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SPIRAL DECAY AND SENSOR CALIBRATION DIFFERENTIAL CORRECTION PROGRAMS

Volume II. Operating Instructions

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-65-76

19 FEBRUARY 1965

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496L SYSTEM PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Prepared under Contract No. AF 19(628) -3377 by Aeronutronic, a Division of Philco Corporation, Newport Beach, California

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In order to eliminate manual procedures in the updating of orbits utilizing the Spiral Decay program, the Ballistic coefficient B and related geophysical parameters will be input on Parameter Card 2, rather than on Cards 3 and 4, as in the past. For introducing updated elements into the program, all information is now conveyed on P Cards 1 and 2, and no manual punching is required to update the values of drag.

Two other changes have been made. The day number (DDD) will be used on all input-output formats, following B-3 practice. In addition, two additional significant figures are available in the Ballistic coefficient, a need arising out of the rapidly improving accuracy performance of the Spacetrack system.

The attached formats for Parameter Cards 2, 3 and 4 should be introduced into your manual.

Effective Date: 1965 Day 95

Posted
25 Jun 65
Wrzek, TSgt

ESD-TDR-65-76

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FOREWORD

This Technical Documentary Report has been prepared in four volumes, as follows:

Volume	Title	Contractor's Publication Number
I	Program Development	U-3005
II	Operating Instructions	U-3006
III	Programmer's Manual	U-3007
IV	Operations Summary (U)	S-2990

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

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SECTION 1

INTRODUCTION

This volume contains instructions which enable a non-programmer to use the Spiral Decay Program (SPIRDECA) under the control of the B-3 executive on the Philco 212 computer. The program has been designed for use in the SPACETRACK center of NORAD.

The theoretical details have been presented in Volume I of the report. Programming details will be presented in Volume III.

The diverse uses and many options of the program demand some attention on the part of the analyst in submitting cases. It is suggested that the input deck be reviewed immediately before submission with special attention to the parameter cards. For the utmost precision, it is necessary to use the best values of solar activity indices (supplied by the Air Weather Service) and geopotential coefficients (P-cards 6, 7 and 8). A few seconds forethought may save much computer and analyst time. If it is necessary to submit a series of runs with very similar decks, use should be made of the Remark cards permitted by the Executive System. These cards have the letters REM in columns 17-19, columns 20-24 blank and the alphanumeric remarks following. Remark cards may be placed immediately before the SPS JOB card.

During the training and experimentation at SPACETRACK, analysts have found operation of the program to be comparatively easy. Many of the operational features of the program were suggested by personnel of the 1st Aerospace Surveillance Squadron.

SECTION 2

SPIRAL DECAY PROGRAM OPERATING INSTRUCTIONS

The B-3 version of the Spiral Decay Program (SPIRDECA) has been modified to eliminate OBSWGT and the OBSWGT control card (P Card 0), and to accept 984, rather than 400, observations. The program may be used in three modes: (1) Differential Correction, (2) Prediction or (3) a combined Differential Correction and Prediction.

2.1 INPUT/OUTPUT INSTRUCTIONS

Examples of the job deck setups for each mode of operation are shown in Figures 1-3.

Logical	0	Scratch	WR
	1	B-3 Master	
	2	Input	WR
	4	SEAI	WR
	7	Weight Tape	
	12	Scratch	WR
	11	Output Tape	WR

Logical tapes 0, 7, 12 are optional and should be used for the following:

Logical 0 - if the number of observations exceeds 492

Logical 7 - to override or add to the assembled weights and biases

Logical 12 - if a binary ephemeris tape is requested.

The program output and a dump, if taken, is printed from logical tape 11 on Data Select 1. Cards are punched on Data Select 2.

The binary ephemeris tape (Logical 12) may be used as input to two programs, XYZLA and PUNCH, to generate look angles.

SPIRDECA may also be interfaced with the GIPAR program. The input decks must be stacked and run together. Five points may be passed to GIPAR by use of P Card 10 (Figure 18).

