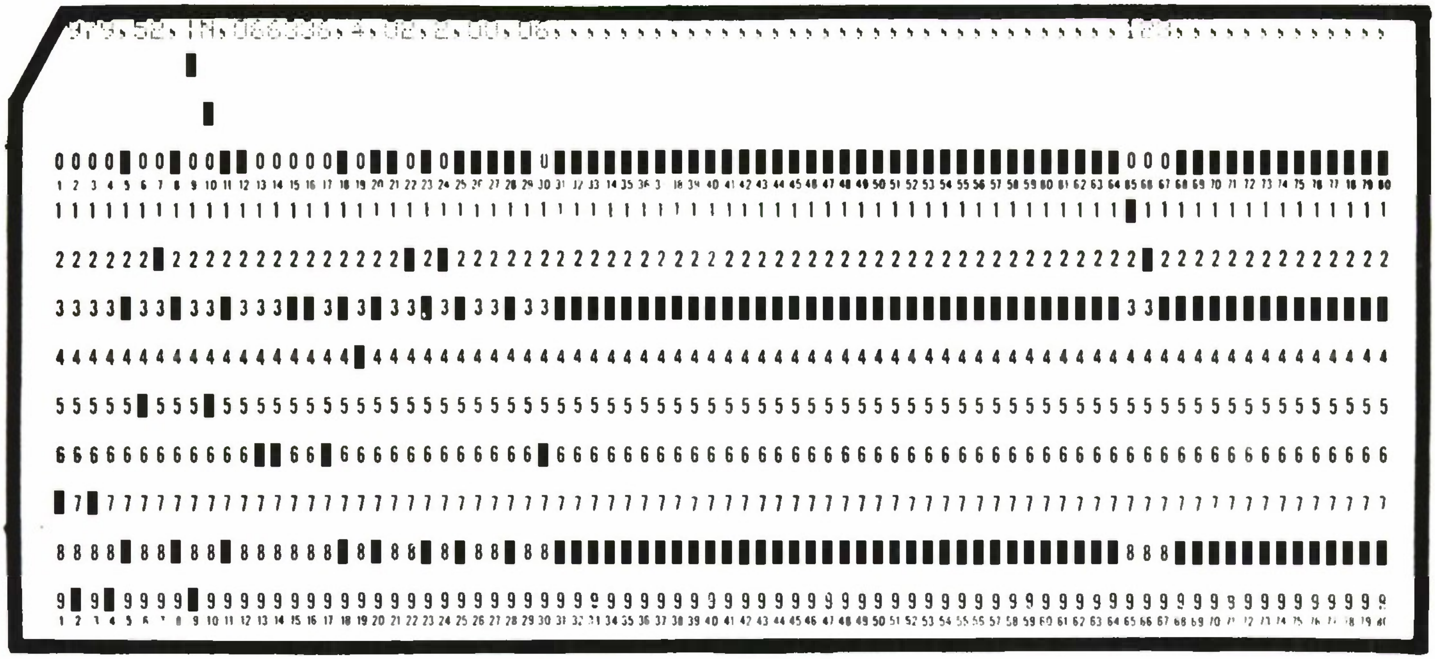
4.4.3 DAC Output

DAC parameters are a special output of position and time data designed to interface with other SPADATS programs. These parameters are punched on cards, printed, and stored in specific computer core locations.

DAC parameters are output automatically when DAC cards are input to supply the desired update times. Core storage results automatically, and cards are punched from logical tape 11 in DATA SELECT 2.

