X-580-74-87

NASA TM X-70626

IMPMOT USER'S MANUAL

(NASA-TM-X-70626) IMPMOT USER'S MANUAL (NASA) 92 p CSCL 22A

N74-21501

Unclas
G3/30 36519

APRIL 1974

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

For information concerning availability
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Technical Information Division, Code 250
Goddard Space Flight Center
Greenbelt, Maryland 20771

(Telephone 301-982-4488)

X-580-74-87

IMPMOT USER'S MANUAL

Documented By

D. J. Stewart
Mission Support Computing and Analysis Division
GSFC

M. J. Bishop
Computer Sciences Corporation

April 1974

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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SECTION 1

INTRODUCTION

This User's Manual describes the input and output variables as well as the Job Control Language necessary to utilize the IMP-H apogee motor firing program, IMPMOT. The IMPMOT Program can be executed as either a stand-alone program or as a member of the Flight Dynamics System (FDS). This program is used to determine the time and attitude at which to fire the IMP-H apogee boost motor.

The IMPMOT Program is written in FORTRAN IV for use on the IBM 360 series computer. It was created by modifying the existing RAEMOT Program (See Reference 1) in the following ways:

1. The branches necessary to bypass the circular orbit targeting logic were created. The alternate initial velocity guidance which was implemented is described in Appendix A.
2. For each apogee motor ignition time, the logic necessary to perform a parametric scan upon firing attitude was developed.
3. The interfaces with the FDS were established.
4. An 8th order Runga-Kutta integration subroutine was implemented in order to propagate the satellite state vector through the apogee motor burn.
5. The logic to accommodate a multisegment apogee motor thrust profile was developed.

6. The logic necessary to create and maintain the sequential excursion file was developed. This file contains the satellite state vectors after the apogee motor burn for each combination of ignition time and firing attitude examined.

The IMPMOT Program has two guidance schemes available at the users request.

1. Circular orbit guidance
2. Initial velocity guidance

1.1 Circular Orbit Guidance Technique

When using the circular orbit guidance technique, the program will achieve a circular orbit by trading off orbit inclination and nodal position for eccentricity. Due to the fixed amount of delta-V supplied by the solid propellant apogee motor, one of three firing modes will exist.

1. Excess energy—in which the delta-V supplied by the apogee motor exceeds the delta-V required to achieve a circular orbit.
2. Sufficient energy—in which the delta-V supplied by the apogee motor equals the delta-V required to achieve a circular orbit.
3. Deficient energy—in which the apogee motor does not supply enough delta-V to achieve a circular orbit.

For the excess energy mode, two firing attitudes are possible. The IMPMOT Program computes the in-plane delta-V necessary to establish a circular orbit and dissipates the excess apogee motor delta-V out-of-plane (hence, the change in orbit inclination and node). This out-of-plane component can be directed either above or below the transfer trajectory plane (which explains the two possible firing attitudes). The program will examine each of the two firing attitudes.

For the sufficient energy mode, only one firing attitude is possible. The program will apply all of the apogee motor delta-V such that circular orbit velocity can be obtained.

The deficient energy mode indicates that a circular orbit can no longer be obtained.

Greater detail of the circular orbit guidance technique can be found in the RAEMOT documentation in Reference 1.

1.2 Initial Velocity Guidance Technique

When using the initial velocity guidance scheme, the program maximizes the magnitude of the in-plane velocity vector by firing the apogee motor along the velocity vector at the ignition time. Appendix A of this document describes this technique in detail.

1.3 Program Capabilities

Regardless of the guidance scheme employed, the user has the capability to exercise the following options.

1. A scan upon apogee motor ignition time, t_f, can be performed in the range:

$$t_A - \Delta t_S \leq t_f \leq t_A + \Delta t_S$$

where:

t_A is the time at which the satellite reaches apogee of the transfer trajectory

Δt_S is input when using the initial velocity guidance scheme; or is determined based upon the delta-V supplied by the apogee motor when using the circular orbit guidance scheme.*

2. For each ignition time defined above, the user may elect to fire the apogee motor in a fixed direction. This can be accomplished by inputting the desired firing attitude. Whenever the firing attitude is input, the selected guidance scheme is overridden.

3. The user may elect to examine only one ignition time. This can be accomplished by inputting the desired firing time. In this case the ignition time scan (defined in item 1 above) is not performed.

4. For each combination of ignition time and attitude (either computed or input), the effects of attitude uncertainties upon the orbit resulting from the apogee motor burn will be examined by superimposing the attitude uncertainties upon the firing attitude. The following attitude combinations are examined for each ignition time

*When using the circular orbit guidance scheme, the ignition time scan is terminated whenever the delta-V supplied by the apogee motor is insufficient to establish a circular orbit.

$$\alpha_D \quad , \delta_D$$

$$\alpha_D + U_\alpha , \delta_D$$

$$\alpha_D - U_\alpha , \delta_D$$

$$\alpha_D \quad , \delta_D + U_\delta$$

$$\alpha_D \quad , \delta_D - U_\delta$$

where

α_D is the spin axis right ascension**

δ_D is the spin axis declination

U_α is the uncertainty in spin axis right ascension

U_δ is the uncertainty in spin axis declination

5. In addition to examining the effects of attitude uncertainties, the user can perform a parametric scan upon firing attitude about the input or computed firing attitude at each ignition time. The range of the attitude excursion is defined by:

$$\alpha_D - n\sigma_\alpha \leqslant \alpha \leqslant \alpha_D + n\sigma_\alpha$$

$$\delta_D - m\sigma_\delta \leqslant \delta \leqslant \delta_D + m\sigma_\delta$$

where:

σ_α is the increment for the excursion upon right ascension

σ_δ is the increment for the excursion upon declination

**The IMPMOT Program assumes that the thrust vector is coincident with the negative spin axis. The apogee motor firing attitude is specified by the spin axis right ascension and declination.

n and m are arbitrary input integers.

In this manner an entire grid (centered about the input or computed firing attitude) can be considered for each ignition time.

6. The user can elect to have the satellite post maneuver state vectors for each combination of ignition time and firing attitude (defined in items 1 through 5 above) stored in a sequential file. This file can then be accessed by other programs to perform various studies or to serve as a starting point for orbit determination after the apogee motor burn.

The IMPMOT Program can use any one of four sources of satellite ephemeris information.

1. FDS Orbit File
2. ORB1 tape
3. EPHEM tape
4. Card input for use in the Brouwer propagator (BPACKC)

Any one of three sources of attitude information (if the user elects to input the firing attitude) can be used:

1. FDS Attitude File
2. SPINAT attitude prediction tape
3. Card input

Either of two sources of attitude uncertainty information can be used.

1. FDS Attitude File

2. Card input

SECTION 2

INPUT DEFINITIONS AND FORMATS

This section discusses the input required on FORTRAN logical unit number 5. Seventeen data cards are required to exercise fully all of the options of this program. The content and format of these cards are described in Tables 1 through 12. Some additional comments are provided below.

Cards 1A, 2A, 3A, 4A, 5A, 7A and 8A are each data option indicator cards and each must precede its corresponding data card 1B, 2B, 3B, 4B, 5B, 7B and 8B, respectively. If a particular B-card is omitted, then the corresponding A-card must also be omitted.

Cards 2A and 2B are not applicable for the current version of the IMPMOT Program. These cards are reserved for future use and will be ignored by the program if they appear in the data stream.

There are two circumstances when it is desirable to omit one or more data cards.

1. If the scan upon apogee motor ignition time is desired, both cards 7A and 7B must be omitted.
2. If the program is to compute the firing attitude for each ignition time (based upon either the circular orbit guidance scheme or the initial velocity scheme), both cards 8A and 8B must be omitted.

2.1 Card Group 1: FDS Interfaces

Card 1 contains the FDS interface information. The parameters on this card (see Table 1) control the levels of the orbit and attitude information used, as well as the level of the FDS Manager Summary Report generated. The levels referred to herein relate to the various entry points of a direct access sequential data set.

2.1.1 Orbit Data Source Indicators

For IORB2 = 0, either epoch elements (card input, an ORB-1 tape, or an EPHEM tape must be provided.

For IORB2 = 1, satellite ephemeris information will be retrieved from the FDS Orbit File residing on FORTRAN logical unit number 20. Level LVLOBT of this file will be used.

2.1.2 Attitude Data Source Indicators

For IATT2 = 0, attitude information (if desired) is supplied either via Card 8B or the SPINAT tape.

For IATT2 = 1, satellite attitude information will be retrieved from the FDS Attitude File residing on FORTRAN logical unit number 25. Level LVLATT of this data set will be used. Whenever the firing attitude is input (either via card 8B or the Attitude File), this input firing attitude will be used for all apogee motor ignition times.

2.1.3 FDS Manager Summary Report Indicators

For LVLFDR = 0, the FDS Manager Summary Report will not be generated. For LVLFDR > 0, level, LVLFDR, of the FDS Manager Summary Report (see Table 1) will be written to FORTRAN logical unit number 50. This data set is sequential direct access. No more than 100 lines, containing 72 alphameric characters each, will be written per level. A scratch sequential data set, on FORTRAN logical unit number 10, must be provided if LVLFDR ≠ 0. For LVLFDR = -1, the next available level of the FDS Manager Summary Report will be written. For this option, the first eight bytes of each logical record on the data set defined by FORTRAN logical unit number 50 must be preinitialized with "NO DATA ".

The parameter ISEXST controls the generation of the sequential excursion file. This file contains the satellite state vectors after the apogee motor burn for each combination of ignition time and firing attitude examined. For ISEXST = 0, the sequential excursion file will not be generated. For ISEXST = n, the sequential excursion file will be written on FORTRAN logical unit number 11. The program will assign reference numbers to each ignition time-firing attitude combination starting with "n". Each logical record (which corresponds to one ignition time-firing attitude combination) of this file contains the following information.