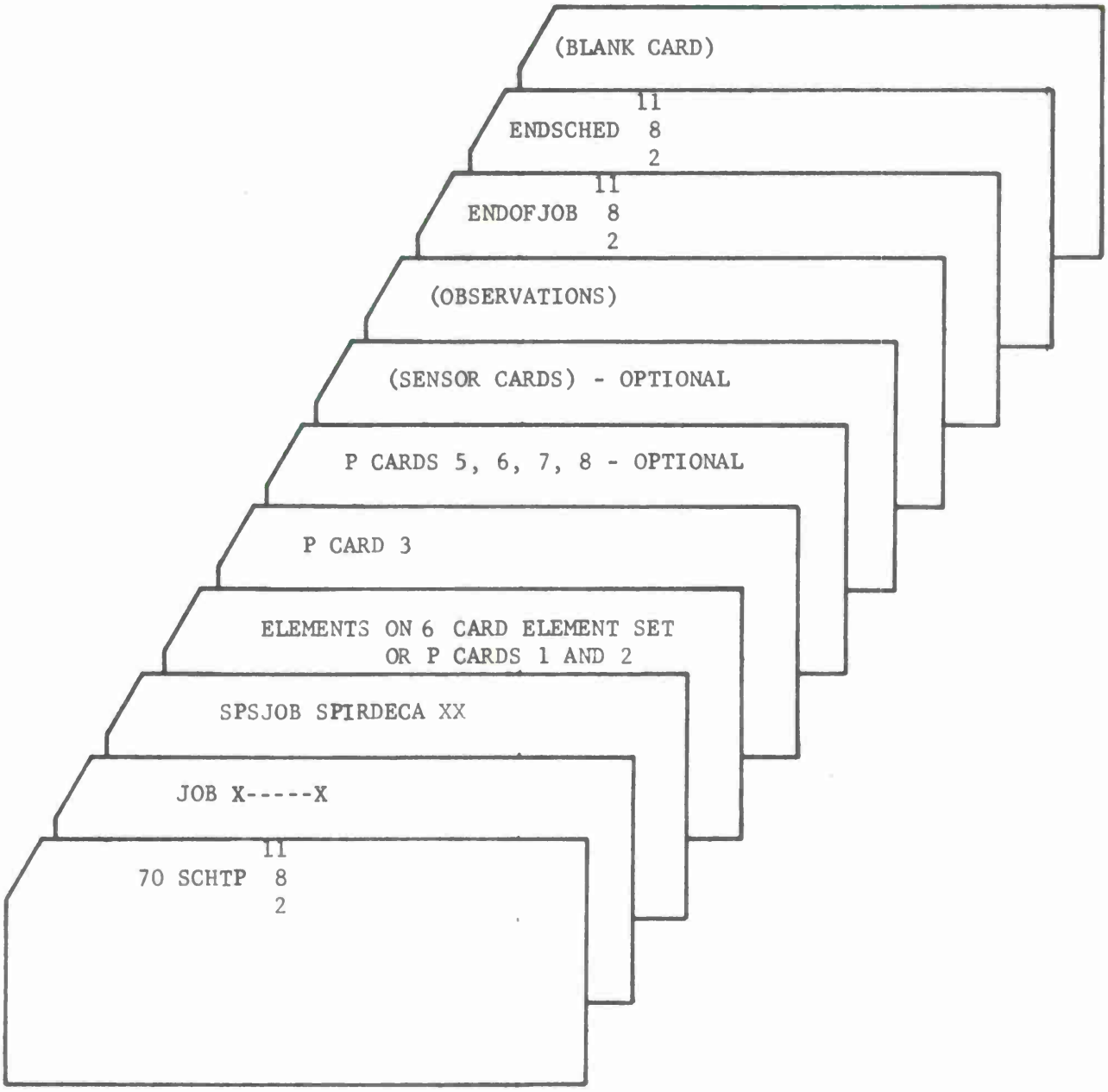


FIGURE 1. SPIRDECA INPUT DECK FOR DIFFERENTIAL CORRECTION RUN

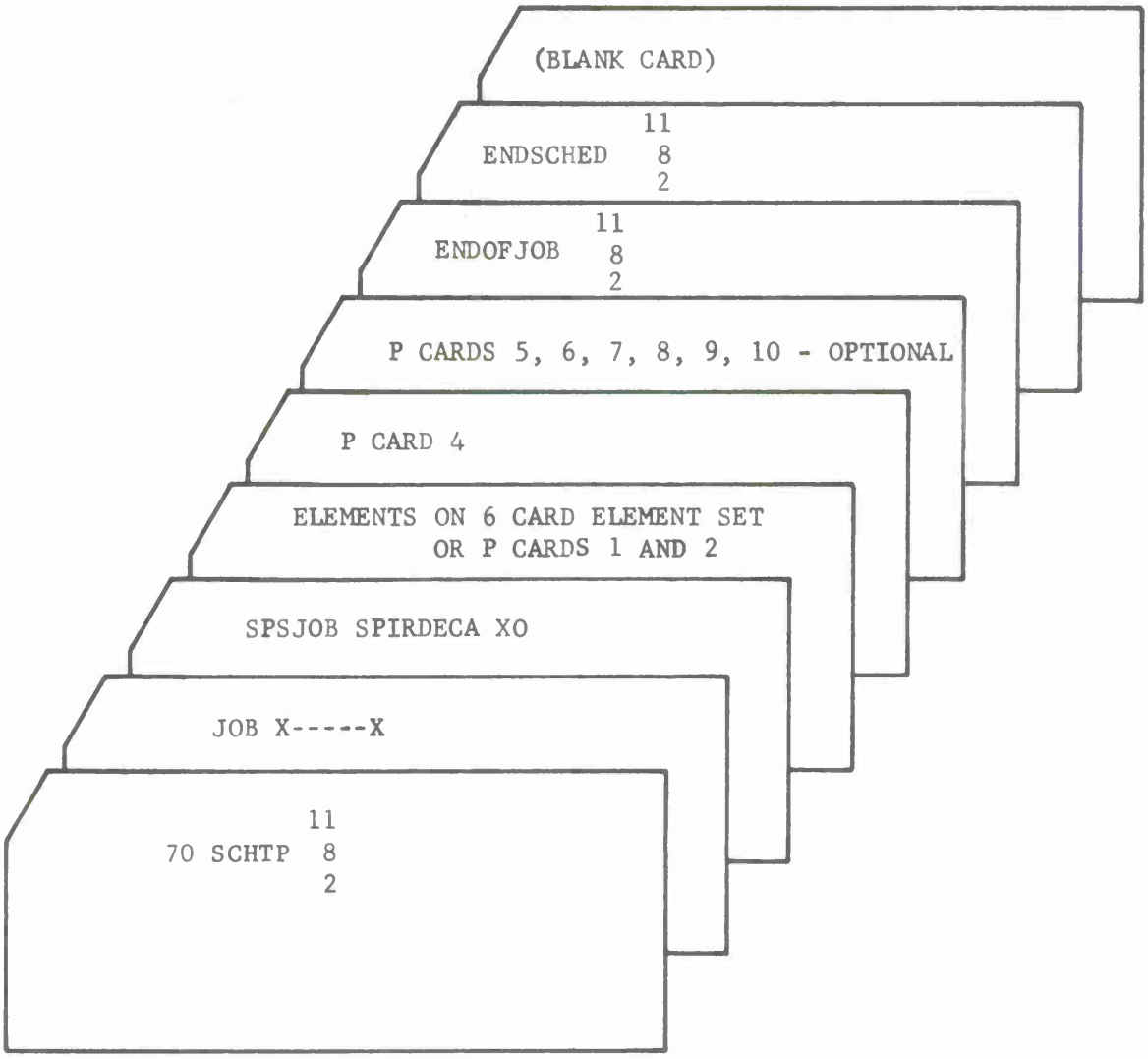


FIGURE 2. SPIRDECA INPUT DECK FOR PREDICTION RUN

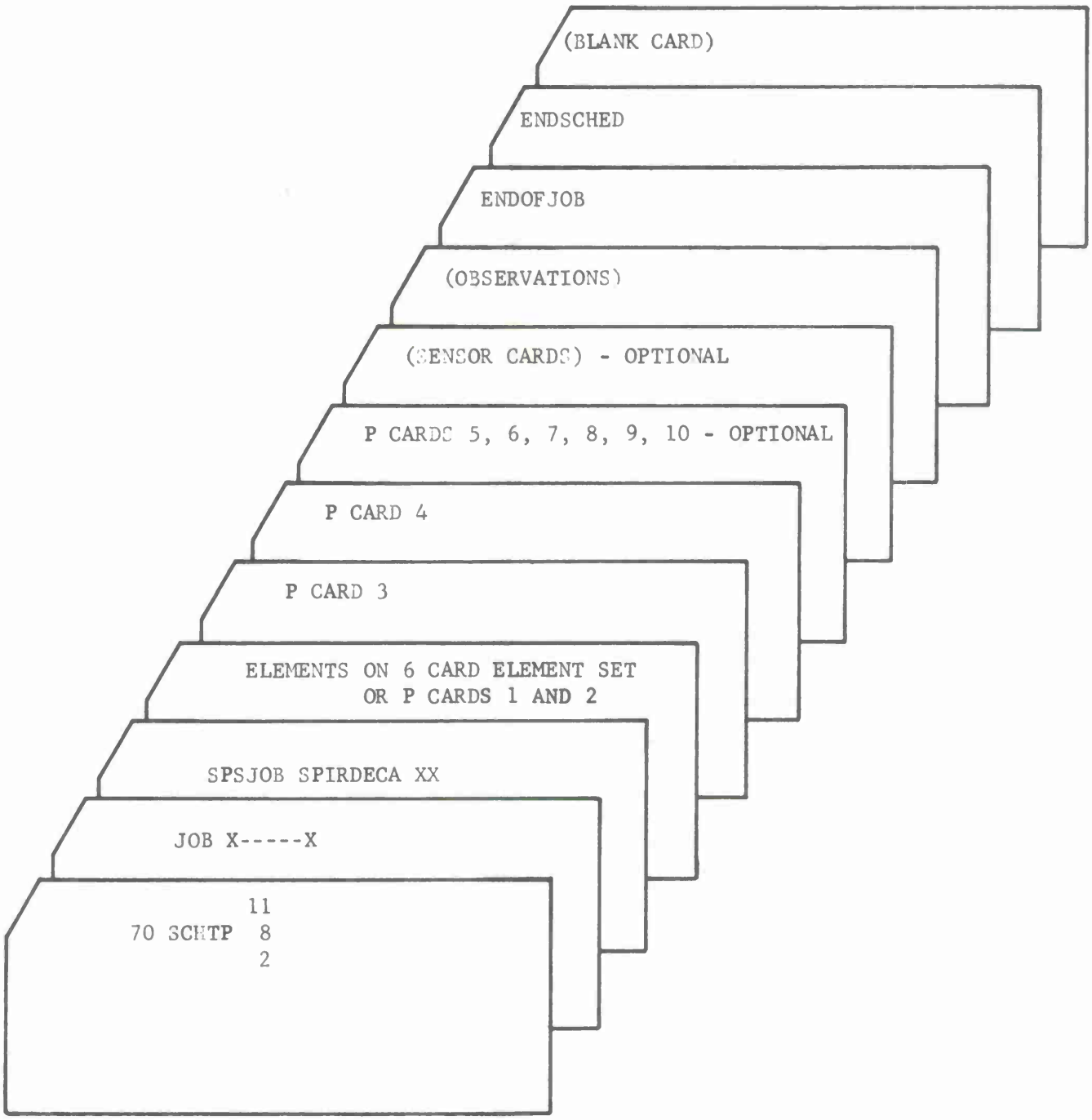
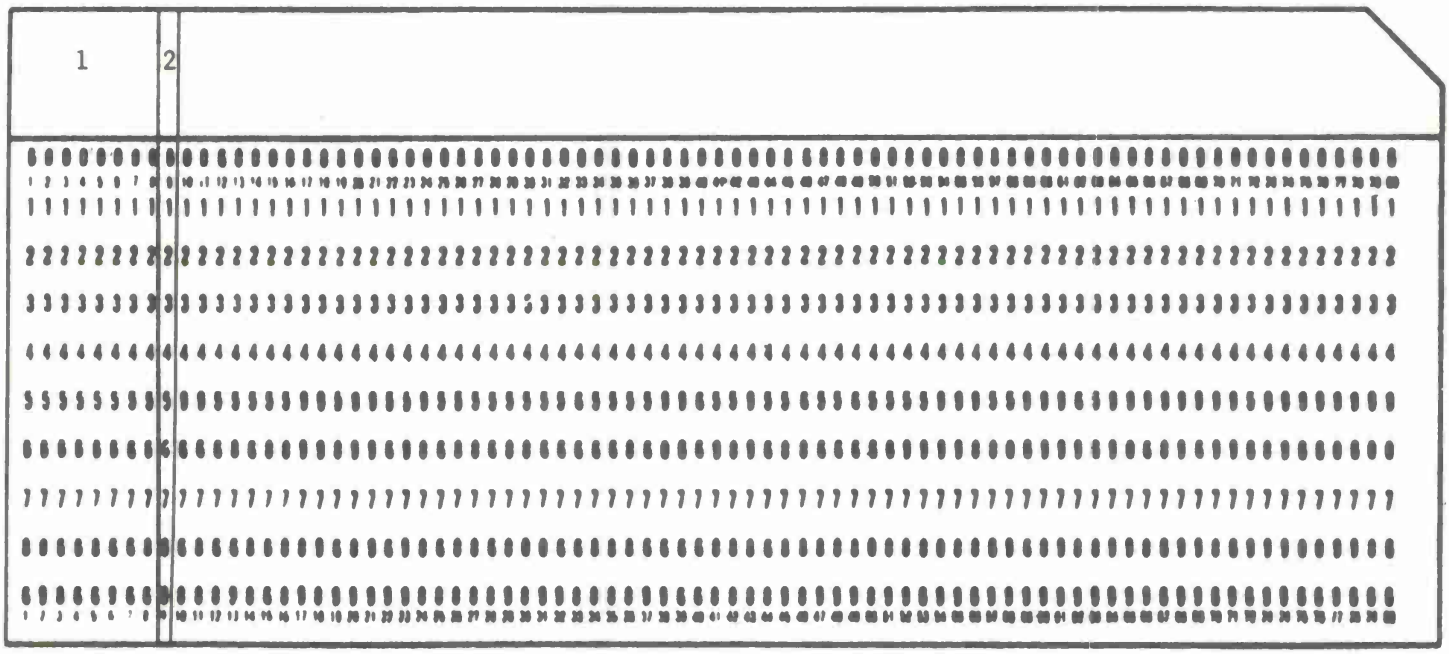
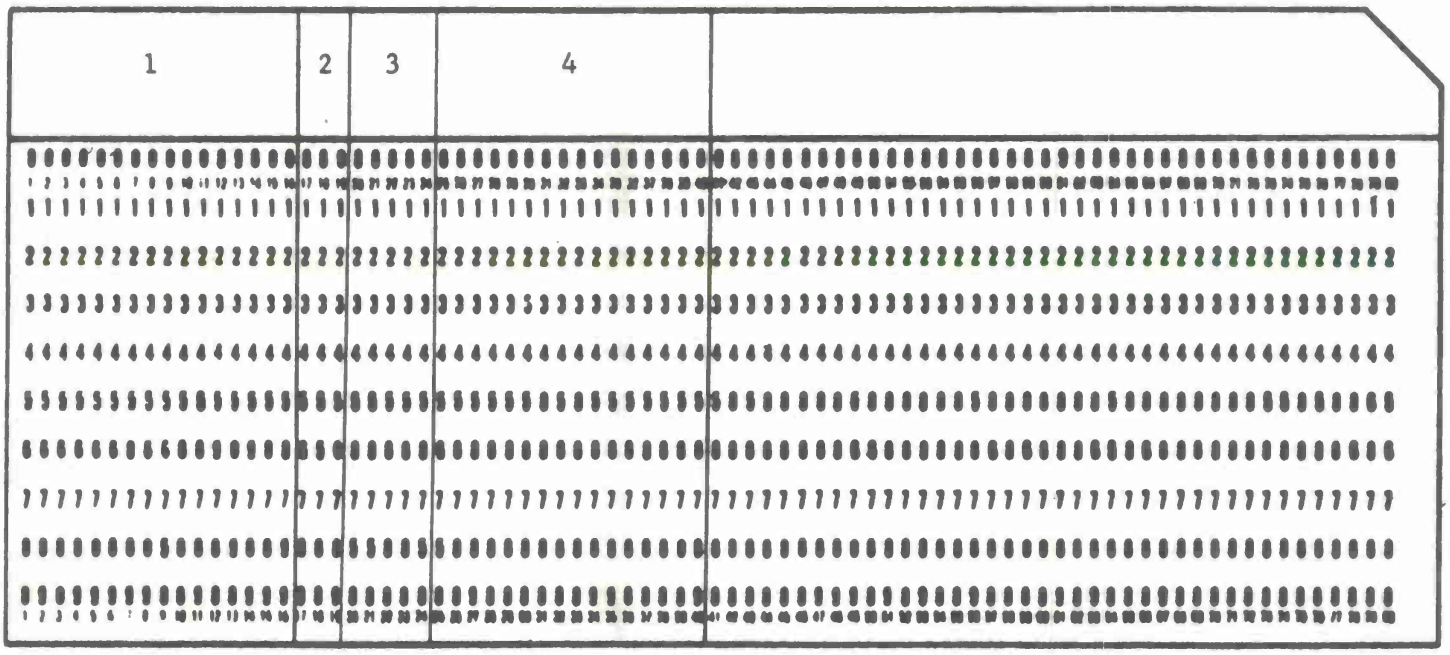


FIGURE 3. SPIRDECA INPUT DECK FOR COMBINED DC AND PREDICTION



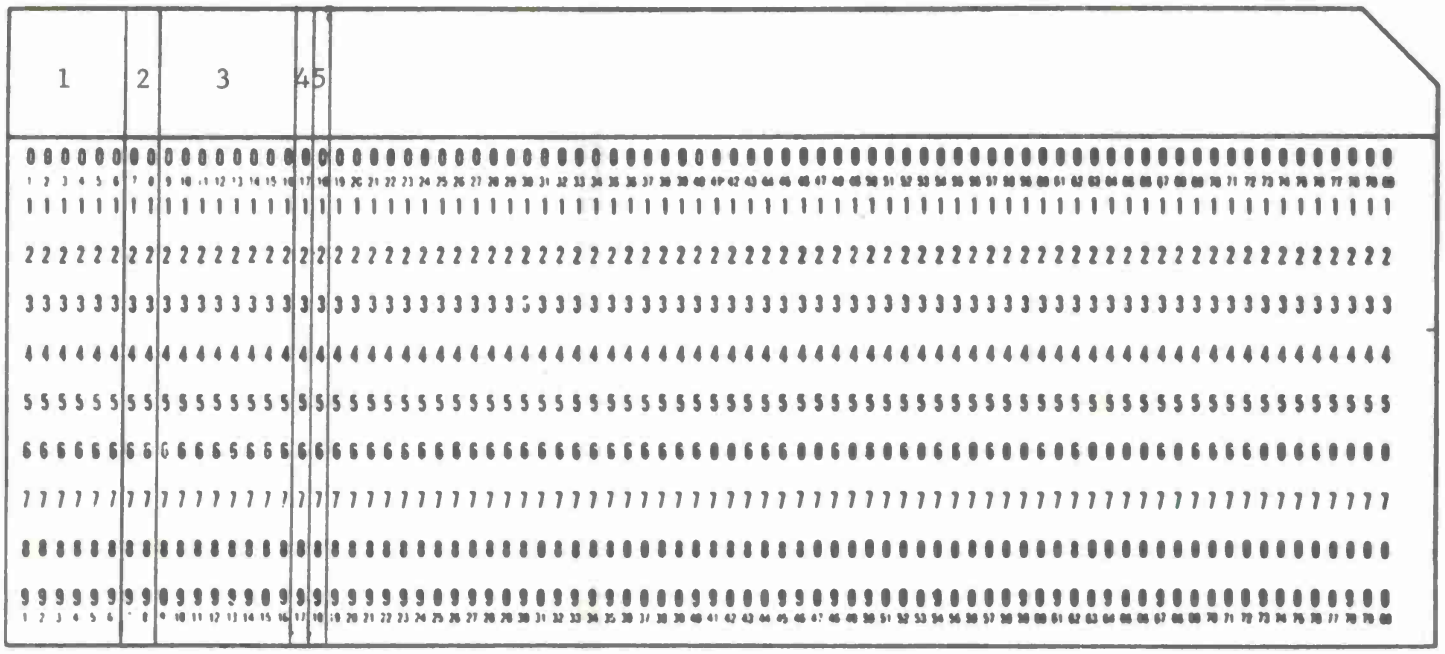
Field	Column	Contents
1	1-8	70 SCHTP
2	9	(11-8-2) Multiple punch

FIGURE 4. SCHEDULE TAPE CARD



Field	Column	Contents
1	1-16	Not Used
2	17-19	JOB
3	20-24	Not Used
4	25-40	Job ID