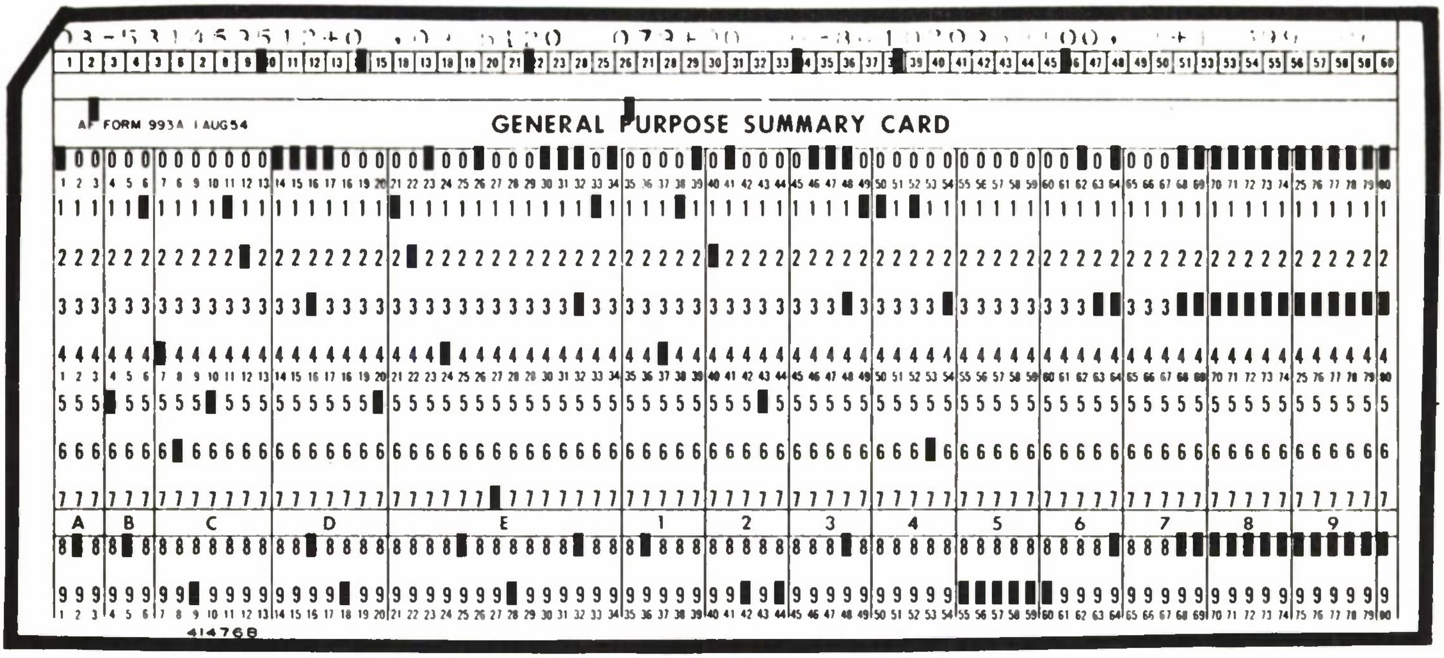
4.4.3.1 DAC Punched Cards

ESPOD will punch the second and third card of a 3-card set. The first card is a header card which must be keypunched or otherwise obtained before using the 3-card set as input to another program. All three cards are described in Figures 4-27, 4-28, and 4-29.