1. Ignition time
2. Burn-out time

3. Firing attitude

4. Satellite position and velocity vectors after the apogee motor burn

5. The osculating orbital elements after the apogee motor burn

When specifying ISEXST = n, at least n-1 logical records must have been previously written on the data set defined by FORTRAN logical unit number 11. The term "File 11" is synonymous with the sequential excursion file.

2.2 Card Groups 1A and 1B: Thrust Profile

Card 1A contains "99991" in card columns 1-5 (see Table 2). Upon reading this card, the program branches to the logic necessary to read Card 1B. Card 1B contains the apogee motor burn integration control parameters as well as the polynomial coefficients for the multisegment thrust profile. Card 1B is physically composed of several data cards. The number of cards is determined by the input parameters which control the number of thrust segments and the number of coefficients per thrust segment (parameters NSEG and NCOEFF, respectively).

When reading card 1B, the program begins by reading the number of thrust segments (NSEG) and the number of coefficients per each segment (NCOEF(i) where i = 1, 2, . . . NSEG). A maximum of 10 segments is permitted. Each segment may have a maximum of 10 coefficients describing it. The polynomial, P_i, which describes the thrust in the i^{th} segment is defined by:

$$P_i = \sum_{j=1}^{n} C_{j,i} \, t_i^{j-1} \qquad (2.2\text{-}1)$$

where

n – is the number of coefficients describing the i^{th} segment (n = NCOEF(i)).

t_i – is the segment time (details of this segment time will be given in subsequent paragraphs).

From the above equation it is seen that the order of the polynomial describing the i^{th} segment is NCOEF(i)-1.

The program then reads a card containing the segment number (ISEG), the begin time and end time for the segment (BEGTM and ENDTM, respectively) and the integration time step to be used for the segment (TINCS).* Next, the coefficients describing the ISEG segment are read. The program will read in fields of 10 until NCOEF (ISEG) coefficients have been entered.

The program will then read parameters ISEG, BEGTM, ENDTM, TINCS and COEFF (in the order described in the preceding paragraph) until the data for all NSEG segments have been entered.

The segment time, t_i, in equation 2.2-1 is measured from the begin time for each segment. Thus, t_i at the begin time of each segment is always zero. The relationship between the segment time for the i^{th} segment and the time

*The begin times and end times for each segment are referenced to the beginning time of the apogee motor burn. Hence, the begin time for the first segment is 0. The beginning time of the i^{th} segment must equal to the end time of the $i-1^{st}$ segment.

measured from the beginning of the apogee motor burn, t, is given below

$$t = t_i + \text{BEGTM (i)}$$

The program internally accounts for this time shift. The user must only remember that:

1. The begin and end times are measured relative to the beginning of the apogee motor burn
2. The coefficients describing the thrust polynomials ($C_{j,i}$) are based upon segment time (t_i).

2.3 Card Groups 2A and 2B: Reserve

Cards 2A and 2B are not used in the current version of IMPMOT. Their presence is reserved for future improvements to this program. These cards will be ignored if input.

2.4 Card Groups 3A and 3B: Attitude and Guidance Data Card

Card 3A contains "99993" in card columns 1-5 (see Table 2). Upon reading this card, the program branches to the logic necessary to read Card 3B (see Table 5). Card 3B contains spin axis uncertainty parameters (DELA and DELD); ignition time scan increment (DELTIM); attitude excursion parameters (SIGALP, SIGDEL, NSIGAL and NSIGDE); guidance option switch (LET); and indicators for attitude and attitude uncertainty sources (JATT and JERR). As mentioned in Section 1, the user has one of two sources available for entering attitude uncertainty (either via the FDS Attitude File or via card input).

If JERR = 0, attitude uncertainty (in terms of the uncertainty in spin axis right ascension and declination) is entered via parameters DELA and DELD. If JERR = 1 and the Attitude File option is selected (IATT2 = 1 on Card 1), the attitude uncertainty will be retrieved from level LVLATT (see Card 1) of the FDS Attitude File.

Through the parameters NSIGAL and NSIGDE, the user selects the range of the attitude excursion to be performed for each ignition time. If NSIGAL and NSIGDE are both zero, then the attitude excursion will not be performed. For NSIGAL ≠ 0 and NSIGDE ≠ 0 the attitude excursion will be performed for each combination of:

$$\alpha_D - \text{NSIGAL} \cdot \text{SIGALP} \leqslant \alpha \leqslant \alpha_D + \text{NSIGAL} \cdot \text{SIGALP}$$

$$\delta_D - \text{NSIGDE} \cdot \text{SIGDEL} \leqslant \delta \leqslant \delta_D + \text{NSIGDE} \cdot \text{SIGDEL}$$

where

α_D —is the input or computed spin axis right ascension

α_D —is the input or computed spin axis declination

SIGALP and SIGDEL are defined in Table 5.

For NSIGAL ≠ 0 and NSIGDE = 0, the excursion is performed for:

$$\alpha_D - \text{NSIGAL} \cdot \text{SIGALP} \leqslant \alpha \leqslant \alpha_D + \text{NSIGAL} \cdot \text{SIGALP}$$

$$\delta = \delta_D$$

For NSIGAL = 0 and NSIGDE ≠ 0, the excursion is performed for:

$$\alpha = \alpha_D$$

$$\delta_D - \text{NSIGDE} \cdot \text{SIGDEL} \leqslant \delta \leqslant \delta_D + \text{NSIGDE} \cdot \text{SIGDEL}$$

The increments for the attitude excursions described above are:

$$\Delta\alpha = \text{SIGALP}$$

$$\Delta\delta = \text{SIGDEL}$$

If the user elects to input the firing attitude via the FDS Attitude File, the parameter JATT is set equal to 1 (whenever JATT = 1, the Attitude File option, IATT2, must be set equal to 1, see Card 1).

The parameter LET indicates the guidance scheme to be employed. For LET = 0, the circular orbit guidance scheme will be used. The program will attempt to achieve a circular orbit for each apogee motor ignition time by trading off orbital inclination and node for eccentricity. The scan upon apogee motor ignition time will be terminated whenever the delta-V supplied by the apogee motor is insufficient to achieve a circular orbit (hence, the parameter DELSRM is ignored). Greater detail concerning this scheme can be found in the RAEMOT Program documentation in Reference 1.

For LET = 1, the initial velocity guidance technique is employed. For each ignition time, the program will apply the apogee motor delta-V in the direction defined by the instantaneous velocity vector at the beginning of the burn. The range of the scan upon ignition time is controlled by the input parameter DELSRM (See Table 5). Greater detail concerning this guidance scheme can be found in Appendix A.

2.5 Card Groups 4A and 4B: Apogee Motor Characteristics

Card 4A contains "99994" in card columns 1-5. Upon reading this card, the program will branch to the logic necessary for reading Card 4B. Card 4B contains the target orbit parameters and the apogee boost motor characteristics. The target orbit semimajor axis, eccentricity and inclination are used only for the purpose of computing the residuals between the target orbit and the orbit resulting from the apogee boost motor burn and do not in any way affect the guidance scheme. The apogee boost motor impulse, XIMPLS, is defined by:

$$XIMPLS = WEXP \cdot I_{SP}$$

where:

WEXP is the fuel weight expended during the apogee boost motor burn. I_{SP} is the apogee boost motor specific impulse.

An alternate expression for XIMPLS if thrust is assumed to be variable during the apogee motor burn is given below

$$XIMPLS = \frac{\dot{w} \int_0^{t_B} T/W \, dt}{\ln (w_i/w_f)}$$

where

T = thrust

t_B = apogee motor burn time

$\dot{w}$ = weight flowrate

w = instantaneous spacecraft weight

w_i = spacecraft weight at the beginning of the apogee motor burn

w_f = spacecraft weight at the end of the apogee motor burn

2.6 Card Groups 5A and 5B: Ground Station Data

Cards 5A and 5B are optional. The default ground station data presented in Table 13 are assumed if these cards are not input.

It is necessary that at least one ground station see the satellite at the apogee motor ignition time. If none of the ground stations can see the satellite, the ignition time is unacceptable and the program will proceed to the next card-stacked case (see Section 2.13).

Card 5A contains "99995" in card columns 1-5. Upon reading card 5A, the program will branch to the logic necessary to read Card 5B. Card 5B contains the ground station information (see Table 7). Up to 15 type 5B cards may follow a 5A card. Card 5A is read only at the beginning of this series. After the last 5B card in the series, a blank card is inserted.

Station longitude is measured east from Greenwich from 0 to 360 degrees. Hence, a station at longitude 90 degrees west must be input as 270 degrees. If the station lies south of the equator, all non-zero latitude variables (LATD, LATM and LATS) must be input negative.

2.7 Card Group 6A: Program Pause

Card 6A is optional. It contains "99996" in card columns 1-5. Upon reading this card, the program enters a "pause" state and displays the number "7117" to the computer operator.

To terminate the "pause" state, the computer operator enters any one-digit-character (non blank) via the computer console. During the "pause" state, the allocation of various I/O devices can be modified (e. g. different ORB1 and EPHEM tapes can be mounted or dismounted within a job step). This option should only be used by an experienced user running the program in a "hands-on" mode.

2.8 Card Groups 7A and 7B: Firing Time

Cards 7A and 7B are optional input cards. They are input only if the user does not want the program to scan upon apogee boost motor ignition time. Card 7A contains "99997" in card columns 1-5 (see Table 2). Upon reading Card 7A, the program branches to the logic necessary to read Card 7B. Card 7B contains the calendar date and time of the desired apogee motor firing time (see Table 8).