FIGURE 5. JOB CARD



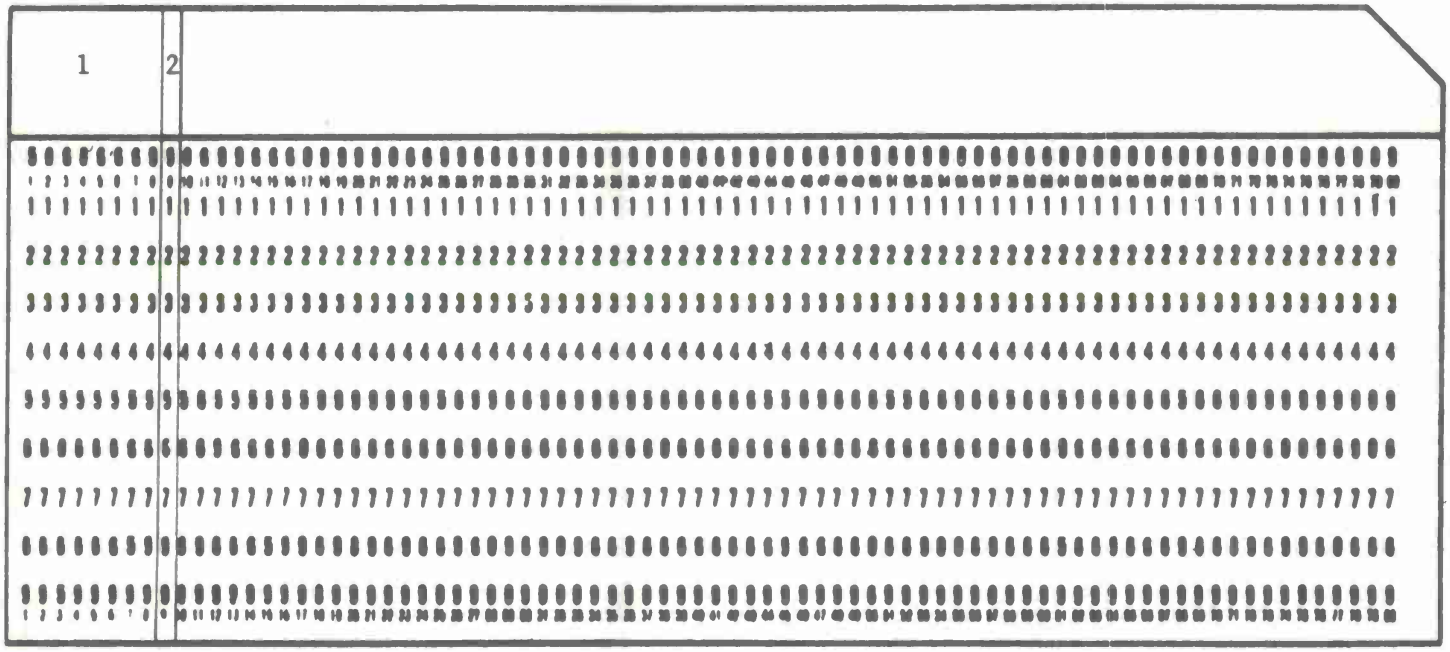
Field	Column	Contents
1	1-6	SPSJOB
2	7-8	Not Used
3	9-16	SPIRDECA
4	17	Input Option (See below)
5	18	Output Option (=0 if $\leq$ 492 observations, =1 if $>$ 492 obs. and $\leq$ 984 obs.)

Input Options

Option	Sensor Cards	Element Cards	Observation Cards	Parameter Cards
0	D	D	D	D
1	T	D	D	D
2	D	0	D	D
3	T	0	D	D
4	0	D	0	D
5	0	0	0	D

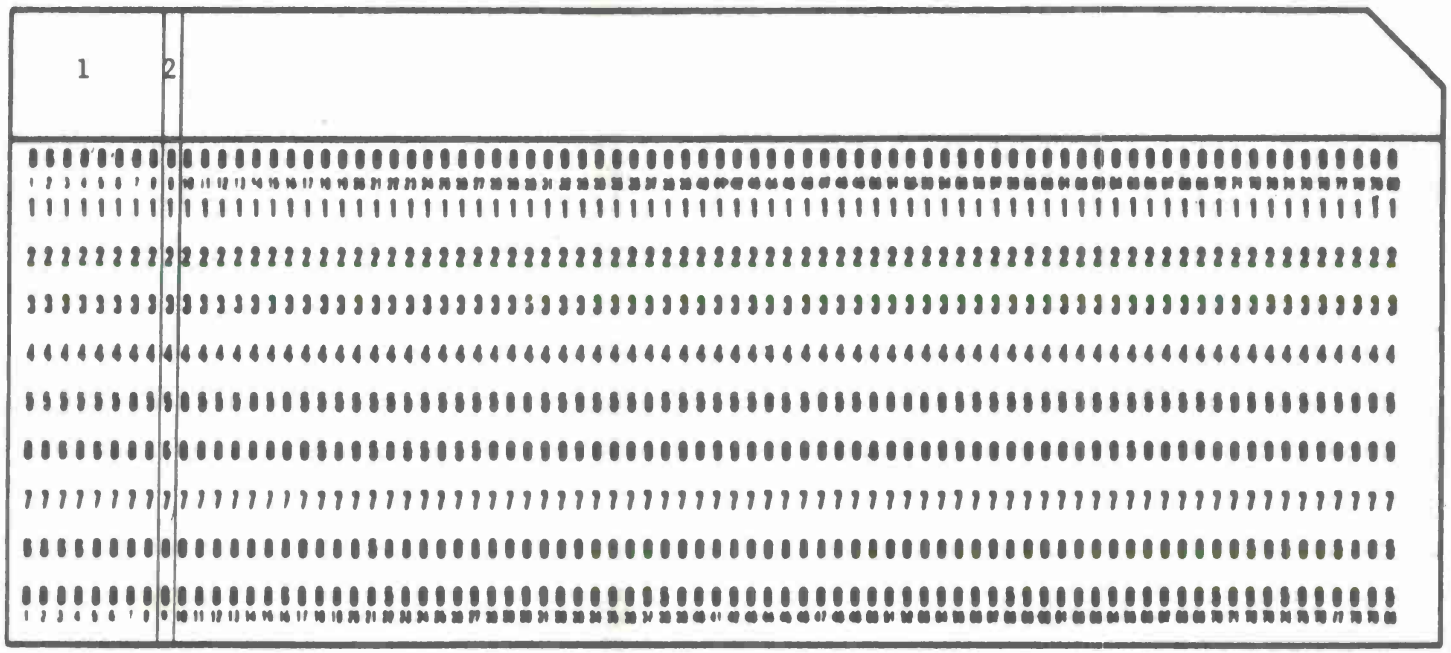
where: D means cards are in the input deck
0 means cards are not in the input deck
T means data should be taken from the SEAI tape.

FIGURE 6. SPSJOB CARD



Field	Column	Contents
1	1-8	ENDOFJOB
2	9	(11-8-2) Multiple punch

FIGURE 7. END JOB CARD



Field	Column	Contents
1	1-8	ENDSCHED
2	9	(11-8-2) Multiple punch

Note: This card must be followed by a blank card.

FIGURE 8. END SCHEDULE TAPE CARD

2.2 PARAMETER CARDS

Card formats for the input parameter cards are included in Figures 9-18.

a. P Cards 1 and 2

Elements may be input in two formats ($\underline{r}$, $\underline{\dot{r}}$ or L, $\underline{a}$, $\underline{h}$) on P cards 1 and 2. When this is done, a 6 card element set is not required as input.

b. P Card 3

The information necessary to control the differential correction is on P card 3

c. P Card 4

The control information to run a prediction is on P card 4.

d. P Card 5

This is on optional card which contains error criteria for the Adams-Bashforth integration. It should be used only to override the assembled values, which are currently 10^{-8}, for each element.

e. P Card 6

P card 6 is an optional card and contains the zonal harmonic terms to be used in the bulge perturbations. It is necessary only when one wants to change the assembled values, which are:

J_2 = 1082.50 x 10-6

J_3 = -2.553 x 10-6

J_4 = -1.807 x 10-6

J_5 = -8.3 x 10-8

f. P Cards 7 and 8

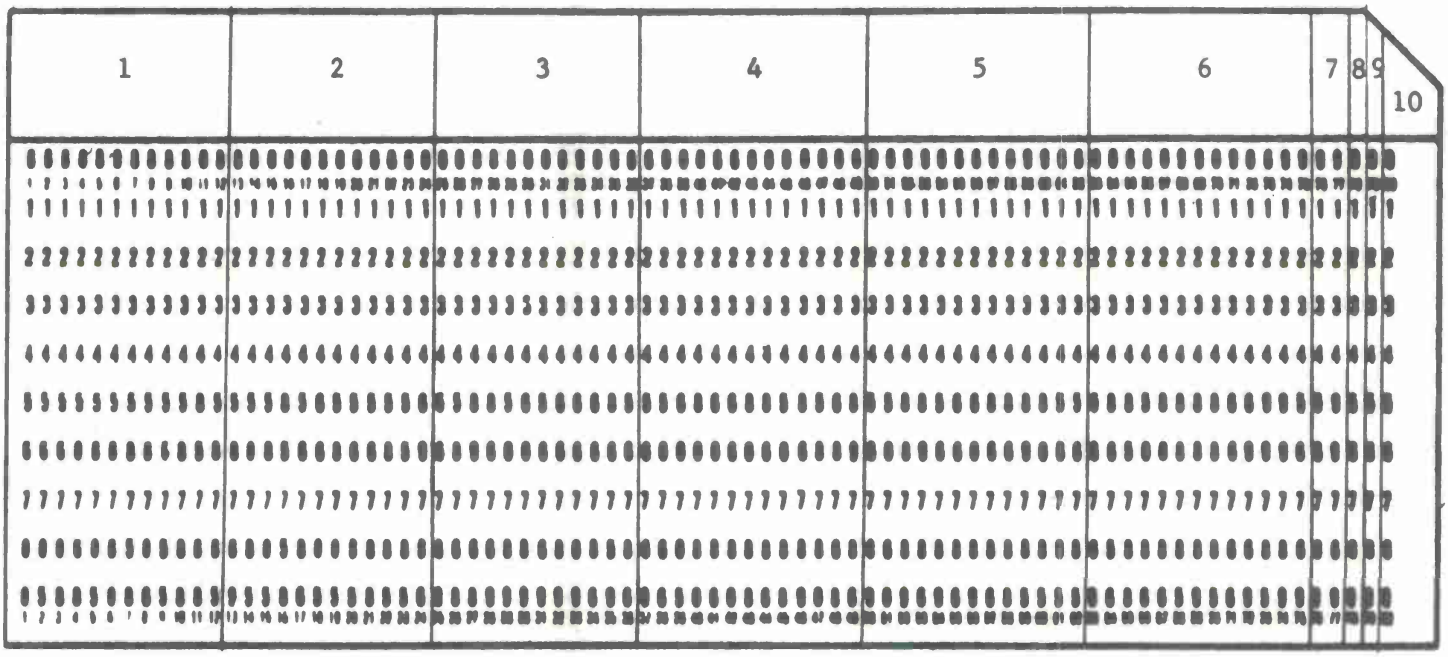
If tesseral harmonics are needed in the bulge perturbations, the coefficients (S_{nm} and C_{nm}) must be entered on P cards 7 and 8. Both cards must be in the input deck, if this option is used, even if all the fields are not filled in.

g. P Card 9

This optional card controls the printed output of the prediction ephemeris. Only the intervals specified will be printed.

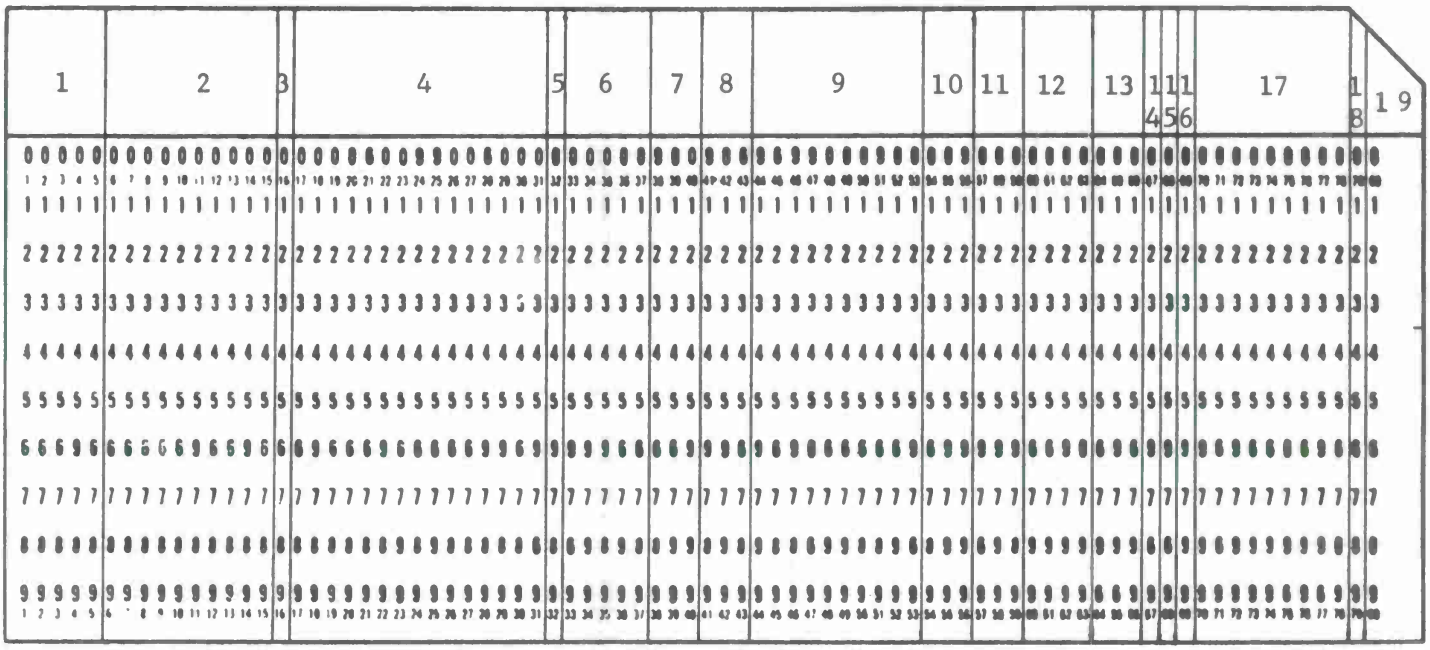
h. P Card 10

This optional control card is necessary only when GIPAR will be run immediately after SPIRDECA. The times specified will be given to GIPAR and also printed if the print option is set.