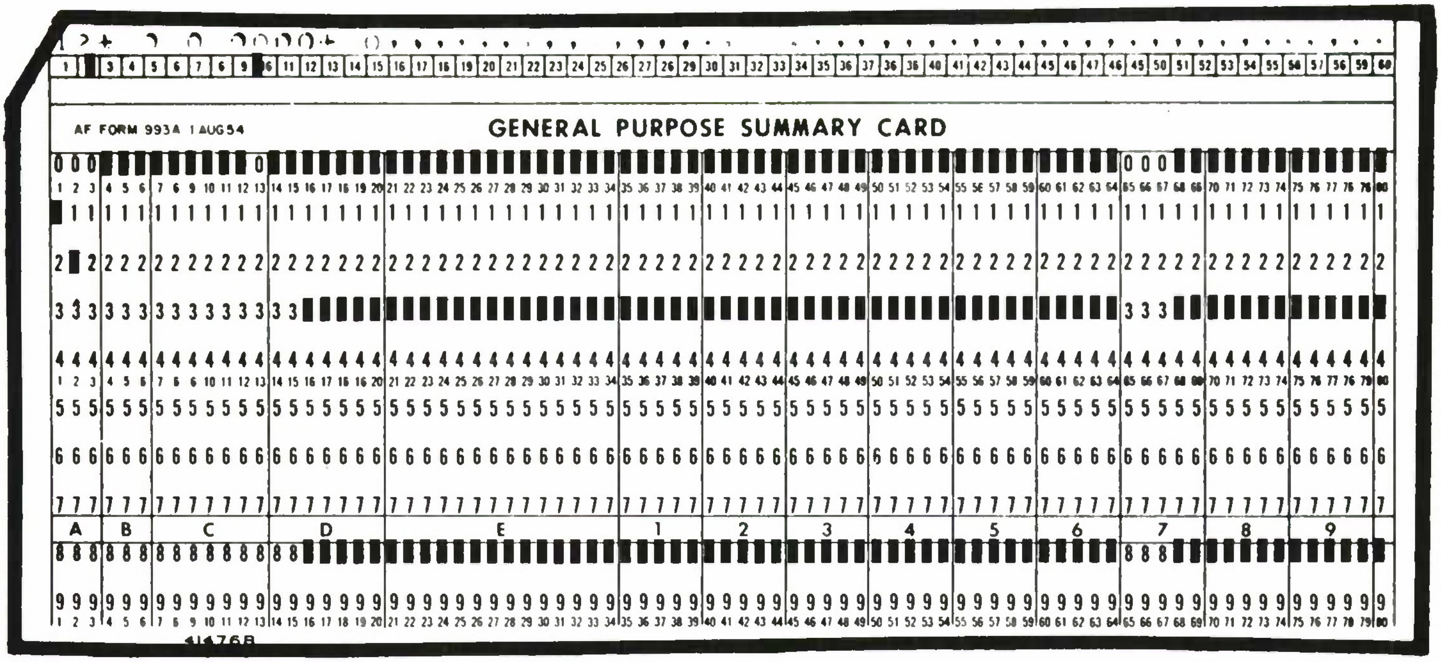
Column	Content	Description
1-5		Same as run input header card
6-7	SS	Source cards
8-21		Same as run input header card
22	N	N is number from column 3 of type-89 card
23-64		Same as run input header card
65-67	NNN	Sequence number from columns 4-6 of type-87
68-80	, - - - ,	Filler

Figure 4-27. DAC Card Set, Card 1 (Header)



Column	Content	Description
1-2	08	Code for X position component
3-15	±mm --- mm ± ee	X position component - in earth radii
16	,	Separator
17-18	09	Code for Y position component
19-31	±mm --- mm ± ee	Y position component - in earth radii
32	,	Separator
33-34	10	Code for Z position component
35-47	±mm --- mm ± ee	Z position component - in earth radii
48	,	Separator
49-50	11	Code for time
51-63	±mm --- mm ± ee	Time from January 0 - in whole days
64	,	Separator
65-67	NNN	Sequence number
68-80	, ---,	Filler

Figure 4-28. DAC Card Set, Card 2



Column	Content	Description
1-2	12	Code for time
3-15	±mm --- mm ± ee	Time - fraction of a whole day
16-64	,---,	Filler
65-67	NNN	Sequence number
68-80	,---,	Filler

Figure 4-29. DAC Card Set, Card 3

4.4.3.2 DAC Core Storage

The data on the 3-card set, when the DAC data option is elected, will be stored starting at the octal locations for the first case as shown in Table 4-I. A word of ZZZZZZZZ indicates the end of the last set of DAC data.

Table 4-1. DAC Core Storage

Core Location	Content	Description
15100	(floating point number)	X position component in earth radii
15101	(floating point number)	Y position component in earth radii
15102	(floating point number)	Z position component in earth radii
15103	(floating point number)	Time from January 0— whole days
15104	(floating point number)	Time from January 0— fractional days
.	.	.
.	.	.
.	.	.
Ranges from 15105 to 15124	ZZZZZZZZ	Words of Z's which indicates that this is the end of the last set.