The program assumes that the firing time input on this card is the desired burn-out time, t_{B0}, for the apogee motor. The apogee motor ignition time (t_f) corresponding to t_{B0} is defined by:

$$t_f = t_{B0} - TBOOST - BRNDLY$$

where

TBOOST – is the apogee motor burn time (see Table 6)

BRNDLY – is the apogee motor burn delay (see Table 6)

2.9 Card Groups 8A and 8B: Firing Attitude

Cards 8A and 8B are optional input cards. They are input only if the user wishes to suppress internal calculation of apogee motor firing attitude and specify a particular firing attitude. Card 8A contains "99998" in card columns 1-5.

Upon reading Card 8A, the program branches to the logic necessary to read Card 8B. Card 8B contains input attitude information (see Table 9). If the Attitude File option is used (IATT = 1, on Card 1 and the parameter JATT = 1 (see Table 5), the variables ALPHA and DELTA on this card may be left blank.

2.10 Card Group 9: Apogee Search Interval

Unless the desired apogee motor firing time is input (see Section 2.8), the program must perform a search in order to find apogee of the transfer trajectory. The details of this search procedure are discussed in Section A.1 of Appendix A.

Card 9 contains the start and end times for the apogee search (see Table 10). The program begins its search for apogee of the transfer trajectory at the time defined by IBGRUN. If apogee does not lie within the time interval bounded by IBGRUN and IEDRUN, the search is terminated and the program proceeds to the next card-stacked case (see Section 2.13). By proper selection of the start and end times, various apogees of the transfer trajectory may be examined.

If the FDS Orbit File, ORB-1 tape, or EPHEM tape is used, care must be taken to ensure that neither IBGRUN or IEDRUN extend beyond the bounds of the available satellite ephemeris data.

If the desired firing time is input, the input begin and end times will be ignored by the program.

2.11 Card Group 10: Transfer Orbit Characteristics

Card 10 (see Table 11) contains the transfer orbit characteristics as well as the following indicators specifying:

1. Transfer orbit elements tape
2. Use of a spin axis prediction tape
3. Perturbations to be considered for the Brouwer propagator
4. Use of debug print
5. Time reduction factor to be used during the apogee search

If either the FDS Orbit File, ORB-1 tape or EPHEM tape is used, the following parameters may be left blank: TRSMA, TRECC, TRINC, TRMEAN, TROMEG, TRNODE and IPSET.

2.11.1 Orbit Information Sources

Card 10 in conjunction with Card 1 informs the program of the source of the satellite ephemeris information to be used. As mentioned in Section 1, the

IMPMOT Program has a choice of one of four sources for this information.

1. FDS Orbit File
2. ORB1 tape
3. EPHEM tape
4. Card input for use by the Brouwer propagator (subroutine BPACKC)

The option switches which flag each of these sources are described below.

2.11.1.1 Flags for the FDS Orbit File

To use the FDS Orbit File, the user inputs IORB2 = 1 on Card 1 and indicates the level of the Orbit File to be used via the parameter LVLOBT (see Table 1). In addition the parameter TRSMA (input on Card 10) must be left blank.

2.11.1.2 Flags for an ORB1 Tape

An ORB1 tape may be supplied in either a seven-track or nine-track format. Regardless of the format, the parameters IORB2 must be zero; TRSMA must be left blank; and IEPHEM is set equal to 0.

If a seven-track ORB1 tape is used, ITRACK is set equal to 7 (when using any other option, including either the Orbit File or EPHEM tape, ITRACK should be set equal to 9). The seven-track double-precision ORB1 tape is supplied on DD name GENTAP. The seven-track tape will be converted to nine-track single-precision format and stored on FORTRAN logical unit number 17. If the debug print control (IBUG) is set, the conversion of the first 50 records of the ORB1 tape will be printed.

If a nine-track ORB1 tape is used, it must be in single-precision format. The nine-track single-precision ORB1 tape is entered directly on FORTRAN logical unit number 17. The parameter ITRACK must also be set equal to 9.

2.11.1.3 Flags for an EPHEM Tape

If an EPHEM tape is used, the parameters IORB2 must be zero; TRSMA must be left blank; and IEPHEM is set equal to 1. The nine-track single-precision EPHEM tape is then entered on FORTRAN logical unit number 17.

2.11.1.4 Flags for the Brouwer Propagator

To input orbital elements via cards and use the Brouwer propagator, IORB2 on Card 1 must be set equal to 0. The orbital elements are then entered via Card 10 via parameters TRSMA, TRECC, TRINC, TRMEAN, TROMEG and TRNODE. These input elements may be either:

1. Brouwer mean elements (IELEM = 0 for this case)
2. Osculating elements (IELEM = 1 for this case)

2.11.2 Attitude Information Source

Card 10 in conjunction with Cards 1 and 3B inform the program of the source of input firing attitude data (see Sections 1, 2.4 and 2.9 for the implications of inputting the firing attitude). As mentioned in Section 1, the IMPMOT Program can use any one of three sources for this information.

1. FDS Attitude File
2. SPINAT attitude prediction tape
3. Card input

The option switches which flag each of these sources are described below.

2.11.2.1 Flags for the FDS Attitude File

In order to use the FDS Attitude File, the user inputs IATT2 = 1 on Card 1 and indicates the level of the Attitude File to be used via the parameter LVLATT (see Table 1). The parameter ISPIN on Card 10 (see Table 11) must be set to zero, and JATT on Card 3B is set to one. In addition, Cards 8A and 8B are omitted.

2.11.2.2 Flags for the SPINAT Tape

To use the SPINAT attitude prediction tape, the user inputs: IATT2 = 0 on Card 1; JATT = 0 on Card 3B; and ISPIN = 1 on Card 10. Cards 8A and 8B are omitted. The SPINAT tape is entered via FORTRAN logical unit number 36.

2.11.2.3 Flags for Card Input Attitude Data

The user can elect to input the firing attitude via Cards 8A and 8B. Section 2.9 describes the format of these cards. To use this option the user inputs: JATT2 = 0 on Card 1; JATT = 0 on Card 3B; and ISPIN = 0 on Card 10.

2.12 Card Group 11: Transfer Trajectory Epoch

Card 11 contains the epoch time of the transfer trajectory as well as user supplied comments (see Table 12). If the Orbit File, ORB1 or EPHEM option is used, the epoch times may be left blank.

2.13 Multiple Card-Stacked Cases

This program can run any number of card-stacked cases per job step. The number of cases need not be known in advance. In order to run multiple cases, cards 1A through 11 are repeated in sets for each case.

If the Orbit File or Attitude File option is selected, their levels may not be altered among the stacked cases. After the desired number of cases have been stacked (which may consist of only a single case), a card containing "99999" in card columns 1-5 is inserted. Figure 1 illustrates the data card stacking sequence for multiple cases.

Table 1. Card Group 1: FDS Interfaces (Sheet 1 of 2)

CARD 1				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
LVLOBT	I5	1-5	ORBIT LEVEL	
LVLATT	I5	6-10	ATTITUDE LEVEL	
IORB2	I5	11-15	ORBIT FILE INDICATOR. THIS PARAMETER DETERMINES IF THE "ORBIT FILE" IS TO BE USED TO PROVIDE SATELLITE EPHEMERIS INFORMATION. = 0 IMPLIES THAT THE ORBIT FILE WILL NOT BE USED. = 1 IMPLIES THAT LEVEL "LVLOBT" OF THE ORBIT FILE, RESIDING ON FORTRAN LOGICAL UNIT 20, WILL BE USED.	
IATT2	I5	16-20	ATTITUDE FILE INDICATOR. THIS PARAMETER CONTROLS THE USE OF THE "ATTITUDE FILE". = 0 IMPLIES THAT THE ATTITUDE FILE IS NOT TO BE USED. = 1 IMPLIES THAT LEVEL "LVLATT" OF THE ATTITUDE FILE, RESIDING ON FORTRAN LOGICAL UNIT 25, WILL BE USED TO PROVIDE SPIN AXIS RIGHT ASCENSION, DECLINATION AND UNCERTAINTY.	
LVLFDR	I5	21-25	FDS MANAGER REPORT INDICATOR. THIS PARAMETER DETERMINES IF THE FDS MANAGER SUMMARY REPORT WILL BE WRITTEN ON FORTRAN LOGICAL UNIT NUMBER 50.* = 0 IMPLIES THAT THE FDS MANAGER SUMMARY REPORT WILL NOT BE WRITTEN. = n IMPLIES THAT LEVEL "n" OF THE FDS MANAGER SUMMARY REPORT WILL BE WRITTEN. = −1 IMPLIES THAT THE NEXT AVAILABLE LEVEL OF THE FDS MANAGER SUMMARY REPORT WILL BE WRITTEN.**	
ICOPY	I5	26-30	HARD COPY INDICATOR. THIS PARAMETER CONTROLS THE WRITING OF LEVEL "LVLFDR" OF THE FDS MANAGER SUMMARY REPORT TO FORTRAN LOGICAL UNIT NUMBER 6. = 0 IMPLIES THAT NO COPY OF THE FDS MANAGER SUMMARY REPORT WILL BE PROVIDED. = 1 IMPLIES THAT A COPY OF THE CURRENT LEVEL OF THE FDS MANAGER SUMMARY REPORT WILL BE DIRECTED TO UNIT 6.	

*If LVLFDR ≠ 0, a scratch sequential data set on FORTRAN logical unit number 10 must be provided.

**If LVLFDR = −1, the first eight bytes of each logical record of the data set on FORTRAN logical unit number 50 must be preinitialized with "NO DATA ".