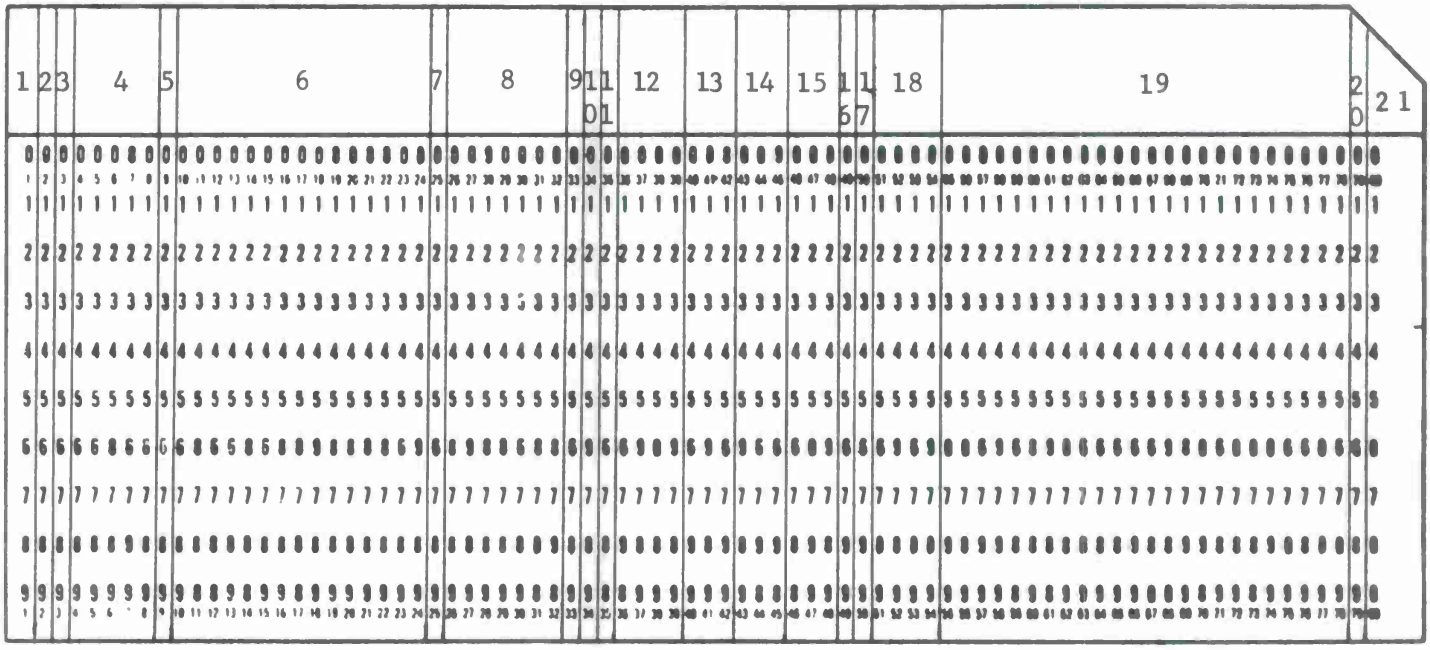
Field	Column	Contents	
1	1-12	L_o (deg)	x (km)
2	13-24	a_{xno}	y (km)
3	25-36	a_{yno}	z (km)
4	37-49	h_{xo} $(er)^{\frac{1}{2}}$	$\dot{x}$ (m/sec)
5	50-62	h_{yo} $(er)^{\frac{1}{2}}$	$\dot{y}$ (m/sec)
6	63-75	h_{zo} $(er)^{\frac{1}{2}}$	$\dot{z}$ (m/sec)
7	76-77	Not Used	
8	78	Element Type = A $(L,\underline{a},\underline{h})$ or = B $(\underline{r},\underline{\dot{r}})$	
9	79	Card Number = 1	
10	80	Card Type = P	

FIGURE 9. ELEMENT CARD 1
(P CARD 1)



Field	Column	Contents
1	1-5	Satellite Number
2	6-15	Satellite Name
3	16	Not Used
4	17-31	Epoch (YYDDDHHMMSS.SSS)
5	32	Not Used
6	33-37	Revolution Number
7	38-40	Element Set Number
8	41-43	Kappa - Upper bound for factor modifying B
9	44-53	$B = C_D A/m$ (m^2/kg)
10	54-56	F_{10} = Solar flux for epoch day at 10.7 cm
11	57-59	F_{10} = Average solar flux for 3 months at 10.7 cm
12	60-63	A_p = Planetary magnetic index (0 illegal)
13	64-66	γ = Reflectivity for radiation pressure
14	67	Bulge perturbation flag (0 = No, 1 = Yes)
15	68	Drag perturbation flag (0 = No, 1 = Yes)
16	69	Radiation pressure flag (0 = No, 1 = Yes)
17	70-78	Not Used
18-19	79-80	"2P"

FIGURE 10. ELEMENT CARD 2
(P CARD 2)

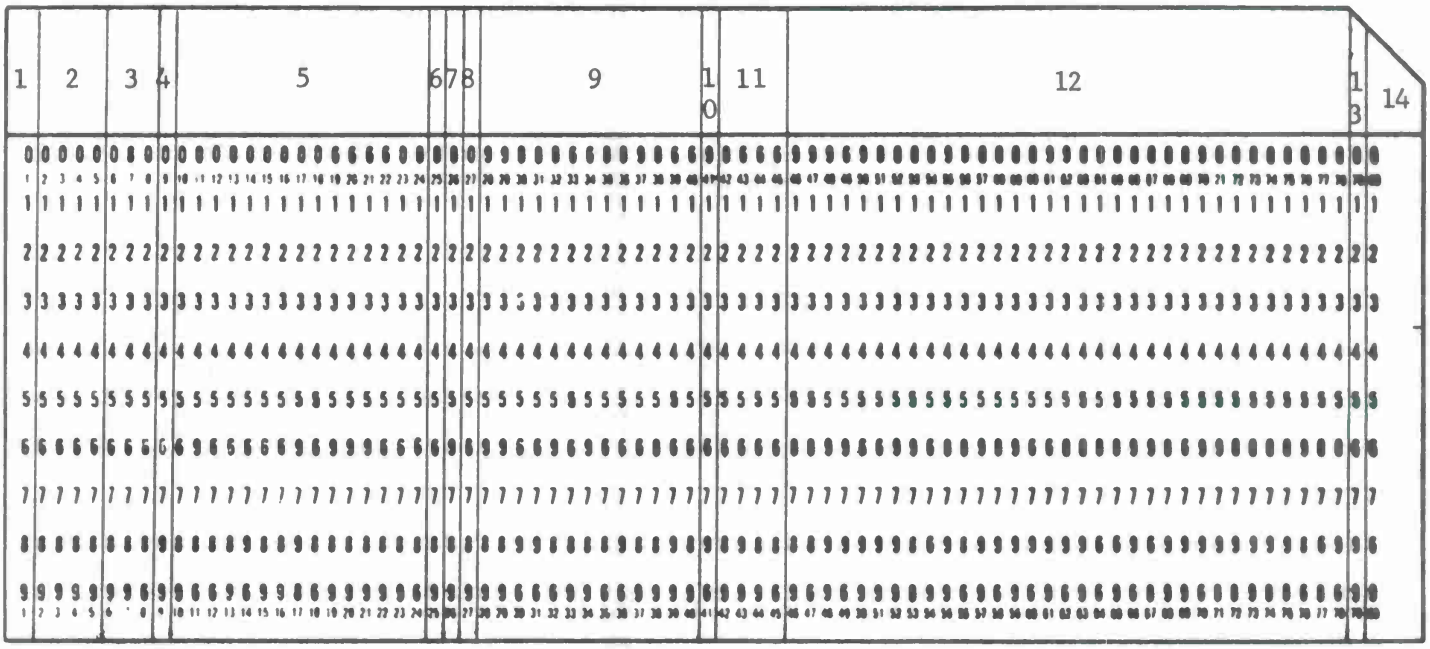


Field	Column	Contents
1	1	Print input obs. (0 = No, 1 = Yes)
2	2	Weight flag (0 = Use assembled weights, 1 = Read from tape)
3	3	Print weights and biases (0 = No, 1 = Yes)
4	4-8	Not Used
5	9	New Epoch mode (0 = by Time, 1 = by Rev., 2 = Time of last obs.)
6	10-24	New Epoch time (YYDDDHHMMSS.SSS) or Rev. No. (NNNNN)
7	25	Not Used
8	26-32	Elements to correct (n, a_{xn}, a_{yn}, U_o, Ω, i, B)
9	33	Max. number of differential corrections
10	34	Correct n only on 1st pass (0 = No, 1 = Yes)
11	35	Δq check (0 = No, 1 = Yes)
12	36-39	Maximum Δq (km)
13	40-42	1st pass rejection (km) for range, azimuth, elevation
14	43-45	1st pass rejection (km/sec) for range rate
15	46-48	RMS multiplier (Recommended value: 4)

FIGURE 11. DIFFERENTIAL CORRECTION CONTROL CARD
(P CARD 3)

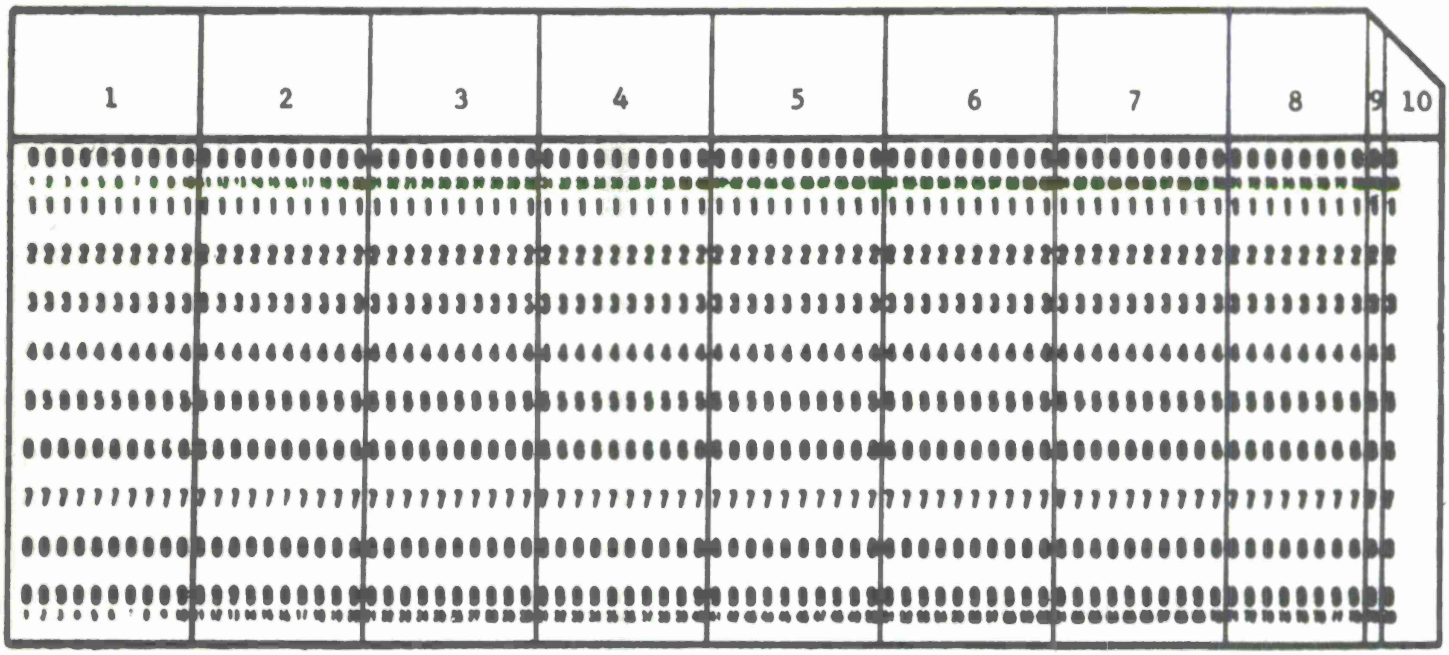
Field	Column	Contents
16	49	Residual output (0 = none, 1 = 1st and last pass, 2 = every time)
17	50	Print angle residuals in (0 = deg, 1 = km)
18	51-54	Convergence criterion (.xxx or 1E-x)
19	55-78	Not Used
20	79	Card Number = 3
21	80	Card Type = P

FIGURE 11. DIFFERENTIAL CORRECTION CONTROL CARD (continued)
(P CARD 3)