4.4.3.3 DAC Printed Output

While the punched cards are the form in which the DAC output is used, the data are also presented in the trajectory printout. Figure 4-30 shows DAC data printed output following a block of trajectory printout. At the bottom of Figure 4-30 is the comparison point from a subsequent ESPOD run which had the data immediately above as DAC input. The black background for these subsequently obtained data is used to emphasize that they will never appear consecutively in this manner, but are shown here for ease of illustration. The DAC data printed are described as follows:

COMPARISON POINT 1

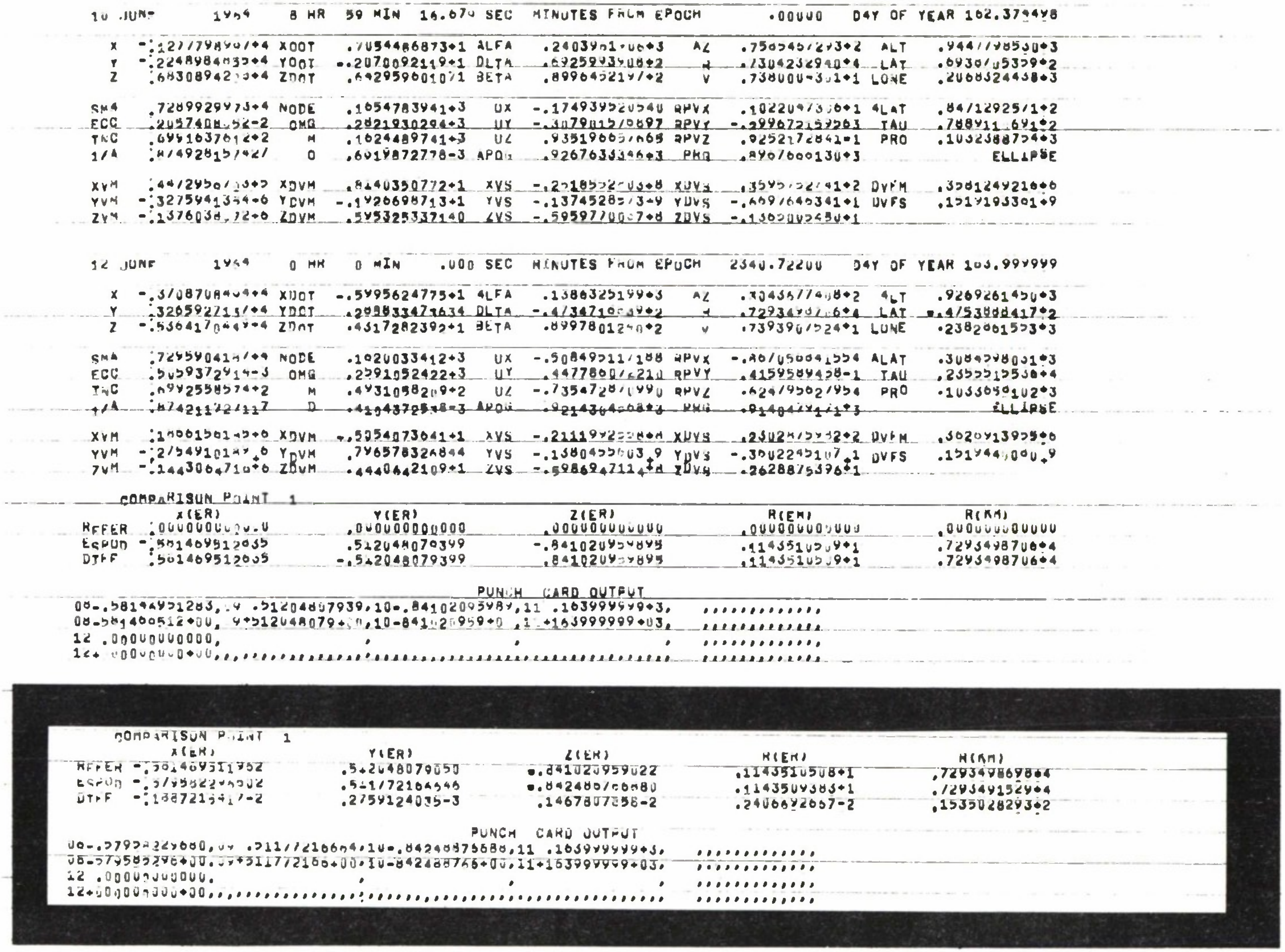
Column Symbol	Description
X(ER) Y(ER) Z(ER)	The X, Y, Z position components in the geocentric inertial Cartesian coordinates used in ESPOD. They are true of $0^h.0$ day of epoch. Units are earth radii.
R(ER)	Radius vector magnitude to the vehicle position, in earth radii from the geocenter.
R(KM)	Radius vector magnitude to the vehicle position, in kilometers from the geocenter.