Table 1. Card Group 1: FDS Interfaces (Sheet 2 of 2)

CARD 1				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
ISEXST	I5	31-35	SEQUENTIAL EXCURSION FILE FLAG.* THIS PARAMETER CONTROLS THE GENERATION OF THE SEQUENTIAL EXCURSION FILE. = 0 IMPLIES THAT THE SEQUENTIAL EXCURSION FILE WILL NOT BE GENERATED. HOWEVER, REFERENCE NUMBERS WILL BE ASSIGNED TO EACH IGNITION TIME–ATTITUDE COMBINATION. = n IMPLIES THAT THE SEQUENTIAL EXCURSION FILE WILL BE WRITTEN TO FORTRAN LOGICAL UNIT NUMBER 11. THE PROGRAM WILL ASSIGN REFERENCE NUMBERS TO EACH FIRING TIME–ATTITUDE COMBINATION STARTING WITH "n". EACH LOGICAL RECORD OF THIS FILE CONTAINS THE FOLLOWING INFORMATION. 1. IGNITION TIME 2. BURN-OUT TIME 3. FIRING ATTITUDE 4. SATELLITE POSITION AND VELOCITY VECTORS AFTER THE APOGEE MOTOR BURN 5. THE OSCULATING ORBITAL ELEMENTS AFTER THE APOGEE MOTOR BURN. NOTE: WHEN SPECIFYING ISEXST = n, AT LEAST n–1 LOGICAL RECORDS MUST HAVE BEEN PREVIOUSLY WRITTEN ON THE DATA SET DEFINED BY FORTRAN LOGICAL UNIT NUMBER 11.	

*The term "FILE 11" is synonymous with the sequential excursion file. This file can be accessed by other members of the FDS to obtain the satellite state vector after the apogee motor burn.

Table 2. Card Groups 1A through 8A: Data Option Indicators

CARDS 1A THROUGH 8A				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
IOPER	I5	1-5	DATA OPTION INDICATOR. DEPENDING UPON THE VALUE OF THIS PARAMETER, THE FOLLOWING OPERATIONS ARE PERFORMED:	

VALUE	CARD	OPERATION
99991	1A	THE INTEGRATION PARAMETERS FOR THE APOGEE BOOST MOTOR BURN (CARD 1B) ARE READ.
99992	2A	RESERVED FOR FUTURE USE.
99993	3A	THE PERTUBATIONS CARD (3B) IS READ.
99994	4A	THE TARGET ORBIT AND BOOST PARAMETER CARD (4B) IS READ.
99995	5A	THE STATION PARAMETER CARDS (5B) ARE READ.
99996*	6A	A PROGRAM PAUSE IS GENERATED. THE NUMBER '7117' IS DISPLAYED TO THE COMPUTER OPERATOR.
99997	7A	THE APOGEE BOOST MOTOR FIRING TIME CARD (7B) IS READ.
99998	8A	THE ATTITUDE PARAMETER CARD (8B) IS READ.

*A computer operator response is required for this option.

Table 2. Card Group 1B: Thrust Profile (Sheet 1 of 2)

CARD 1B*				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
NSEG	I5	1-5	NUMBER OF POLYNOMIAL SEGMENTS DESCRIBING THE THRUST CURVE DURING THE APOGEE MOTOR BURN. (MAXIMUM OF 10)	
NCOEF (1)	I5	5-10	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 1st SEGMENT**	
(2)	I5	11-15	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 2nd SEGMENT**	
(3)	I5	16-20	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 3rd SEGMENT**	
(4)	I5	21-25	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 4th SEGMENT**	
(5)	I5	26-30	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 5th SEGMENT**	
(6)	I5	31-35	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 6th SEGMENT**	
(7)	I5	36-40	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 7th SEGMENT**	
(8)	I5	41-45	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 8th SEGMENT**	
(9)	I5	46-50	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 9th SEGMENT**	
(10)	I5	51-55	THE NUMBER OF POLYNOMIAL COEFFICIENTS FOR THE 10th SEGMENT**	
ISEG	I5	1-5	SEGMENT NUMBER.	
BEGTM	F10.0	11-20	THE START TIME OF THE ISEG SEGMENT (MEASURED FROM THE START OF THE APOGEE MOTOR BURN).	SECONDS
ENDTM	F10.0	21-30	THE END TIME OF THE ISEG SEGMENT	SECONDS
TINCS	F10.0	31-40	THE INTEGRATION STEP SIZE FOR THE ISEG SEGMENT	SECONDS

*CARD 1B is physically composed of several cards (note the indicated card columns).

**The order of the polynomial describing the Ith segment is NCOEF(J)–1.

Table 2. Card Group 1B: Thrust Profile (Sheet 2 of 2)

CARD 1B				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
COEF (10, 10)	8F10.0	1-80	COEFFICIENTS OF THE POLYNOMIAL FOR THE ISEG SEGMENT. THE POLYNOMIAL, P_i, DESCRIBING THE i^{th} SEGMENT IS DEFINED BY: $P_i = \sum_{j=1}^{n} C_{j,i} t_i^{j-1}$ A MAXIMUM OF 10 COEFFICIENTS ARE ALLOWED. MORE THAN ONE CARD MAY BE USED. THE PROGRAM WILL READ IN FIELDS OF 10 UNTIL NCBEF (ISEG) COEFFICIENTS HAVE BEEN ENTERED.	lb_f per $(SECOND)^{j-1}$

The program will reread the parameters ISEG, BEGIM, ENDTM, TINCS and COEFF until the data for all NSEG segments have been entered.

Table 4. Card Group 2A: Reserve

CARD 2B*				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
DA	F10.0	1-10	CURRENTLY A DUMMY VARIABLE	
DD	F10.0	11-20	CURRENTLY A DUMMY VARIABLE	
ESCALE	F10.0	21-30	CURRENTLY A DUMMY VARIABLE	
XMAXIT	F10.0	31-40	CURRENTLY A DUMMY VARIABLE	

*This card is not recognized by the current version.

Table 5. Card Group 3B: Attitude and Guidance Data (Sheet 1 of 3)

CARD 3B				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
DELA*	F10.0	1-10	UNCERTAINTY IN SPIN AXIS RIGHT ASCENSION	DEGREES
DELD*	F10.0	11-20	UNCERTAINTY IN SPIN AXIS DECLINATION	DEGREES
DELTIM	F10.0	21-30	TIME INCREMENT FOR THE APOGEE MOTOR IGNITION TIME EXCURSION. THE VARIATION OF APOGEE MOTOR IGNITION TIME WILL BE EQUAL TO THIS NUMBER.	SECONDS
SIGALP	F10.0	31-40	THE INCREMENT OF SPIN AXIS RIGHT ASCENSION ($\Delta\alpha$) FOR THE ATTITUDE EXCURSION	DEGREES
SIGDEL	F10.0	41-50	THE INCREMENT OF SPIN AXIS DECLINATION ($\Delta\delta$) FOR THE ATTITUDE EXCURSION	DEGREES
DELSRM**	F10.0	51-60	THE TIME PERIOD ABOUT APOGEE FOR THE IGNITION TIME EXCURSION. THE PROGRAM WILL EXAMINE FIRING TIMES, t_f, IN THE RANGE OF: $t_A - \text{DELSRM} \leq t_f \leq t_A + \text{DELSRM}$ WHERE t_A IS THE TIME AT WHICH THE SATELLITE REACHES THE APOGEE OF THE TRANSFER TRAJECTORY. THE TIME INCREMENT (Δt) FOR THIS EXCURSION IS DEFINED BY DELTIM.	MINUTES
NSIGAL	I3	61-63	THIS PARAMETER CONTROLS THE SCAN UPON SPIN AXIS RIGHT ASCENSION FOR THE ATTITUDE EXCURSION = 0 IMPLIES THAT NO SCAN UPON SPIN AXIS RIGHT ASCENSION WILL BE PERFORMED = n IMPLIES THAT A SCAN WILL BE PERFORMED ABOUT THE INPUT OR CALCULATED SPIN AXIS RIGHT ASCENSION (α_D) IN THE RANGE OF: $\alpha_D - n \cdot \text{SIGALP} \leq \alpha \leq \alpha_D + n \cdot \text{SIGALP}$ THE INCREMENT FOR THIS SCAN ($\Delta\alpha$) IS DEFINED BY $\Delta\alpha = \text{SIGALP}$	

*If the Attitude File option is selected (IATT2 = 1), and JERR = 1, these parameters may be left blank.
**This parameter is recognized only if LET = 1.

Table 5. Card Group 3B: Attitude and Guidance Data (Sheet 2 of 3)

CARD 3B				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
NSIGDE	I3	64-66	THIS PARAMETER CONTROLS THE SCAN UPON SPIN AXIS DECLINATION FOR THE ATTITUDE EXCURSION = 0 IMPLIES THAT NO SCAN UPON SPIN AXIS DECLINATION WILL BE PERFORMED = n IMPLIES THAT A SCAN WILL BE PERFORMED ABOUT THE INPUT OR CALCULATED SPIN AXIS DECLINATION (δ_D) IN THE RANGE OF: $\delta_D - n \cdot \text{SIGDEL} \leq \delta \leq \delta_D + n \cdot \text{SIGDEL}$ THE INCREMENT FOR THIS SCAN ($\Delta\delta$) IS DEFINED BY: $\Delta\delta = \text{SIGDEL}$	
LET	I3	67-69	GUIDANCE INDICATOR. THIS PARAMETER CONTROLS THE GUIDANCE SCHEME EMPLOYED BY THE PROGRAM = 0 FOR EACH IGNITION TIME THE PROGRAM WILL COMPUTE THE FIRING ATTITUDES TO ACHIEVE A CIRCULAR ORBIT. THE IGNITION TIME EXCURSION WILL BE TERMINATED WHEN THE IMPULSE SUPPLIED BY THE APOGEE MOTOR IS INSUFFICIENT TO ACHIEVE A CIRCULAR ORBIT. = 1 FOR EACH IGNITION TIME, THE PROGRAM WILL APPLY TO APOGEE MOTOR IMPULSE ALONG THE INSTANTANEOUS VELOCITY VECTOR. THE IGNITION TIME EXCURSION IS CONTROLLED BY THE INPUT PARAMETER DELSRM.	
JERR*	I3	70-72	ATTITUDE UNCERTAINTY SOURCE INDICATOR = 0 IMPLIES THAT THE ATTITUDE UNCERTAINTY WILL BE SUPPLIED VIA THE INPUT PARAMETERS DELA AND DELD = 1 IMPLIES THAT THE ATTITUDE UNCERTAINTY WILL BE RETRIEVED FROM THE ATTITUDE FILE.	