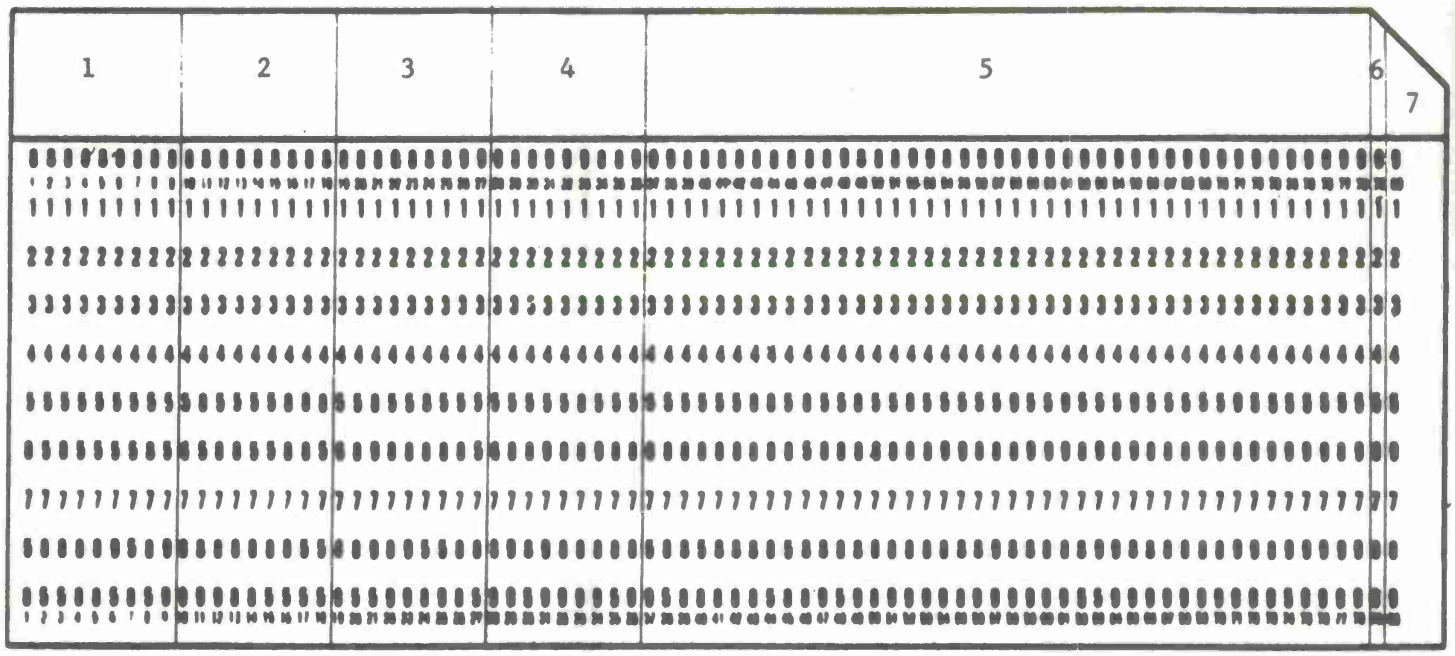
Field	Column	Contents
1	1	Not Used
2	2-5	Δt (min) - Print interval
3	6-8	Not Used
4	9	Final prediction time flag (0 = by Time, 1 = by Rev)
5	10-24	Time (YYDDDMMSS.SSS) or Rev. (NNNNN)
6	25	Not Used
7	26	Not Used
8	27	Prediction output flag (0 = none, 1 = t, $\underline{r}$, $\underline{r}$; 2 = t, ϕ, λ, h; 3 = both)
9	28-40	Not Used
10	41	Binary tape output flag (Ephemeris tape) 0 = No, 1 = Yes)
11	42-45	Δt (min) for Ephemeris tape
12	46-78	Not Used
13	79	Card Number = 4
14	80	Card Type = P

FIGURE 12. PREDICTION CONTROL CARD
(P CARD 4)



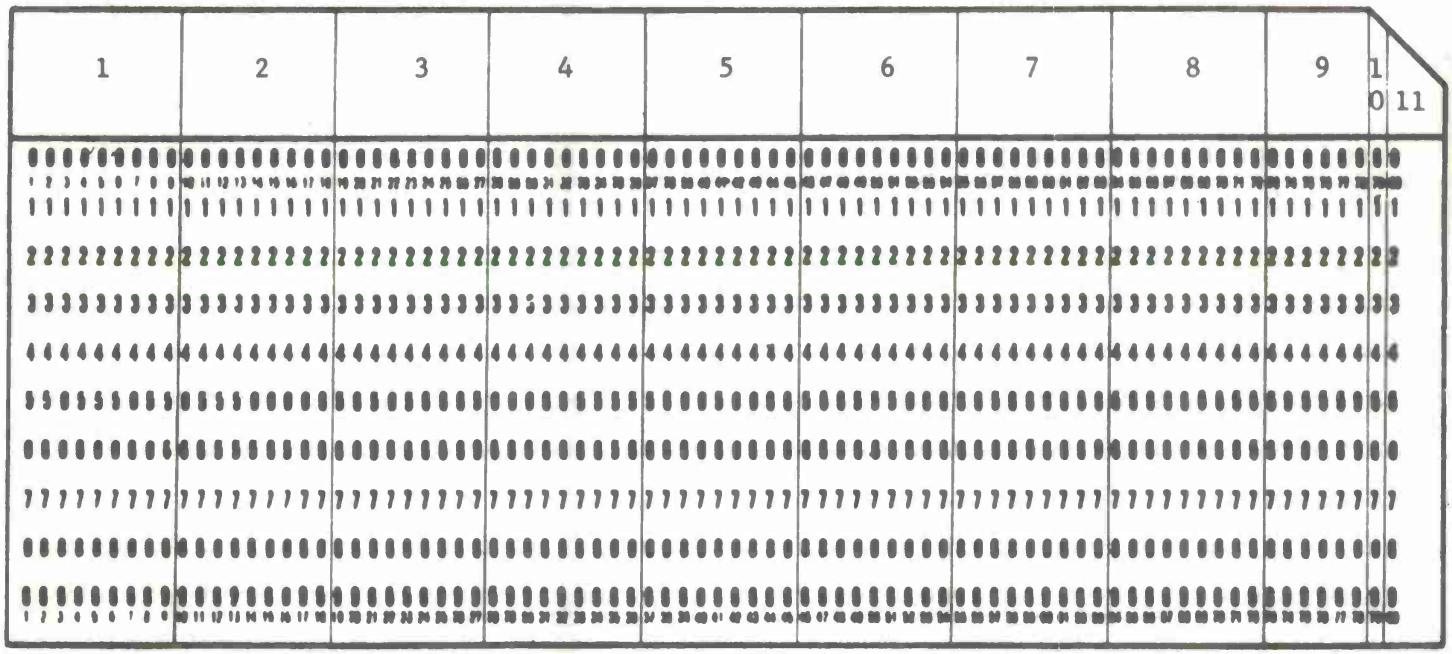
Field	Column	Contents
1	1-10	a_L
2	11-20	a_{ax}
3	21-30	a_{ay}
4	31-40	a_{az}
5	41-50	a_{hx}
6	51-60	a_{hy}
7	61-70	a_{hz}
8	71-78	Not Used
9	79	Card Number = 5
10	80	Card Type = P

FIGURE 13. ERROR CRITERIA CARD
(P CARD 5)



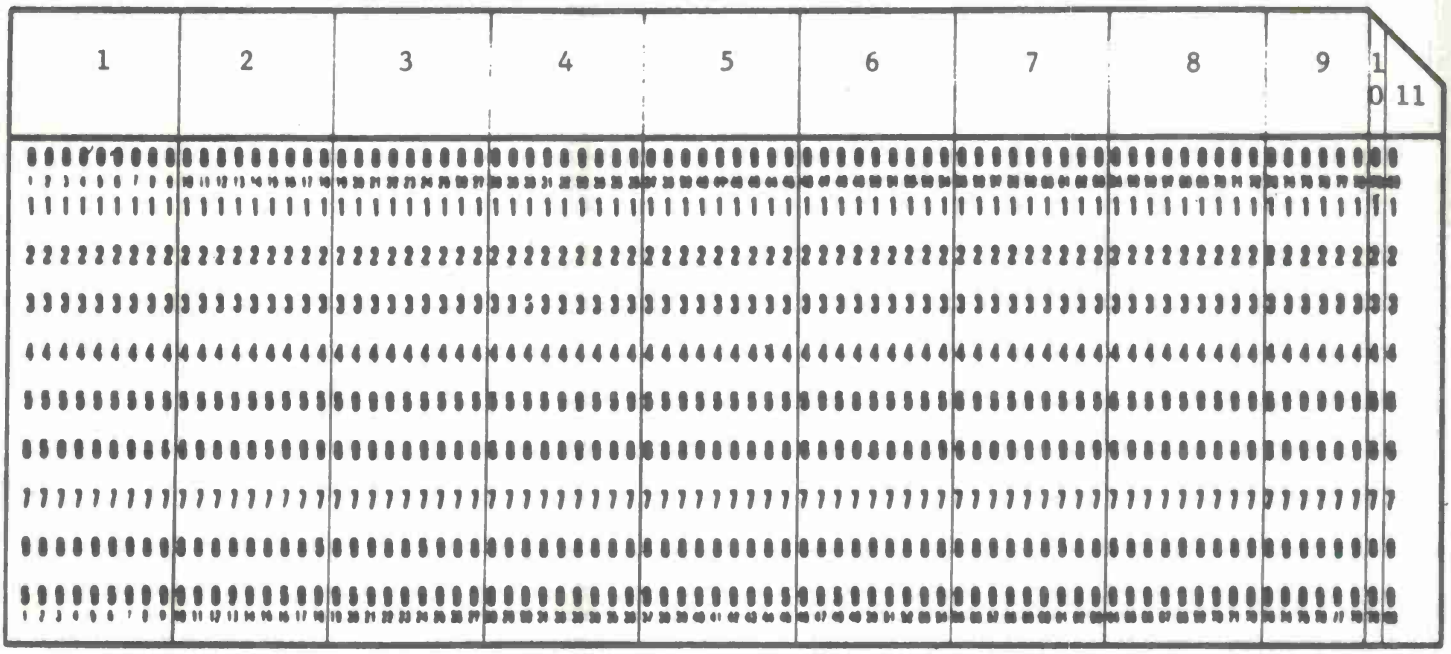
Field	Column	Contents
1	1-9	J_2
2	10-18	J_3
3	19-27	J_4
4	28-36	J_5
5	37-78	Not used
6	79	Card Number = 6
7	80	Card Type = P

FIGURE 14. ZONAL COEFFICIENT CARD
(P CARD 6)



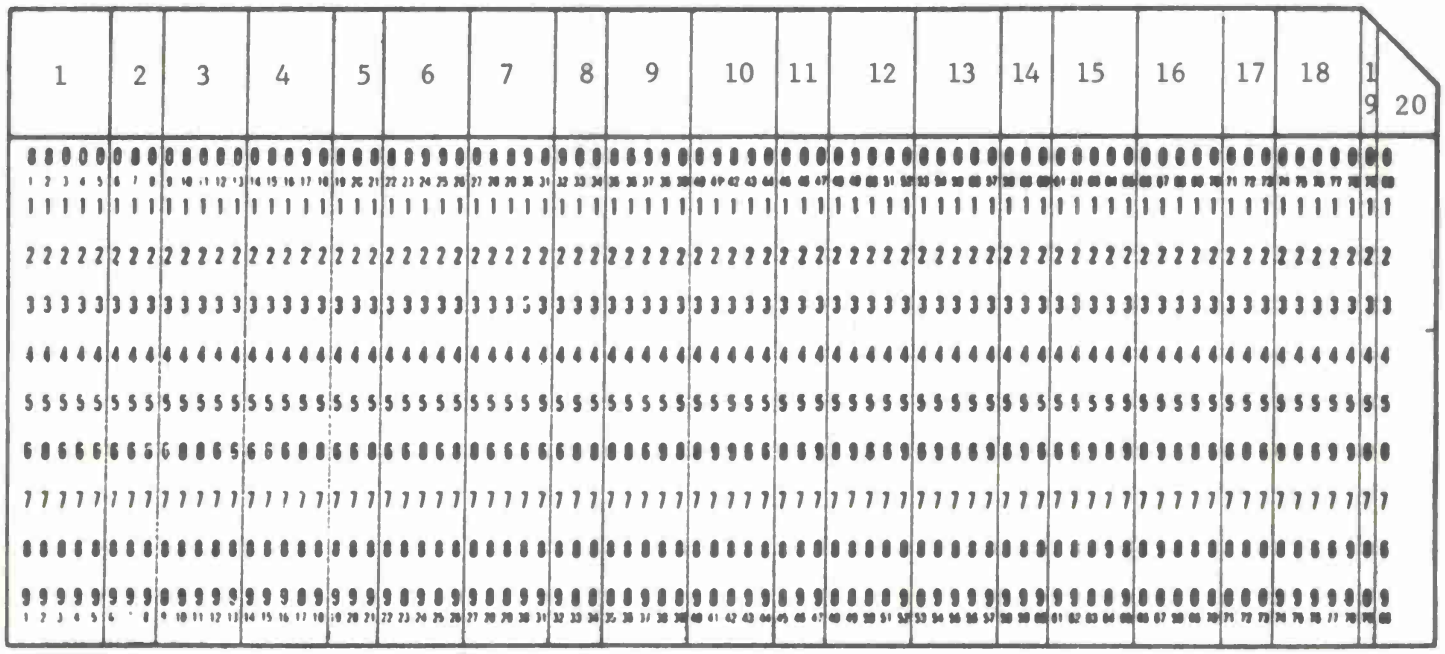
Field	Column	Contents
1	1-9	C_{22}
2	10-18	S_{22}
3	19-27	C_{31}
4	28-36	S_{31}
5	37-45	C_{32}
6	46-54	S_{32}
7	55-63	C_{33}
8	64-72	S_{33}
9	73-78	Not used
10	79	Card number = 7
11	80	Card type = P