Line Symbol	Description
REFR	The "reference" or value input to ESPOD or DAC cards. These can be all zeroes when DAC output is being obtained initially for new update times.
ESPOD	The values for the preceding parameters which result from this iteration, taken at the same update time.
DIFF	The "reference" value minus the ESPOD value. Indicates the change in the position prediction resulting from this iteration.

PUNCH CARD OUTPUT

Line	Description
1	The data punched on Card 2 of a 3 Card Set of DAC data, in an easily interpreted form.
2	The card image, exactly as it is punched, of Card 2 of the 3 Card Set.
3	The data punched on Card 3 of a 3 Card Set of DAC data, in an easily interpreted form.
4	The card image, exactly as it is punched, of Card 3 of the 3 Card Set.

Note: The parameters punched on these cards are described in Section 4.4.3.1 of this document.



```
10 JUNE       1964    8 HR   59 MIN  16.670 SEC  MINUTES FROM EPOCH        .00000   DAY OF YEAR 162.374498

   X  -.1277798907+4 XDOT   .7054486873+1 ALFA   .2403961406+3   AZ   .7565457293+2  ALT   .9447798530+3
   Y  -.2248984835+4 YDOT  -.2070092119+1 DLTA   .6925993908+2    H   .7304232940+4  LAT   .6930705359+2
   Z   .6830894200+4 ZDOT   .6429596010/1 BETA   .8996452197+2    V   .7380003501+1 LONE   .2068324438+3

 SMA   .7289929973+4 NODE   .1654783941+3   UX  -.1749395205+0 RPVX   .1022047306+1 ALAT   .8471292571+2
 ECC   .2057408552-2  OMG   .2821930294+3   UY  -.3079015/0697 RPVY  -.2996721597263  TAU   .7889116691+2
 TNC   .6991637612+2    M   .1624489741+3   UZ   .9351966571065 RPVZ   .9252172841-1  PRO   .1032388754+3
 1/A   .8749281574+27   O   .6019872778-3 APOG   .9267633346+3  PRG   .8967600130+3           ELLIPSE

 XVM   .4472950733+5 XDVM   .8440350772+1  XVS  -.2518552003+8 XDVS   .3595752741+2 DVFM   .3581249216+6
 YVM  -.3275941354+6 YDVM  -.1926698713+1  YVS  -.1374528573+9 YDVS  -.6697645341+1 DVFS   .1519193301+9
 ZVM  -.1376038172+6 ZDVM   .5953253371+0  ZVS  -.5959770057+8 ZDVS  -.1362005450+1

12 JUNE       1964    0 HR    0 MIN    .000 SEC  MINUTES FROM EPOCH   2340.72200   DAY OF YEAR 163.999999

   X  -.3708708404+4 XDOT  -.5995624775+1 ALFA   .1386325199+3   AZ   .3043677408+2  ALT   .9269261450+3
   Y   .3265927157+4 YDOT   .2988334731634 DLTA  -.4734710549+2    H   .7293497076+4  LAT  -.4753888417+2
   Z  -.5364170447+4 ZDOT   .4317282392+1 BETA   .8997801240+2    V   .7393907524+1 LONE   .2382861553+3

 SMA   .7295904187+4 NODE   .1920033412+3   UX  -.5084951171188 RPVX  -.8670500441554 ALAT   .3084298031+3
 ECC   .5059372914-3  OMG   .2591052422+3   UY   .4477860742210 RPVY   .4159589458-1  TAU   .2355515530+4
 TNC   .6992558574+2    M   .4931058209+2   UZ  -.7354728710990 RPVZ   .6247950271954  PRO   .1033650102+3
 1/A   .8742117224117   O   .4104372548-3 APOG   .9214364068+3  PRG   .9140479111+3           ELLIPSE

 XVM   .1066156145+6 XDVM  -.5954073641+1  XVS  -.2111972558+8 XDVS   .2302875982+2 DVFM   .3620913955+6
 YVM  -.2754910187+6 YDVM   .7965783268844 YVS  -.1380455603+9 YDVS  -.3502245107+1 DVFS   .1519440000+9
 ZVM  -.1443064710+6 ZDVM   .4440642109+1  ZVS  -.5986947114+8 ZDVS   .2628875396+1

      COMPARISON POINT  1
           X(ER)                  Y(ER)                  Z(ER)                  R(ER)                  R(KM)
 REFER  .0000000000000         .0000000000000         .0000000000000         .0000000000000         .0000000000000
 ESPOD -.5614695120635         .5120480790399        -.8410209548995         .1143510509+1          .7293498706+4
 DIFF   .5614695120635        -.5120480790399         .8410209548995         .1143510509+1          .7293498706+4

                                         PUNCH  CARD OUTPUT
08-.5814495128 3,09 .5120480793 9,10-.8410209598 9,11 .1639999999+3,    ,,,,,,,,,,,,,
08-5614695120+00, 9+5120480790+00,10-8410209590+0 ,11+1639999999+03,    ,,,,,,,,,,,,,
12 .0000000000000,              ,                 ,                ,    ,,,,,,,,,,,,,
12+ 0000000000+00,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,    ,,,,,,,,,,,,,

      COMPARISON POINT  1
           X(ER)                  Y(ER)                  Z(ER)                  R(ER)                  R(KM)
 REFER -.5614695111952         .5420480790050        -.8410209590022         .1143510508+1          .7293498698+4
 ESPOD -.5795822465002         .5417721645446        -.8424887068080         .1143509383+1          .7293491529+4
 DIFF  -.1887215417-2          .2759124035-3          .1467807358-2          .2406692657-2          .1535028293+2

                                         PUNCH  CARD OUTPUT
08-.5795822966 0,09 .5117721660 4,10-.8424887568 8,11 .1639999999+3,    ,,,,,,,,,,,,,
08-5795822960+00,09+5117721660+00,10-8424887560+00,11+1639999999+03,    ,,,,,,,,,,,,,
12 .0000000000000,              ,                 ,                ,    ,,,,,,,,,,,,,
12+0000000000+00,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,    ,,,,,,,,,,,,,
```