*If the Attitude File option is not selected, these parameters must be left blank.

Table 5. Card Group 3B: Attitude and Guidance Data (Sheet 3 of 3)

CARD 3B				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
JATT*	I3	73-75	ATTITUDE SOURCE INDICATOR. = 0 IMPLIES THAT: a. THE FIRING ATTITUDE IS TO BE COMPUTED (IF CARD 8B IS NOT INPUT) b. THE FIRING ATTITUDE WILL BE INPUT VIA CARD 8B = 1 IMPLIES THAT THE FIRING ATTITUDE WILL BE RETRIEVED FROM THE ATTITUDE FILE.	

*If the Attitude File option is not selected, these parameters must be left blank.

Table 6. Card Group 4B: Apogee Motor Characteristics

CARD 4B				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
TGSMA	F10.0	1-10	TARGET ORBIT SEMIMAJOR AXIS	KILOMETERS
TGECC	F10.0	11-20	TARGET ORBIT ECCENTRICITY	
TGINC	F10.0	21-30	TARGET ORBIT INCLINATION	DEGREES
TBOOST	F10.0	31-40	APOGEE MOTOR BURN TIME	SECONDS
WLOAD	F10.0	41-50	TOTAL SPACECRAFT WEIGHT BEFORE THE APOGEE BOOST MOTOR BURN	POUNDS
WEXP	F10.0	51-60	WEIGHT EXPENDED DURING APOGEE BOOST MOTOR BURN	POUNDS
XIMPLS	F10.0	61-70	APOGEE BOOST MOTOR IMPULSE. THIS VARIABLE IS DEFINED BY: $XIMPLS = WEXP \cdot I_{SP}$ WHERE I_{SP} IS APOGEE BOOST MOTOR SPECIFIC IMPULSE IN SECONDS.	POUND-SECONDS
BRNDLY	F10.0	71-80	BURN DELAY. THIS PARAMETER IS USED TO BIAS THE APOGEE MOTOR IGNITION TIME. ASSUMING THAT t_{BO} DEFINES THE DESIRED APOGEE MOTOR BURN-OUT TIME, THE IGNITION TIME, t_f, IS COMPUTED BY: $t_f = t_{Bo} - TBOOST-BRNDLY$	SECONDS

Table 7. Card Group 5B: Ground Station Data

CARD 5B*				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
STANAM	A6	1-6 7-10	STATION NAME BLANK	
LATD**	I5	11-15	DEGREES OF STATION LATITUDE (POSITIVE NORTH)	DEGREES
LATM	I5	16-20	MINUTES OF STATION LATITUDE	MINUTES
LATS	I5	21-25	SECONDS OF STATION LATITUDE	SECONDS
LOND***	I5	26-30	DEGREES OF STATION LONGITUDE	DEGREES
LONM	I5	31-35	MINUTES OF STATION LONGITUDE	MINUTES
LONS	I5	36-40	SECONDS OF STATION LONGITUDE	SECONDS
HTMET	F10.0	41-50	STATION HEIGHT (ABOVE MEAN EQUATORIAL RADIUS)	METERS
SELMIN	F10.0	51-60	MINIMUM STATION ELEVATION ANGLE	DEGREES

*This card may be repeated a maximum of 15 times. A blank card must be input after the last station card.
**If the station lies south of the equator, all non-zero latitude variables must be input as negative integers.
***Station longitude is measured east from Greenwich from 0 to 360 degrees.

Table 8. Card Group 7B: Firing Time

CARD 7B*				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
IFIRTM(1)	I2	1-2	YEAR OF FIRING TIME (LAST TWO DIGITS) (00 to 99)	
IFIRTM(2)	I2	3-4	MONTH OF FIRING TIME (01 to 12)	
IFIRTM(3)	I2	5-6	DAY OF FIRING TIME (01 to 31)	
IFIRTM(4)	I2	9-10	HOUR OF FIRING TIME (00 to 23)	
IFIRTM(5)	I2	11-12	MINUTE OF FIRING TIME (00 to 59)	
IFIRTM(6)	I2	13-14	SECOND OF FIRING TIME (00 to 59)	
			THE PROGRAM ASSUMES THAT THE FIRING TIME INPUT ON THIS CARD, t_{Bo}, IS THE DESIRED BURN-OUT TIME. THE APOGEE MOTOR IGNITION TIME, t_f, IS DEFINED BY: $t_f = t_{Bo}$ – TBOOST-BRNDLY	
			SEE TABLE 6 FOR THE DEFINITIONS OF TBOOST AND BRNDLY	

*If the scan upon ignition time is desired, cards 7A and 7B are not input.

Table 9. Card Group 8B: Firing Attitude

CARD 8B*				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
ALPHA**	F10.0	1-10	INPUT SPIN AXIS RIGHT ASCENSION FOR APOGEE BOOST MOTOR FIRING	DEGREES
DELTA**	F10.0	11-20	INPUT SPIN AXIS DECLINATION FOR APOGEE BOOST MOTOR FIRING	DEGREES
APDELT	F10.0	21-30	TIME PERIOD AROUND APOGEE FOR INPUT ATTITUDE TO BE USED	MINUTES

*If it is desired to have the program calculate the firing attitude, cards 8A and 8B are omitted from the data card deck.
**If the attitude file option is used (IATT2 = 1), this parameter may be left blank.

Table 10. Card Group 9: Apogee Search Interval

CARD 9				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
LORBIT	I5	1-5	ORBIT NUMBER AT START TIME	
IBGRUN(1)*	I5	6-10	YEAR OF START TIME (E.G. 1972)	
IBGRUN(2)	I5	11-15	MONTH OF START TIME (01 to 12)	
IBGRUN(3)	I5	16-20	DAY OF START TIME (01 to 31)	
IBGRUN(4)	I5	21-25	HOUR OF START TIME (01 to 23)	
IBGRUN(5)	I5	26-30	MINUTE OF START TIME (00 to 59)	
IEDRUN(1)*	I5	31-35	YEAR OF END TIME (E.G. 1972)	
IEDRUN(2)	I5	36-40	MONTH OF END TIME (01 to 12)	
IEDRUN(3)	I5	41-45	DAY OF END TIME (01 to 31)	
IEDRUN(4)	I5	46-50	HOUR OF END TIME (00 to 59)	
IEDRUN(5)	I5	51-55	MINUTE OF END TIME (00 to 59)	
KPDATE**	I6	61-66	PACKED YEAR, MONTH, AND DAY OF RUN PREPARATION (YYMMDD)	
KPHR**	I2	67-68	HOUR OF RUN PREPARATION.	

*By proper selection of the start and end times, various apogees may be examined.
**These parameters are optional and may be left blank without interfering with program execution.

Table 11. Card Group 10: Transfer Trajectory Characteristics (Sheet 1 of 3)

CARD 10				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
TRSMA*	F10.0	1-10	TRANSFER ORBIT SEMIMAJOR AXIS. IF THIS PARAMETER IS LEFT BLANK, THEN EITHER THE ORBIT FILE, THE ORB1 OR THE EPHEM OPTION MUST BE USED. A. IF THE ORBIT FILE OPTION IS USED (IORB2 = 1), THEN THE MULTILEVEL ORBIT FILE MUST RESIDE ON FORTRAN LOGICAL UNIT NUMBER 20. B. IF THE ORB1 OPTION IS SELECTED (IORB2 = 0, TRSMA = 0.0 AND IEPHEM = 0), THEN EITHER: a. A SEVEN-TRACK DOUBLE-PRECISION ORB1 TAPE MUST BE SUPPLIED ON DD NAME GENTAP (IF ITRACK = 7) AND A DATA SET MUST BE ALLOCATED FOR THE CONVERSION OF THIS SEVEN-TRACK TAPE TO NINE-TRACK SINGLE-PRECISION FORMAT ON FORTRAN LOGICAL UNIT NUMBER 17. b. A NINE-TRACK SINGLE-PRECISION ORB1 TAPE MUST BE SUPPLIED ON FORTRAN LOGICAL UNIT NUMBER 17. C. IF THE EPHEM OPTION IS SELECTED (IORB2 = 0, TRSMA = 0.0 and IEPHEM = 1), THEN A NINE-TRACK SINGLE-PRECISION EPHEM TAPE MUST BE SUPPLIED ON FORTRAN LOGICAL UNIT NUMBER 17.	KILOMETERS
TRECC*	F10.0	11-20	TRANSFER ORBIT ECCENTRICITY	
TRINC*	F10.0	21-30	TRANSFER ORBIT INCLINATION	DEGREES
TRMEAN*	F10.0	31-40	TRANSFER ORBIT MEAN ANOMALY	DEGREES
TROMEG*	F10.0	41-50	TRANSFER ORBIT ARGUMENT OF PERIGEE	DEGREES
TRNODE*	F10.0	51-60	TRANSFER ORBIT RIGHT ASCENSION OF THE ASCENDING NODE	DEGREES
IELEM	I1	65	TRANSFER ORBIT ELEMENTS TYPE INDICATOR. THIS PARAMETER COMMUNICATES THE TYPE OF TRANSFER ORBIT ELEMENTS PROVIDED. = 0 IMPLIES THAT BROUWER MEAN ELEMENTS ARE INPUT = 1 IMPLIES THAT OSCULATING ELEMENTS ARE INPUT WHEN USING EITHER THE ORBIT FILE, ORB1 OR EPHEM OPTION, IT IS RECOMMENDED THAT THIS PARAMETER BE INPUT AS 1.	