FIGURE 15. TESSERAL COEFFICIENT CARD (1 of 2)
(P CARD 7)



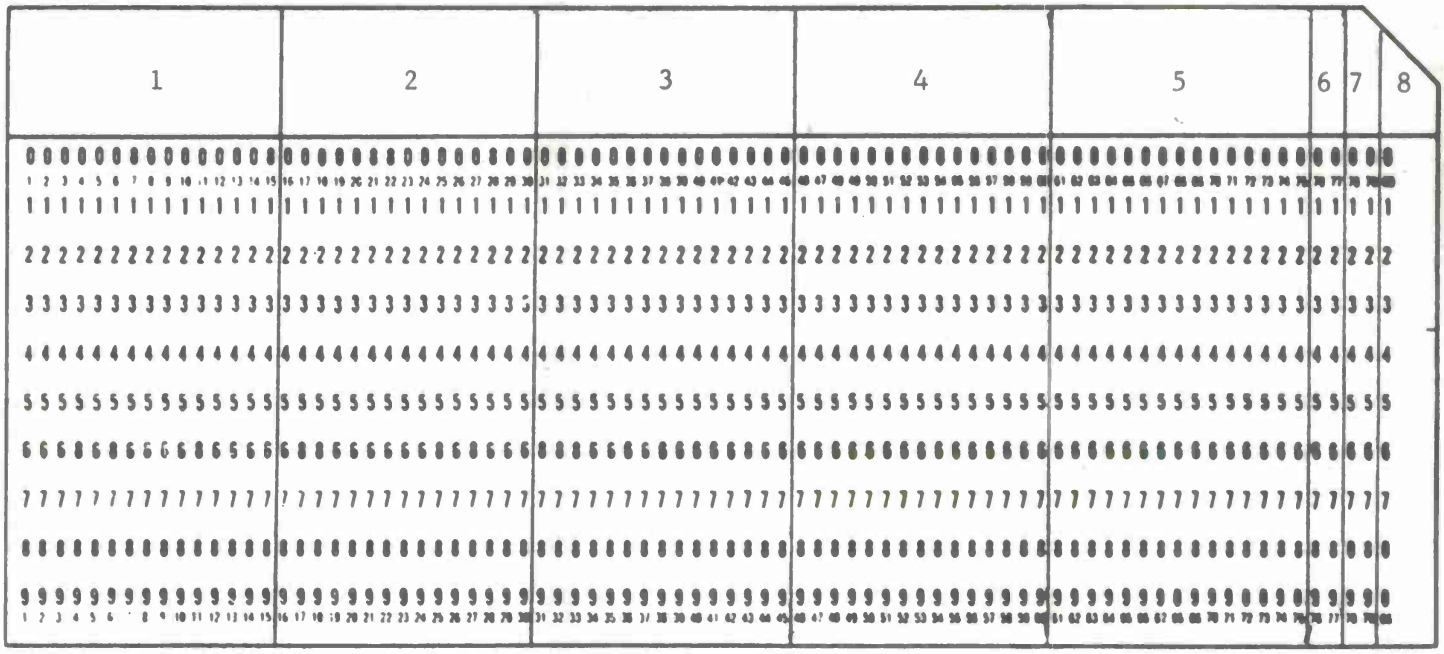
Field	Column	Contents
1	1-9	C_{41}
2	10-18	S_{41}
3	19-27	C_{42}
4	28-36	S_{42}
5	37=45	C_{43}
6	46-54	S_{43}
7	55-63	C_{44}
8	64-72	S_{44}
9	73=78	Not used
10	79	Card Number = 8
11	80	Card Type = P

FIGURE 16. TESSERAL COEFFICIENT CARD (2 of 2)
(P CARD 8)



Field	Column	Contents
1	1-5	t_i - Start output (minutes since epoch)
2	6-8	Δt - Output interval (minutes)
3	9-13	t_f - Stop output (minutes since epoch)
4	14-18	t_i - Start output
5	19-21	Δt - Output interval
6	22-26	t_f - Stop output
7	27-31	t_i - Start output
8	32-34	Δt - Output interval
9	35-39	t_f - Stop output
10	40-44	t_i - Start output
11	45-47	Δt - Output interval
12	48-52	t_f - Stop output
13	53-57	t_i - Start output
14	58-60	Δt - Output interval
15	61-65	t_f - Stop output
16	66-70	t_i - Start output
17	71-73	Δt - Output interval
18	74-78	t_f - Stop output
19	79	Card Number = 9
20	80	Card Type = P

FIGURE 17. PREDICTION INTERVAL CONTROL
(P CARD 9)



Field	Column	Contents
1	1-15	YMMDDHHMMSS.SSS
2	16-30	YMMDDHHMMSS.SSS
3	31-45	YMMDDHHMMSS.SSS
4	46-60	YMMDDHHMMSS.SSS
5	61-75	YMMDDHHMMSS.SSS
6	76-77	Not used
7	78-79	Card Number = 10
8	80	Card Type = P

Note: These dates must be in time order and the times must be between the start prediction time (on the element set or P card 2) and the final prediction time (on P card 4). Any times outside this range will be omitted.

FIGURE 18. GIPAR CONTROL CARD
(P CARD 10)

2.3 AUXILIARY WEIGHT TAPE

To change or add station weights or biases in the SPIRDECA program, an auxiliary input tape must be mounted on logical tape unit 7. The deck setup for this tape is shown in Figure 19. The first card is an identifying header and the last card an end card (see Figure 20). Between these cards are the bias-weight input cards (Figure 21).

This input tape is required only when new weights or biases are desired. Storage in the program is limited to 30 sensors. Therefore, the number of distinct sensors appearing in the assembled program plus those on the auxiliary weight tape must not exceed 30. The data on the cards override those in the assembled program. When the auxiliary input tape is to be used, column 2 on P card 3 must have a one-punch (1) to inform the program of the existence of the weight tape.

(TO BE USED AS INPUT ON LOGICAL TAPE 7)

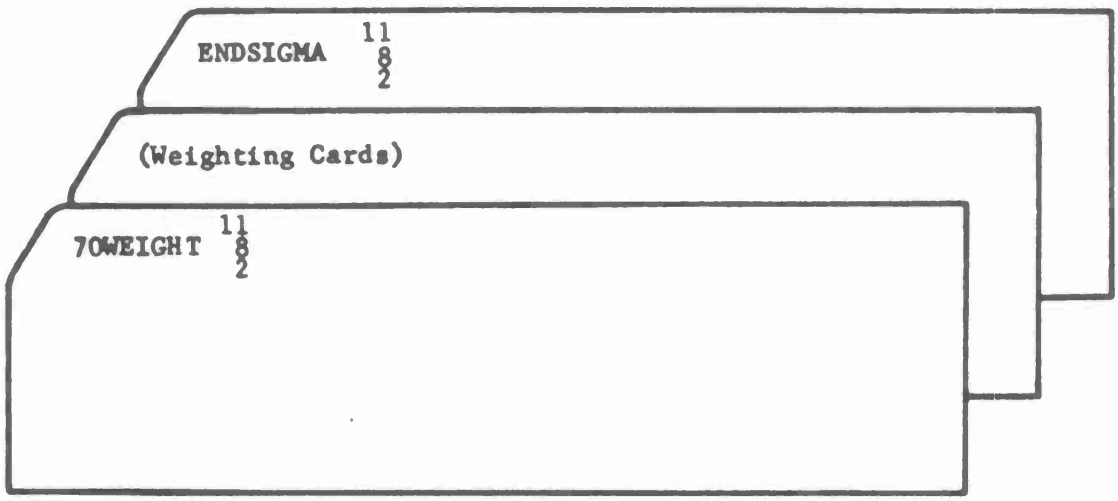
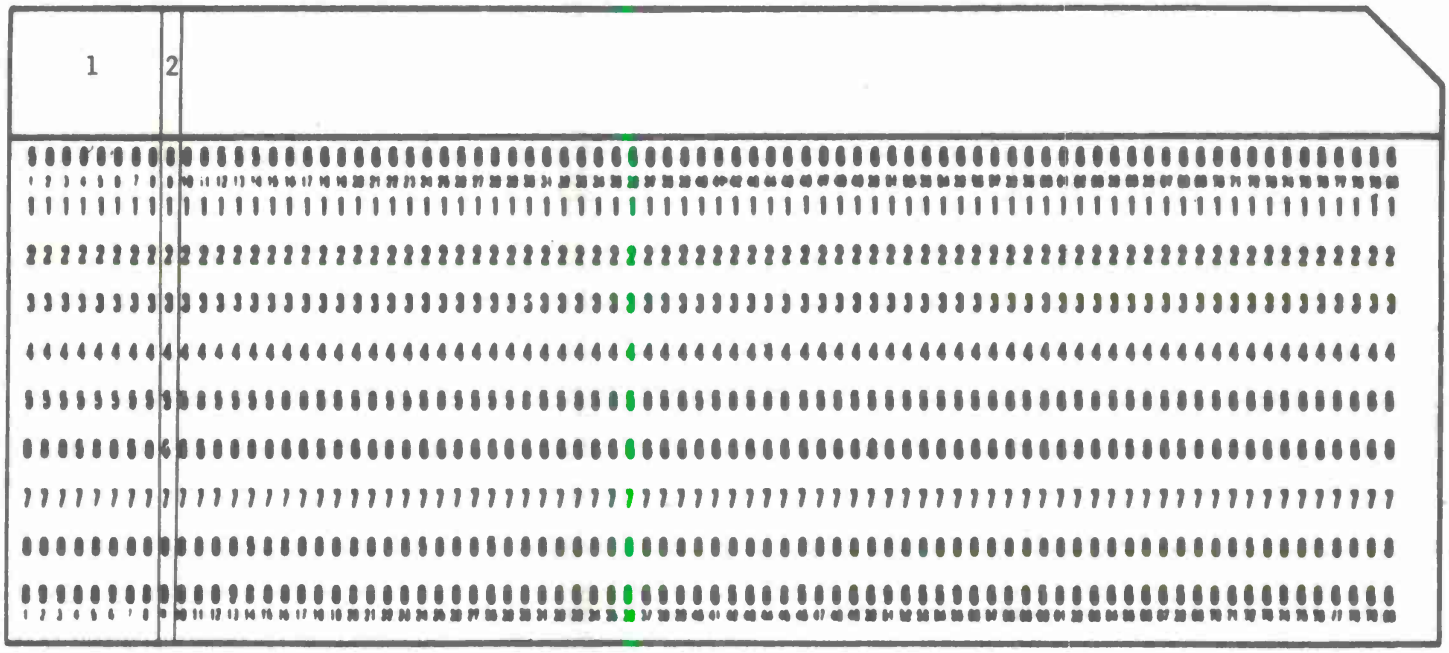
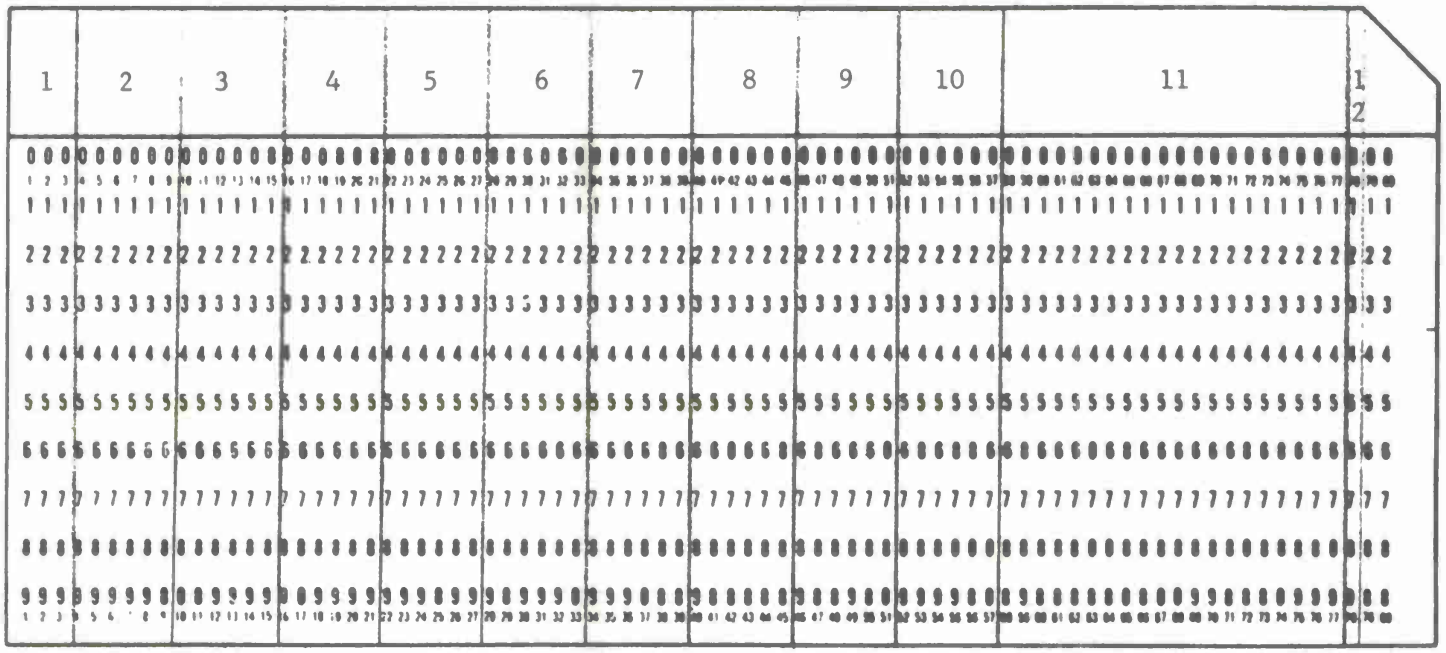