Figure 4-30. Sample ESPOD DAC Data Printout

4.5 MAGNETIC TAPE OUTPUT

A magnetic tape containing satellite ephemeris data may be written by placing a "1" flag in Column 53 of the JDC card. This tape format is compatible with this SPADATS program-generated ephemeris tapes of a similar nature, and may be processed in a like manner.

This magnetic tape output format is described in detail in the "ESPOD Mathematical and Subroutine Description," ESD-TDR-64-395. The description has not been given here because it is beyond the scope of an operating manual.

5. ESPOD CONSTANTS

This section lists the program constants which can be changed with a 99-card. They fall into the general classifications listed below.

Astronomical constants
Earth-potential constants
Geophysical constants
Miscellaneous constants

The utilization of these constants is discussed in detail in ESD-TDR-395 ESPOD, "Mathematical and Subroutine Description," Section 5.

Core Location	Symbol	Value	Description
00141	ω_E	$0.437526906 \times 10^{-2}$	Earth rotational rate (rad/min)
00142	f	$0.335232986 \times 10^{-2}$	Ellipticity - 1/298.3
00143	g	32.087598	g - ft/sec^2
00144	K_e*	$0.55303934 \times 10^{-2}$	Earth gravity constant ($e.r.^3/min^2$)
00145		1.0	Earth-Earth mass ratio
00146		81.3015	Earth-Moon mass ratio
00147		332951.3	Sun-Earth mass ratio
00148		0.81476905	Venus-Earth mass ratio
00149		0.107821	Mars-Earth mass ratio
00150		94.952	Jupiter-Earth mass ratio
00151		317.88665	Saturn-Earth mass ratio

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*It should be noted that the program uses a value of K_e given in SPADATS/SPACETRACK Center Constants (March 1964). If elements derived from the obsolete value of K_e are used, there may be a slight inconsistency between the update as given by ESPOD and the update as given by SGP.