*If either the Orbit File, ORB1 or EPHEM option is used, these parameters are left blank.

Table 11. Card Group 10: Transfer Trajectory Characteristics (Sheet 2 of 3)

CARD 10				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
ISPIN	I1	66	ATTITUDE PREDICTION TAPE INDICATOR = 0 IMPLIES THAT THE ATTITUDE PREDICTION TAPE IS NOT USED = 1 IMPLIES THAT AN ATTITUDE PREDICTION TAPE IS PROVIDED ON FORTRAN LOGICAL UNIT NUMBER 36.	
IPSET*	I1	67	PERTUBATIONS INDICATOR. THIS PARAMETER CONTROLS THE PERTUBATION MODEL USED BY THE BROUWER PROPAGATOR. = 0 IMPLIES NO PERTUBATIONS (TWO-BODY) = 1 IMPLIES THAT SECULAR TERMS ARE ADDED FOR BOTH K2 AND K4** = 2 *IMPLIES THAT LONG AND SHORT PERIOD* TERMS DUE TO BOTH K2 AND K4 ARE ADDED. = 3 IMPLIES THAT K4 IS SET TO ZERO AND IPSET = 2 LOGIC IS USED.	
IDSECC	I1	68	CURRENTLY A DUMMY ARGUMENT (LEAVE BLANK)	
IBUG	I1	69	DEBUG PRINT CONTROL. THIS PARAMETER CONTROLS THE PRINTING OF THE DEBUG OUTPUT. = 0 IMPLIES THAT NO DEBUG OUTPUT IS TO BE WRITTEN = 1 IMPLIES THAT DEBUG OUTPUT IS DESIRED, INCLUDING THE CONVERSION OF THE SEVEN-TRACK ORB1 TAPE (IF APPLICABLE).	
IDIVID	I2	70-71	TIME REDUCTION FACTOR. DURING THE SEARCH TO FIND APOGEE OF THE TRANSFER TRAJECTORY, DELTIM (SEE CARD 3B) WILL BE DIVIDED BY THIS PARAMETER WHEN IN THE VICINITY OF APOGEE OF THE TRANSFER TRAJECTORY (SEE SECTION A.1 OF APPENDIX A.)	
ITRACK	I1	72	ORB1 TRACK INDICATOR. = 7 IMPLIES THAT A SEVEN-TRACK DOUBLE-PRECISION ORB1 TAPE IS INPUT ON DD NAME GENTAP = 9 IMPLIES THAT A NINE-TRACK SINGLE-PRECISION ORB1 TAPE IS INPUT ON FORTRAN LOGICAL UNIT NUMBER 17. IF THE ORB1 OPTION IS NOT SELECTED, IT IS RECOMMENDED THAT THIS PARAMETER BE INPUT AS 9.	

*If either the Orbit File, ORB1 or EPHEM option is used, these parameters are left blank.

**The terms K2 and K4 are Brouwer equivalents of the earth perturbation terms J_2 and J_4 (see Reference 2).

Table 11. Card Group 10: Transfer Trajectory Characteristics (Sheet 3 of 3)

CARD 10				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
IEPHEM	I1	73	EPHEM TAPE INDICATOR = 0 IMPLIES THAT AN EPHEM TAPE IS NOT INPUT = 1 IMPLIES THAT AN EPHEM TAPE IS INPUT ON FORTRAN LOGICAL UNIT NUMBER 17.	

Table 12. Card Group 11: Transfer Trajectory Epoch

CARD 11				
PARAMETER	FIELD	COLUMNS	DEFINITION	UNITS
SATID	A6	1-6	SATELLITE IDENTIFICATION INDICATOR	
IYRE*	I2	11-12	YEAR OF TRANSFER ORBIT EPOCH (LAST TWO DIGITS) (00 to 99)	
IMOE*	I2	13-14	MONTH OF TRANSFER ORBIT EPOCH (01 to 12)	
IDAE*	I2	15-16	DAY OF TRANSFER ORBIT EPOCH (01 to 31)	
IHRE*	I2	19-20	HOUR OF TRANSFER ORBIT EPOCH (01 to 23)	
IMNE*	I2	21-22	MINUTE OF TRANSFER ORBIT EPOCH (00 to 59)	
ISEE*	I2	23-24	SECOND OF TRANSFER ORBIT EPOCH (00 to 59)	
TITLE	8A6	31-78	USER SUPPLIED COMMENTS	

*If the orbit file, ORB1 tape, or EPHEM tape option is selected, these parameters may be left blank.

Table 13. Default Ground Station Table

STATION NAME	NORTH LATITUDE			EAST LONGITUDE			ALTITUDE* M	MINIMUM ELEVATION ANGLE DEG
	DEG	MIN	SEC	DEG	MIN	SEC		
ROSMAN	35	11	46	277	7	27	876.00	10.00
FTMYRS	26	32	54	278	8	5	9.00	10.00
MOJAVE	35	14	49	243	6	1	921.00	10.00
ALASKA	64	52	19	212	9	40	189.00	10.00
ORORAL	-35	-37	-38	148	57	11	947.00	10.00
MADGAR	-19	0	-25	47	18	0	1361.00	10.00
JOBURG	-25	-53	-1	27	42	28	1565.00	10.00
WNKFLD	51	26	45	359	18	14	87.00	10.00
SNTAGO	-33	-8	-56	289	19	53	681.00	10.00
LIMAPU	-11	-46	-35	282	50	59	34.00	10.00
QUITOE	0	-37	-21	281	25	16	3578.00	10.00
NEWFLD	47	44	29	307	16	47	112.00	10.00

*Measured above the mean equitorial radius.

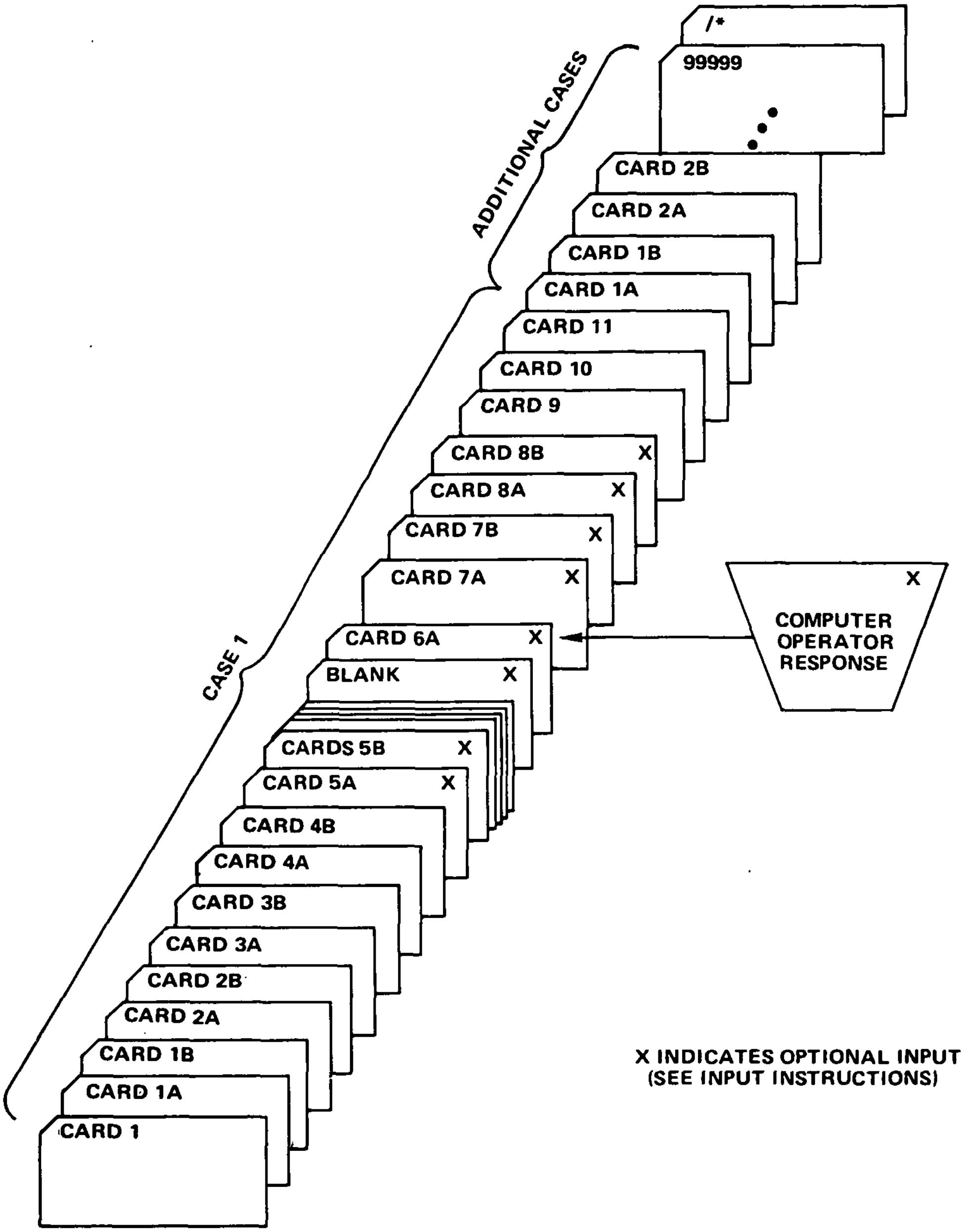

Figure 1. Data-Card Stacking Sequence

SECTION 3

OUTPUT DEFINITIONS

This section discusses the printed output which has been subdivided into the following seven categories.