FIGURE 19. INPUT DECK SETUP TO USE WEIGHTS OR BIASES IN OBSWGT



Field	Column	Contents
1	1-8	If ID CARD - 70WEIGHT If END CONTROL CARD - ENDSIGMA
2	9	(11-8-2) Multiple Punch

FIGURE 20. WEIGHT TAPE CONTROL CARD



Field	Column	Contents
1	1-3	Station number
2	4-9	σ_R km
3	10-15	σ_A deg
4	16-21	σ_E deg
5	22-27	σ_R km/sec
6	28-33	B_R km
7	34-39	B_A deg
8	40-45	B_E deg
9	46-51	B_R km/sec
10	52-57	B_T sec
11	58-77	Not Used
12	78	Use VERLORT/PRELORT correction factors (0 = No, 1 = Yes)

Note: A maximum of 30 sensors may be used with the B-3 master.

FIGURE 21. BIAS - WEIGHT CARD (EDITOR AND B-3 MASTER)

SECTION 3

CALIB OPERATING INSTRUCTIONS

The B-3 version of the Sensor Calibration Program (CALIBA) has been modified to eliminate OBSWGTA and the OBSWGTA control card; and to accept 984, rather than 400, observations.

3.1 INPUT/OUTPUT INSTRUCTIONS

a. Input Deck Setup

The CALIBA program requires four parameter cards in the standard SCHED tape job deck.

P Cards 1 and 2 introduce input elements and epoch, and are identical to those used in SPIRDECA (Section 2, Figures 9 and 10). P Card 0 format is given in Figure 24; P Card 3 format is given in Figure 25.

The P Card images are automatically printed by the SPIRDECA program to simplify the interface between these programs.

b. Tape Setup

Logical	0	Scratch	WR
	1	B-3 Master	
	2	Input	WR
	4	SEAI	WR
	11	Output Tape	WR

Logical tape 0 is optional and should be used if the number of observations exceeds 492.

c. Output

The program output tape is printed in Data Select 1 for program results and dumps, if taken.

The CALIBA program has no teletype or punched card output.

NOTE: All card formats referenced in this figure may be found in Section 2 with the exception of the SPSJOB Card (Figure 23), P Card 0 (Figure 24), and P Card 3 (Figure 25).

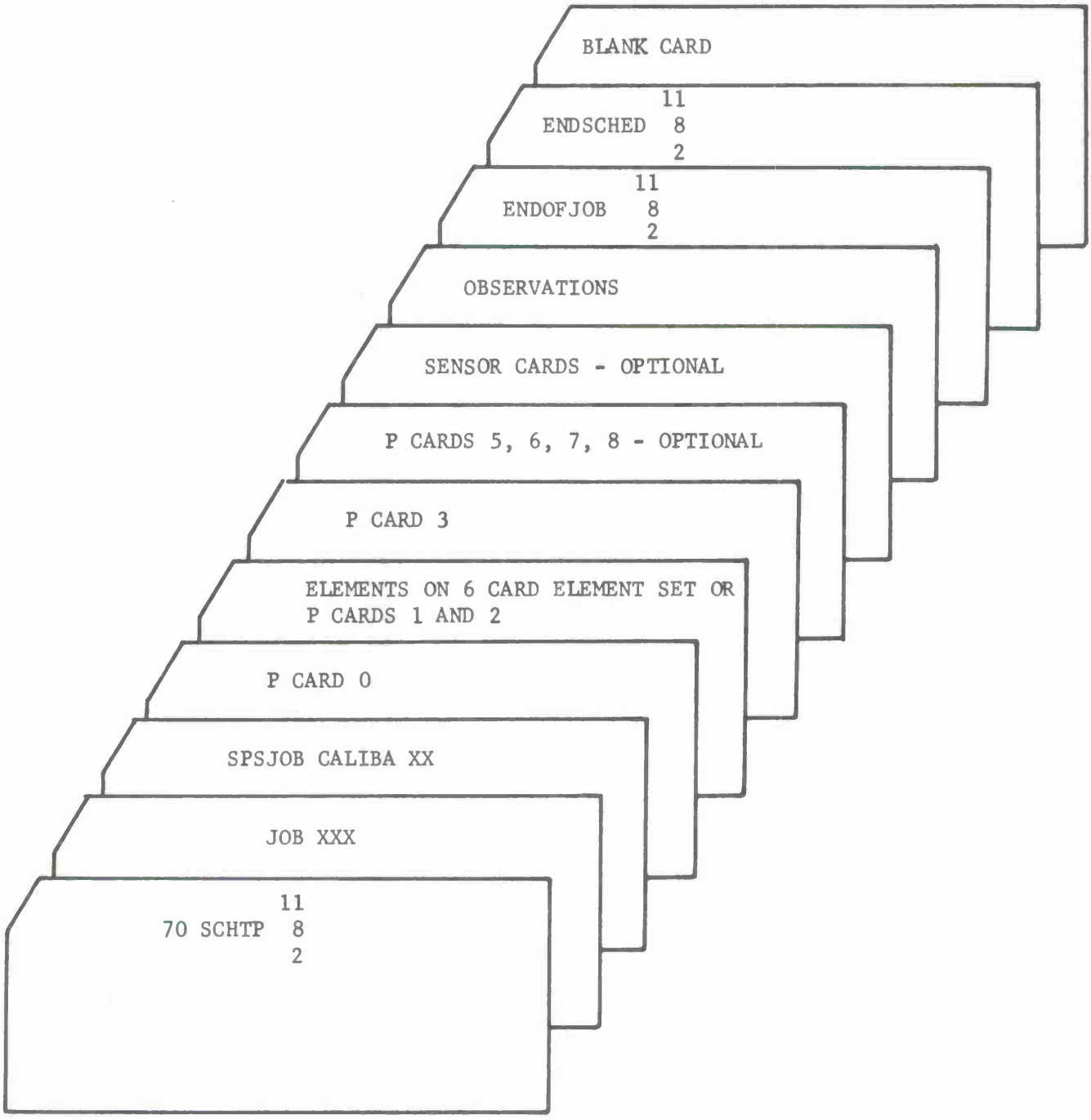
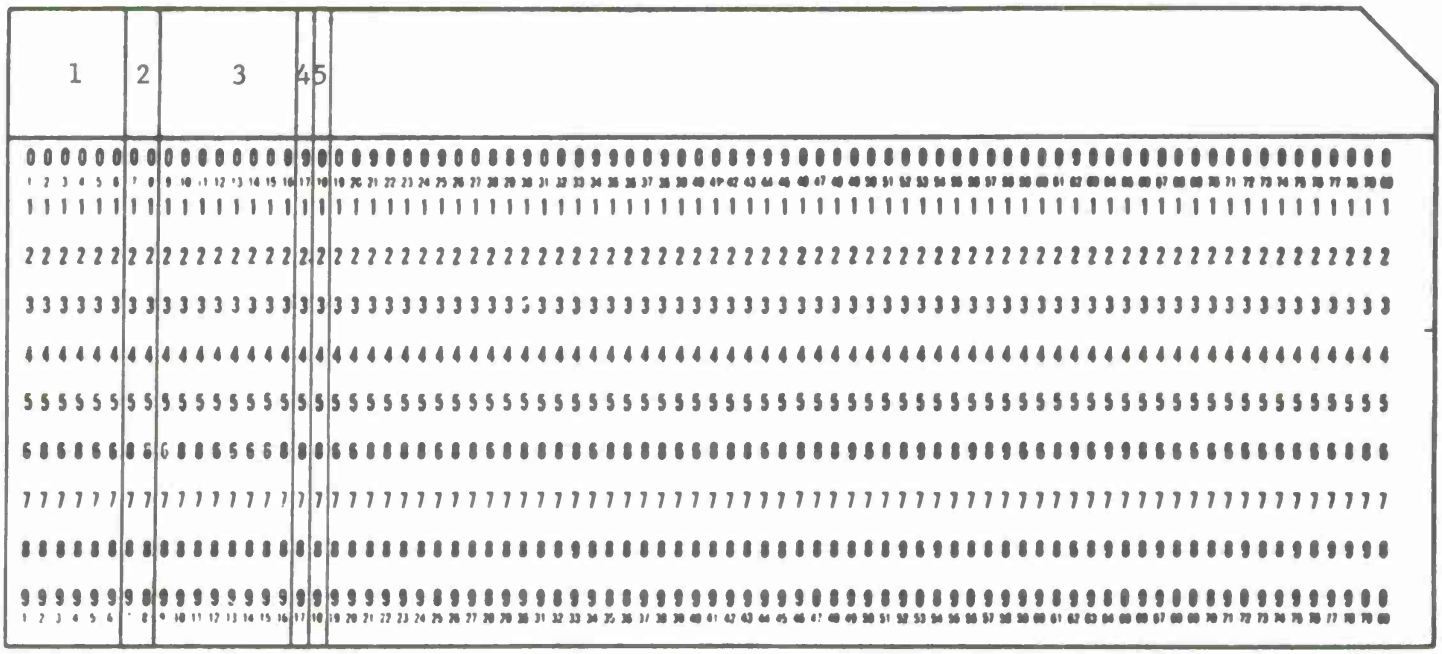


FIGURE 22. CALIBA INPUT DECK SETUP



Field	Column	Contents
1	1-6	SPSJOB
2	7-8	Not Used
3	9-16	CALIBA ΔΔ
4	17	Input Option (See below)
5	18	Output Option (= 0 if ≤ 492 observations = 1 if > 492 observations and ≤ 984 observations)

Input Options

Option	Sensor Cards	Element Cards	Observation Cards	Parameter Cards
0	D	D	D	D
1	T	D	D	D
2	D	0	D	D
3	T	0	D	D
4	0	D	0	D
5	0	0	0	D

Where: D means cards are in the input deck
0 means cards are not in the input deck
T means data should be taken from the SEAI tape

FIGURE 23. SPSJOB CARD

3.2 PARAMETER CARDS

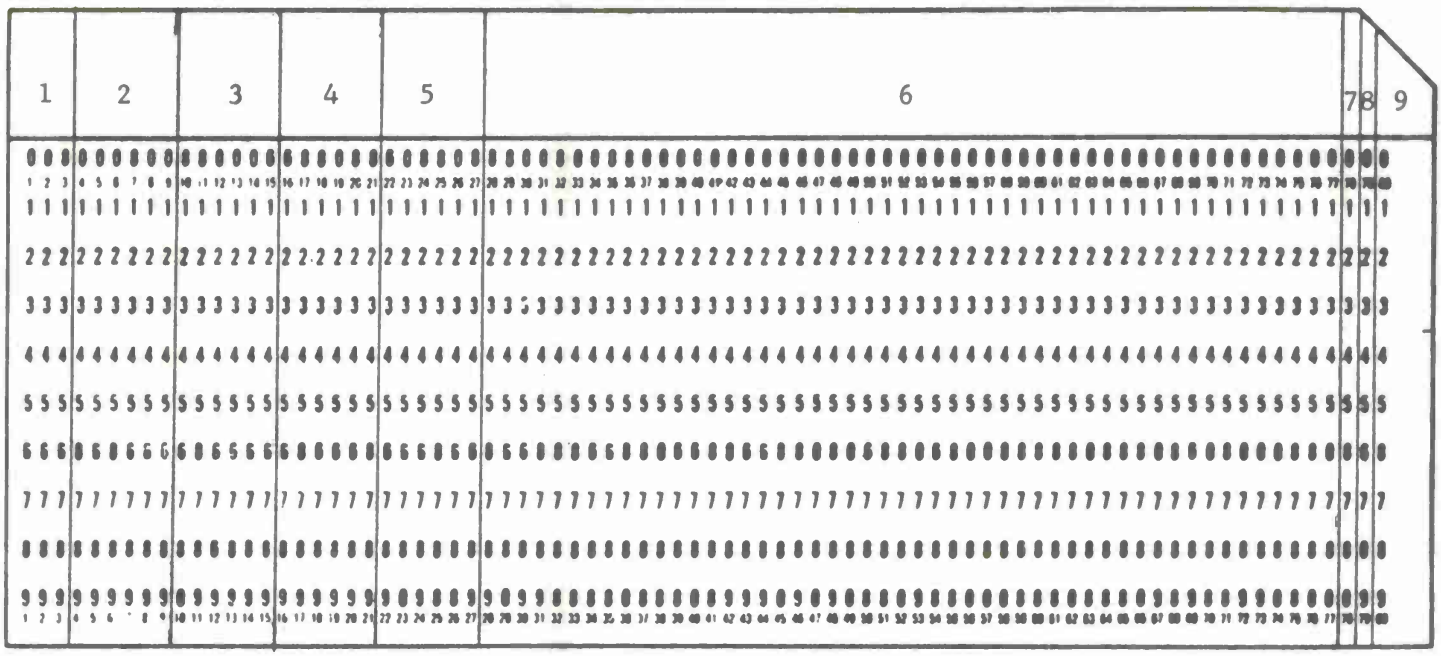
The card formats for the input parameter cards included in this section are:

a. P Card 0

Sensor weight information.