Core Location	Flag	Description
00152	0	Earth-selector flag (automatic)
00153	1	Moon selector
00154	1	Sun selector
00155	0	Venus selector
00156	0	Mars selector
00157	0	Jupitor selector
00158	0	Saturn selector

Core Location	Symbol	Value	Description
00159	J_2	0.10823×10^{-2}	See Section 5.8[*] for interpretation of Earth potential coefficients
00160	J_3	-0.230×10^{-5}	
00161	J_4	-0.180×10^{-5}	
00162	J_5	-0.64×10^{-7}	
00163	J_6	0.390×10^{-6}	
00164	J_7	-0.470×10^{-6}	
00165	J_8	-0.20×10^{-7}	
00166	J_9	0.117×10^{-6}	
00167	J_{10}	0.0	
00168	J_{11}	0.0	
00169	J_{12}	0.0	
00170	$J_{1,1}$	0.0	
00171	$J_{2,1}$	0.0	
00172	$J_{3,1}$	0.395×10^{-5}	
00173	$J_{4,1}$	0.264×10^{-5}	

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[*] ESD-TDR-64-395, "Mathematical and Subroutine Description."

Core Location	Symbol	Value	Description
00174	$J_{5,1}$	0.0	See Section 5.8[*] for interpretation of Earth potential coefficients
00175	$J_{6,1}$	0.0	
00177	$J_{2,2}$	0.232×10^{-5}	
00178	$J_{3,2}$	0.41×10^{-6}	
00179	$J_{4,2}$	0.167×10^{-5}	
00180	$J_{5,2}$	0.0	
00181	$J_{6,2}$	0.0	
00182	$\lambda_{3,1}$	22.0	
00183	$\lambda_{3,2}$	31.0	
00184	$J_{3,3}$	0.191×10^{-5}	
00185	$J_{4,3}$	0.46×10^{-6}	
00186	$J_{5,3}$	0.0	
00187	$J_{6,3}$	0.0	
00188	$\lambda_{4,1}$	163.5	
00189	$\lambda_{4,2}$	54.0	
00190	$\lambda_{4,3}$	-13.0	
00191	$J_{4,4}$	0.56×10^{-6}	
00192	$J_{5,4}$	0.0	
00193	$J_{6,4}$	0.0	
00194	$\lambda_{5,1}$	0.0	
00195	$\lambda_{5,2}$	0.0	
00196	$\lambda_{5,3}$	0.0	
00197	$\lambda_{5,4}$	0.0	
00198	$J_{5,5}$	0.0	

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[*] ESD-TDR-64-395, "Mathematical and Subroutine Description."

Core Location	Symbol	Value	Description
00199	$J_{6,5}$	0.0	See Section 5.8* for interpretation of Earth potential coefficients
00200	$\lambda_{6,1}$	0.0	
00201	$\lambda_{6,2}$	0.0	
00202	$\lambda_{6,3}$	0.0	
00203	$\lambda_{6,4}$	0.0	
00204	$\lambda_{6,5}$	0.0	
00205	$J_{6,6}$	0.0	
00206	$\lambda_{2,2}$	-37.5	
00207	$\lambda_{3,3}$	51.3	
00208	$\lambda_{4,4}$	50.3	
00209	$\lambda_{5,5}$	0.0	
00210	$\lambda_{6,6}$	0.0	
00215	R_E	0.20925738×10^8	Feet per Earth radius
00216		0.3048×10^{-3}	Kilometers per foot
00217		6378.165	Kilometers per Earth radius
00219		6378165.	Meters per Earth radius
00220		23454.865	Earth radii per a.u.
00221		57.29577951	Degrees per radian
00222		6076.1152	Feet per nautical mile
00223		0.0	Nautical miles per Earth radius
00452	KRMS	1.5	K_{RMS} rejection criterion
00454	ϵ	0.1×10^{-2}	Convergence criterion
00479	Δt	128.	Maximum allowable step size, in minutes

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*ESD-TDR-64-395, "Mathematical and Subroutine Description."

Core Location	Symbol	Value	Description
00480	Δt	0.0	Minimum allowable step size, in minutes
00481	y_{min}	0.1	Minimum y for variable step test
00482	10^{3-S}	0.1×10^{-8}	Error control tolerance
00483	R	8.0	Ratio of Runge-Kutta steps per Cowell