1. Initial conditions and apogee motor characteristics
2. Debug print (this will appear only if the debug print option is selected, see Card 10)
3. Ignition-time "case" results*
4. "Special case" summary
5. FDS Manager Summary Report (this will appear only if ICOPY = 1 and LVLFDR $\neq$ 0, see Card 1)
6. Ignition time scan and firing attitude excursion table (this will appear only if an attitude excursion is performed, see Card 3B)
7. Ignition time scan and attitude uncertainty table

The printed output from categories 1 through 5 are directed to FORTRAN logical unit number 6. The output from categories 6 and 7 are directed to FORTRAN logical unit numbers 8 and 9, respectively. Table 14 presents an alphabetical list of each symbol, along with its definition and physical units,

---

*The ignition-time "case" mentioned above is not to be confused with the card-stacked case mentioned in Section 2.13. Within each card-stacked case, a scan upon apogee motor ignition time can be performed (see Section 1). Each ignition time which is examined within a particular card-stacked case is defined to be an ignition-time "case".

which appear in output categories 1, 2, 3, 4, 6 and 7. A "1" to the left of the symbol name indicates that it appears only if the debug print option is selected. Table 15 presents an alphabetical list of symbols appearing in the FDS Manager Summary Report (output category 5).

3.1 Initial Conditions and Apogee Motor Characteristics

Figure 2 presents a sample of this portion of the output. Contained in this section are:

1. Input begin and end times as well as user supplied comments (see Sections 2.10 and 2.12)
2. Transfer orbit characteristics
3. Target orbit characteristics
4. Apogee motor characteristics
5. Attitude uncertainties
6. Thrust profile parameters
7. Ground station data
8. Source of the satellite ephemeris information in the transfer trajectory

3.2 Debug Printout

The debug print precedes the ignition-time "case" with which it is associated. A sample of this debug print is presented in Figure 3. The parameters used in this portion of the output are noted by a "1" on Table 14. The debug print contains:

1. Inertial to orbital frame transformation matrices*
2. Satellite position and velocity vectors prior to the apogee motor burn
3. Delta-V vector supplied by the apogee motor**
4. Apogee motor firing attitude
5. Sensitivity of resulting orbit eccentricity to attitude errors and the residual semimajor axis and inclination (target minus achieved)
6. Orbit true anomaly before and after the apogee motor burn

If the firing attitude is input, either via card input, the SPINAT tape, or the FDS Attitude File, the variables DVB and DVBIJK (see Figure 3 and Table 14) will not be the delta-V vector applied in the inertial and orbital frames. This occurs because these variables are computed and output prior to encountering logic which imposes the fixed input attitude constraint. Whenever the firing attitude is input, these parameters should be ignored.

---

*The orbital frame mentioned above is the local-vertical system defined by the satellite position and velocity vectors. The axes of this local-vertical system ($\hat{i}$, $\hat{j}$ and $\hat{k}$) are defined by:

$$\hat{k} = \frac{\vec{R}}{|\vec{R}|} \qquad \text{(local vertical)}$$

$$\hat{j} = \frac{\vec{R} \times \vec{V}}{|\vec{R} \times \vec{V}|} \qquad \text{(orbit normal)}$$

$$\hat{i} = \hat{j} \times \hat{k} \qquad \text{(local horizontal)}$$

where $\vec{R}$ and $\vec{V}$ are satellite position and velocity vectors, respectively.

**The delta-V vector printed is based upon the magnitude of the delta-V as computed from the parameters input on Card 4B (see Section 2.5 and Table 6).

3.3 Ignition-Time "Case" Results

Each card-stacked case (as mentioned in Section 2.13) generates one or more ignition-time "cases". Each apogee motor ignition time which is examined within a card-stacked case constitutes an ignition-time "case". A sample of an ignition-time "case" output is provided in Figure 4. The information presented for each "case" result includes:

1. Ignition time case number and apogee motor ignition time
2. Spin axis attitude at ignition
3. Satellite position and velocity vectors prior to the apogee motor burn as well as the delta-V required to achieve a circular orbit at the ignition time
4. Delta-V vector applied by the apogee boost motor
5. The angle between the position and velocity vectors at the ignition time
6. Resulting orbit parameters
7. The residual semimajor axis and inclination (target minus achieved)
8. Sensitivity of resulting orbit eccentricity to attitude errors
9. Ground station elevation angles at the apogee motor ignition time

3.4 Special "Case" Summary

A "special case" summary is generated at the end of each card-stacked case. The case numbers which appear in this summary (see Figure 5) refer to the ignition-time "cases". The data in this output portion is self-explanatory.

3.5 FDS Manager Summary Report

If ICOPY = 1 (see Card 1), a printed copy of the FDS Manager Summary Report is provided. A sample of this report is presented in Figure 6. Table 15 presents the symbols and definitions used. Included in the FDS Manager Summary Report are:

1. Orbit level used (OLVL) (if the Orbit File option is not used, this indicator will be zero)
2. Attitude level used (ALVL) (if the Attitude File option is not used, this indicator will be zero)
3. The orbit level corresponding to the attitude level used (AOLV) (if the Attitude File option is not used, this indicator will be zero)
4. Total number of cases processed
5. Epoch orbit elements
6. Input spin axis attitude and uncertainties*
7. Ignition time (day, hour, minute, and second in packed integer format)
8. Spin axis right ascension and declination
9. Resulting orbit:
    a. semimajor axis
    b. inclination

*If the spin axis is not input, the variables AW and DW are set equal to 180 and 0, respectively.

c. right ascension of the ascending node

d. perigee radius

e. apogee radius

3.6 Ignition Time Scan Tables

For each apogee motor ignition time examined, two tables will be generated:

1. Attitude excursion table

2. Attitude uncertainty table

Each of these tables contains:

1. Apogee boost motor ignition time

2. Spin axis right ascension and declination at ignition time

3. Resulting orbit:

   a. semimajor axis

   b. eccentricity

   c. inclination

   d. mean anomaly

   e. argument of perigee

   f. right ascension of the ascending node

   g. radius of perigee

   h. radius of apogee

4. Reference number

The term "FILE 11" which precedes each of these tables is synonymous with the sequential excursion file.

3.6.1 Attitude Excursion Table

If either NSIGAL or NSIGDE or both NSIGAL and NSIGDE are nonzero, an excursion upon firing attitude will be performed (see sample output in Figure 7). The limits and increments for this excursion have been presented in Section 2.4. The symbol "E" stands for the increment of either spin axis right ascension or declination used for the attitude excursion.

3.6.2 Attitude Uncertainty Table

Referring to Figure 8 it is seen that for each ignition time a table is generated for the following attitude combinations:

1. α_D and δ_D
2. $\alpha_D + U_\alpha$ and δ_D
3. $\alpha_D - U_\alpha$ and δ_D
4. α_D and $\delta_D + U_\delta$
5. α_D and $\delta_D - U_\delta$

where:

α_D is the input or calculated spin axis right ascension at ignition time

δ_D is the input or calculated spin axis declination at ignition time

U_α is the uncertainty in spin axis right ascension obtained from either Card 3B (variable DELA) or the Attitude File

U_δ is the uncertainty in spin axis declination obtained from either Card 3B (variable DELD) or the Attitude File.

The symbol "EAW" stands for uncertainty in spin axis right ascension.

The symbol "EDW" stands for uncertainty in spin axis declination.

Table 14. Output Variables (Sheet 1 of 3)

SYMBOL	DEFINITION	UNITS
A	ORBIT SEMIMAJOR AXIS	KILOMETERS
ALPHA	SPIN AXIS RIGHT ASCENSION	DEGREES
ALPHAW	SPIN AXIS RIGHT ASCENSION	DEGREES
AW	SPIN AXIS RIGHT ASCENSION	DEGREES
C	CASE NUMBER	
DEL	UNCERTAINTY IN SPIN AXIS RIGHT ASCENSION OR DECLINATION	DEGREES
DELTA	SPIN AXIS DECLINATION	DEGREES
[1]DELVR	VELOCITY INCREMENT REQUIRED TO OBTAIN A CIRCULAR ORBIT	KILOMETERS PER SECOND
[1]DVB*	COMPONENTS OF THE APOGEE BOOST MOTOR DELTA-V IN THE INERTIAL COORDINATE SYSTEM (X, Y, Z COMPONENTS IN ROW FORMAT)	KILOMETERS PER SECOND
[1]DVBIJK**	COMPONENTS OF THE APOGEE BOOST MOTOR DELTA-V IN THE LOCAL VERTICAL COORDINATE SYSTEM (I, J, K COMPONENTS IN ROW FORMAT)	KILOMETERS PER SECOND
DW	SPIN AXIS DECLINATION	DEGREES
E	ORBIT ECCENTRICITY	
EAW	UNCERTAINTY IN SPIN AXIS RIGHT ASCENSION	DEGREES
ECC	ORBIT ECCENTRICITY	
EDW	UNCERTAINTY IN SPIN AXIS DECLINATION	DEGREES
I	ORBIT INCLINATION	DEGREES
IAFMOD	FIRING MODE INDICATOR = 1 IMPLIES DEFICIENT ENERGY MODE = 2 IMPLIES SUFFICIENT ENERGY MODE = 3 IMPLIES EXCESS ENERGY MODE	
IATTUD	INPUT ATTITUDE INDICATOR = 0 FIRING ATTITUDE IS TO BE COMPUTED = 1 INPUT ATTITUDE IS TO BE USED	
IFIRE	INPUT FIRING TIME INDICATOR = 0 FIRING TIME IS TO BE COMPUTED = 1 INPUT FIRING TIME IS TO BE USED	

[1]Appears only if debug print option is selected.