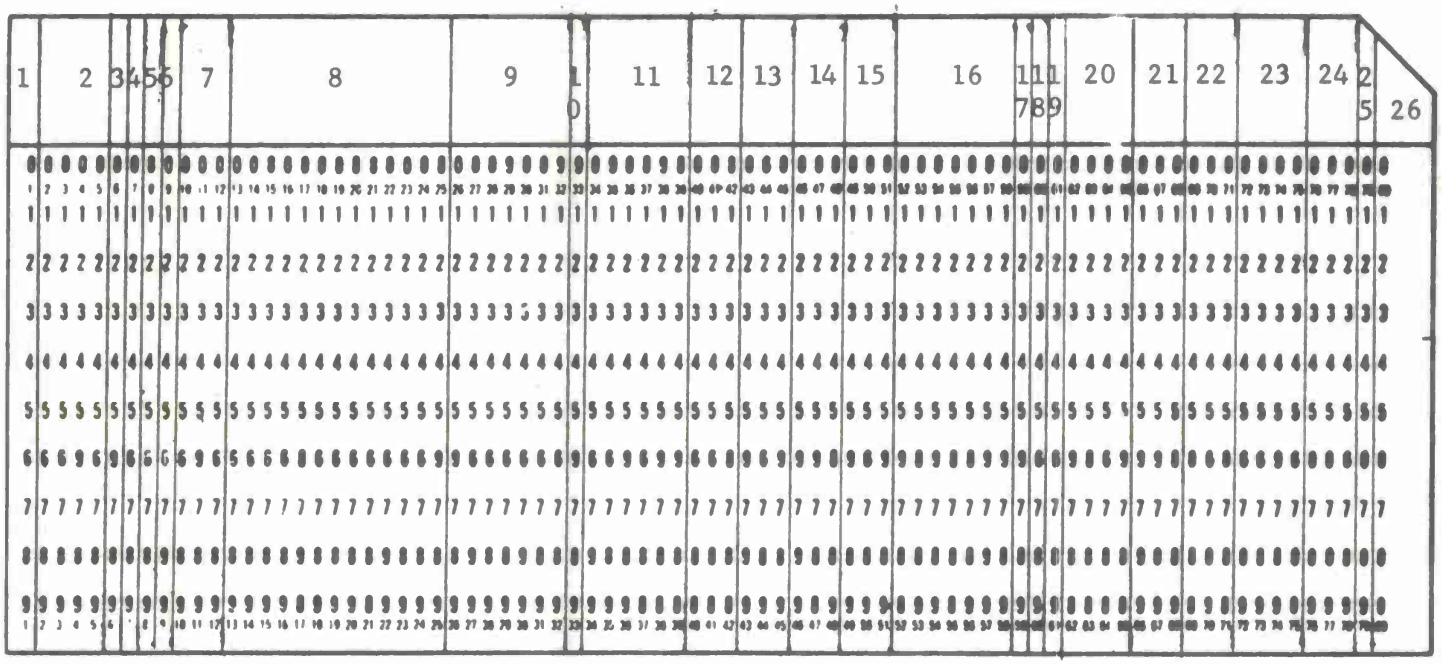
b. P Card 3

Information necessary to control the sensor calibration.



Field	Column	Contents
1	1-3	Station Number
2	4-9	σ_R km.
3	10-15	σ_A deg
4	16-21	σ_E deg
5	22-27	σ_R km/sec
6	28-77	Not Used
7	78	Use correction factors for VERLORT/PRELORT data (0=No, 1=Yes)
8	79	Card Number = 0
9	80	Card Type = P

FIGURE 24 . SENSOR WEIGHT CARD
(P CARD 0)



Field	Column	Contents
1	1	Print Input Observations (0 = No, 1 = Yes)
2	2-5	Not Used
3	6	Bulge Perturbation Flag (0 = No, 1 = Yes)
4	7	Drag Perturbation Flag (0 = No, 1 = Yes)
5	8	Radiation Pressure Flag (0 = No, 1 = Yes)
6	9	Not Used
7	10-12	Sensor Number
8	13-25	Not Used
9	26-32	Elements to Correct(Ω, λ, h_s, L, ρ, A, h)
10	33	Maximum number of differential corrections
11	34-39	Not Used
12	40-42	1st pass rejection (km.) for range, azimuth, elevation
13	43-45	1st pass rejection (km./sec) for range rate
14	46-48	RMS multiplier
15	49-51	Kappa - upper bound for factor modifying B
16	52-58	$B = C_d$ A/m (m^2/kg)
17	59	Residual output [0 = none, 1 = after 1st and last pass; 2 = every time]
18	60	Print angle residuals in deg. (=0), in km (=1)
19	61	Not Used
20	62-65	Convergence criteria (.XXX) or blank

FIGURE 25. CALIBA PROGRAM DIFFERENTIAL CORRECTION CONTROL CARD (P CARD 3)

Field	Column	Contents
21	66-68	F_{10} = Solar flux for epoch day at 10.7 cm.
22	69-71	F_{10} = Average solar flux for 3 months at 10.7 cm.
23	72-75	A_p = Planetary magnetic index (0 = illegal)
24	76-78	α = Reflectivity for radiation pressure
25	79	Card Number = 3
26	80	Card Type = P

FIGURE 25. CALIBA PROGRAM DIFFERENTIAL CORRECTION CONTROL CARD (P CARD 3)

(Continued)

3.3 OBSERVATION DATA

The observation data cards used in the CALIBA program must (1) be from the same sensor, (2) be from the same satellite, and (3) be of the same "observation type".

SECTION 4

SUGGESTED OPERATING PROCEDURES
SPIRAL DECAY PROGRAM

These guidelines for the application of the Spiral Decay Program are based upon several months of program application in the ADC and 496L computation environments. Since an improved SOP will only emerge from continued application and documentation of experience, suggestions for improvement in procedures, documentation or program output should be directed to Aeronutronic personnel at Colorado Springs and at Bedford.

The majority of the guidelines provided herein apply to Spiral Decay exercises with ADC data. Some generalizations to higher altitude satellites and to SCF data (PRELORT/VERLORT) are inferred.

The most frequent source of difficulty in using the Spiral Decay Program involves input card errors. A high degree of flexibility has been built into the program and control of available program options necessitates fairly complicated parameter card formats. The few minutes required of the analyst to recheck the input deck may avoid many false starts on the computer.

4.1 INITIALIZATION

Initialization may be accomplished from P cards 1 and 2, with either L, $\underline{a}$, $\underline{h}$ elements or position and velocity (x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$), or with standard 6-card element sets. Where decay is imminent, say within 10 days, initialization from 6-card elements should be done in two steps, as follows:

(1) With approximately 24 hours of observations and with a 6-card element epoch falling within this 24-hour period, correct n, U_o and B only. For initial estimates of B, use the following:

Payloads	$B = 0.01\ m^2/kgm$
Rocket Bodies	$B = 0.02\ m^2/kgm$

(2) With the final elements provided by SPIRDECA in the form of P cards 1 and 2, rerun the same data package as a 7-element fit. (Be sure to change the input option on SPSJOB card).

An initial three-element fit is necessary, since the estimates on B may be grossly in error. These estimates on B, incidentally, are characteristic of tumbling bodies, for stable objects, lower values are common. B's observed in experimentation range from 0.0034 for object 890, a stable booster-payload combination, to 0.035 for object 707, a tumbling Soviet rocket booster.

4.2 CHOICE OF EPOCH

Two or more epochs must be defined in the course of setting up a Spiral Decay deck. These are the element epoch (P-card 2), new epoch (P-card 3), and final prediction epoch (P-card 4).

Normally, an element epoch within the data interval is preferable to one outside, both to aid convergence and to avoid unnecessary computation time. As the exercise proceeds, the element epoch must be updated, usually with each new addition of data. The most convenient way of automatically advancing epoch is to update the epoch, on each fit, to the latest observation time in the data package, a program option available to the analyst. In this manner, the analyst will receive updated element cards for both the current element epoch as well as the time of the last observation.

The final prediction epoch controls the prediction program. If an ephemeris to decay is desired, the final prediction epoch may be any time beyond the decay time. If, on the other hand, only acquisition messages are to be generated, through the binary ephemeris tape option and the XYZLA program, the final prediction time will define the final time for such messages.

4.3 SELECTION OF DATA

For objects approaching decay, data distribution has an important bearing on convergence. Data should be well distributed in the argument of latitude, U, as well as in time. (For sensors available to SPACETRACK, U is limited to the northern hemisphere, i.e., $0^\circ < U < 180^\circ$). The majority of the data should be derived from trackers, with preference to those given

high weight (e.g., 336, 337 and 345).

If the data are concentrated at the ends of the time interval, with only scattered data between, a seven element fit may fail to converge. This is due to the fact that the program cannot independently determine period and rate-of-change of period from data limited to the boundaries of the time interval.

The required data interval to successfully correct B depends upon perigee altitude and on B. For the last day of lifetime, intervals as short as a half-day may be successful, since the perigee will be $\sim$ 150 km. On the other hand, a perigee altitude of 400 km may require a two-day span; at higher perigee altitudes, drag correction may be impractical unless (1) B is large, i. e. a balloon, or (2) the data are exceedingly good, with long tracks of both range and range-rate data. Since each case is highly individual, depending on the data span and distribution, perigee altitude, B and data quality, a narrow guideline cannot be established.

Once the value of B has stabilized, 6-element fits with short ($\sim$ 12 hour) data spans may be used. This technique would be employed, for example, where data near the decay revolution were being processed, since a 7-element fit under these circumstances may, in the iterative correction procedure, cause the satellite to "decay" prematurely. No recovery is provided in the program for this eventuality.

The versions of SPIRDECA on the B-2 and B-3 masters are limited to two groups of 492 observations (about 2.75 inches of cards). An input option must be changed, depending upon whether the number of observations exceeds 492. The program will sort these observations, so their time order in the input deck is immaterial.

4.4 INTERPRETATION OF RESIDUALS

Residuals may be viewed as a group, through the weighted rms, or individually.

The weighted rms reflects the quality of the fit against norms established for the sensors. In theory, if the sensors behave in the manner described statistically with weights and biases, and if the systematic errors in the residuals are small due to a good fit to the orbit, the weighted rms should approach unity. Larger values are more common, due to these factors:

(1) Sensor performance is poorer than that described with the weights and biases.

(2) Large uncorrected signal components exist in the residuals, which cannot be reduced by the program.

The latter situation is common, for example, where the satellite ceases tumbling during the data span (i.e. the model assumes a single drag parameter for the entire data span), or where the data distribution forces a limitation in the program's degrees of freedom (i.e. one must make a 3, 4, 5, or 6-element fit, rather than a 7-element fit).

Normally a weighted rms greater than 5 indicates excessive signal component in the residuals and the causes should be investigated further. If, for example, SOI data indicate that the tumble rate has been decreasing, one may suspect that stabilization has taken place, particularly if the ballistic coefficient B has decreased more than 5 percent from the previous fit. In such a case, one would delete more old data, making the next 7-element fit with, say, an 18-hour data interval.

One of the best indications that the differential correction is progressing satisfactorily is that the range-rate residuals from tracking radars are small. Range-rate residuals are most sensitive to timing errors, and therefore are the last to "clean up". Therefore, a range-rate residual population with -1, -2 and -3 exponents normally indicates satisfactory convergence.

For the data environment available to the analyst in the conduct of decay exercises, sophisticated data editors are not practical. Manual data editing, based upon examination of the population for "outliers" is often necessary, since the threshold editor used in the program is not particularly discriminating. Avoid the temptation to remove whole passes with self-consistent large residuals, particularly if these fall in a "U" region with relatively little data, for the large residuals may be symptomatic of poor data distribution and editing may compound the problem.

4.5 ACQUISITION MESSAGES

Look angles are normally provided by the GLASGP program. During the last two to three days of satellite lifetime, however, these look angles deteriorate as the SGPDC theory fails to represent the rapidly-changing situation during decay. The recommended alternative during this period is to generate look angles with XYZLA, utilizing a binary ephemeris tape produced by Spiral Decay. Experience has demonstrated that this procedure results in look angles valid to a few seconds in time, even into the decay revolution.