*If firing attitude is input, the values of this parameter should be ignored since they are calculated prior to the imposition of the fixed attitude constraint.

**The element I is the component of DELTA-V normal to the position vector; element J is the component of DELTA-V normal to the orbit plan; element K is the component of DELTA-V along the position vector. If firing attitude is input, the values of this parameter should be ignored.

Table 14. Output Variables (Sheet 2 of 3)

SYMBOL	DEFINITION	UNITS
[1]IFIRST	FIRING TIME SCAN INDICATOR. = 0 IMPLIES THAT THE INDICATED FIRING TIME IS AT THE APOGEE OF THE TRANSFER TRAJECTORY. = 1 IMPLIES THAT THE INDICATED FIRING TIME IS PRIOR TO APOGEE OF THE TRANSFER TRAJECTORY = 2 IMPLIES THAT THE INDICATED FIRING TIME IS AFTER APOGEE OF THE TRANSFER TRAJECTORY	
INCL	ORBIT INCLINATION	DEGREES
IORB1	ORB1 USAGE INDICATOR = 0 IMPLIES THAT AN ORB1 TAPE IS NOT USED = 1 IMPLIES THAT AN ORB1 TAPE IS USED	
[1]ISERCH	DUPLICATE FIRING TIME INDICATOR (SEE IFIRST)	
M	ORBIT MEAN ANOMALY	DEGREES
M ANOM	ORBIT MEAN ANOMALY	DEGREES
N	ORBIT NODE	DEGREES
[1]NGDELA	SENSITIVITY OF RESULTING ORBIT ECCENTRICITY TO NEGATIVE ERRORS IN SPIN AXIS RIGHT ASCENSION.	$(DEGREE)^{-1}$
[1]NGDELD	SENSITIVITY OF RESULTING ORBIT ECCENTRICITY TO NEGATIVE ERRORS IN SPIN AXIS DECLINATION	$(DEGREE)^{-1}$
OMEGA	ORBIT ARGUMENT OF PERIGEE	DEGREES
PERD	TRANSFER TRAJECTORY PERIOD	SECONDS
RA	RADIUS OF APOGEE	KILOMETERS
RP	RADIUS OF PERIGEE	KILOMETERS
RANODE	RIGHT ASCENSION OF THE ASCENDING NODE	DEGREES
[1]RAORBF	POSITION VECTOR, PRIOR TO THE APOGEE BOOST MOTOR BURN, IN THE LOCAL VERTICAL SYSTEM.	KILOMETERS
SMA	SEMIMAJOR AXIS	KILOMETERS
[1]ST	TIME FROM TRANSFER TRAJECTORY EPOCH	SECONDS
[1]TANOMR	ORBIT TRUE ANOMALY AFTER THE APOGEE BOOST MOTOR BURN	DEGREES
[1]TANOMT	ORBIT TRUE ANOMALY BEFORE THE APOGEE BOOST MOTOR BURN	DEGREES
[1]VAORBF	VELOCITY VECTOR, PRIOR TO THE APOGEE BOOST MOTOR BURN, IN THE LOCAL VERTICAL SYSTEM. (THE FIRST ELEMENT REPRESENTS THE COMPONENT NORMAL TO THE POSITION VECTOR; THE SECOND ELEMENT REPRESENTS THE COMPONENT NORMAL TO THE ORBIT PLANE; THE THIRD ELEMENT REPRESENTS THE COMPONENT ALONG THE POSITION VECTOR.)	KILOMETERS PER SECOND

[1]Appears only if DEBUG print option is selected.

Table 14. Output Variables (Sheet 3 of 3)

SYMBOL	DEFINITION	UNITS
[1]VBOOST	APOGEE BOOST MOTOR DELTA-V	KILOMETERS PER SECOND
[1]VC	CIRCULAR ORBIT VELOCITY	KILOMETERS PER SECOND
VELAPO	VELOCITY AT APOGEE OF THE TRANSFER TRAJECTORY	KILOMETERS PER SECOND
W	ORBIT ARGUMENT OF PERIGEE	DEGREES

[1] Appears only if DEBUG print option is selected.

Table 15. FDS Manager Summary Report Variables

SYMBOL	DEFINITION	UNITS
A	SPIN AXIS RIGHT ASCENSION AT IGNITION	DEGREES
ALVL	ATTITUDE LEVEL (IF THE ATTITUDE FILE OPTION IS NOT SELECTED, THIS VARIABLE WILL BE ZERO)	
AOLV	ORBIT LEVEL ASSOCIATED WITH ALVL (IF THE ATTITUDE FILE OPTION IS NOT SELECTED, THIS VARIABLE WILL BE ZERO).	
AW	INPUT SPIN AXIS RIGHT ASCENSION*	DEGREES
D	SPIN AXIS DECLINATION AT IGNITION	DEGREES
DW	INPUT SPIN AXIS DECLINATION*	DEGREES
E	ORBIT ECCENTRICITY	
EAW	UNCERTAINTY IN SPIN AXIS RIGHT ASCENSION	DEGREES
EDW	UNCERTAINTY IN SPIN AXIS DECLINATION	DEGREES
I	ORBIT INCLINATION	DEGREES
M	ORBIT MEAN ANOMALY	DEGREES
N	ORBIT RIGHT ASCENSION OF THE ASCENDING NODE	DEGREES
OLVL	ORBIT LEVEL (IF THE ORBIT FILE OPTION IS NOT SELECTED, THIS PARAMETER WILL BE ZERO)	
P	PERIGEE RADIUS	KILOMETERS
RA	APOGEE RADIUS	KILOMETERS
S	ORBIT SEMIMAJOR AXIS	KILOMETERS
W	ORBIT ARGUMENT OF PERIGEE	DEGREES

*If the spin axis attitude is not input, AW and DW will appear as 180.000 and 0.0, respectively.

```
                                   IMP-H APOGEE MOTOR FIRING

                                   PREPARED        0      0 HRS

                        COVERAGE BEGINS   SEP 25, 1972   12 HOURS   0 MINUTES

                        COVERAGE ENDS     SEP 26, 1972   20 HOURS   0 MINUTES


INPUT ORBIT NO. IS     1

TRANSFER ORBIT ELEMENTS
   SMA,KM          ECC          INCL,DEG      M ANOM,DEG     OMEGA,DEG     RA NODE,DEG
125400.250      0.547165        28.646          0.044         141.259        201.641
     INPUT TRANSFER ORBITAL ELEMENTS ARE OSCULATING.

TRANSFER ORBIT EPOCH    72 923    13624

TARGET ORBIT ELEMENTS

     SMA           ECC            INCL
  233000.000    0.02030250       29.070

BOOST PARAMETERS   TBOOST =    23.75 SECS   WLOAD =    841.42 LBS   WEXP =    248.48 LBS   IMPULSE =  0.71288000E 05 LB-SEC
                   VBOOST =    0.9846 KM/SEC   EXHAUST VELOCITY =    2.8131 KM/SEC   BURN DELAY =       0.0    SEC
                   VBOOST =   3230.28 FT/SEC   EXHAUST VELOCITY =  9229.38 FT/SEC

DEL ALPHA =     1.00 DEGS.    DEL DELTA =     1.00 DEGS.    DELTA TIME =300.00 SEC.
TOTAL NUMBER OF THRUST SEGEMENTS      7
TIME INTERVALS                 0.0                  0.50000000E 00      0.57500000E 01      0.13250000E 02      0.19250000E 02
                               0.20250000E 02       0.21250000E 02      0.23750000E 02
TIME INCREMENT                 0.59999964E-01       0.10000000E 01      0.10000000E 01      0.10000000E 01      0.10000000E 01
                               0.59999964E-01       0.99999964E-01
COEF FOR INTERVAL  1           0.0                  0.72000000E 04
COEF FOR INTERVAL  2           0.36057266E 04      -0.11316699E 03      0.36551542E 01
COEF FOR INTERVAL  3           0.30949019E 04       0.89823517E 02     -0.19607840E 01
COEF FOR INTERVAL  4           0.36387361E 04       0.23631363E 02     -0.26473522E 01
COEF FOR INTERVAL  5           0.36610000E 04       0.14200000E 03     -0.60000000E 03
COEF FOR INTERVAL  6           0.32000000E 04      -0.48000000E 04      0.20000000E 04
COEF FOR INTERVAL  7           0.38742647E 03      -0.37514258E 03      0.90009999E 02

STATION NAME      LATITUDE          LONGITUDE        ALTITUDE      ELEVATION

                 DEG  MIN  SEC    DEG  MIN  SEC          M            DEG
   ROSMAN         35   11   46    277    7   27       876.00        10.00
   FTMYRS         26   32   54    278    8    5         9.00        10.00
   MOJAVE         35   14   49    243    6    1       921.00        10.00
   ALASKA         64   52   19    212    9   40       189.00        10.00
   ORORAL        -35  -37  -38    148   57   11       947.00        10.00
   MADGAR        -19    0  -25     47   18    0      1361.00        10.00
   JOBURG        -25  -53   -1     27   43   28      1565.00        10.00
   WNKFLD         51   26   45    359   13   14        87.00        10.00
   SNTAGO        -33   -8  -56    289   19   53       681.00        10.00
   LIMAPU        -11  -46  -35    282   50   59        34.00        10.00
   QUITOE          0  -37  -21    281   25   16      3578.00        10.00
   NEWFLD         47   44   29    307   16   47       112.00        10.00

DELTIM WILL BE DIVIDED BY 99 DURING THE APOGEE SEARCH.
EPHEM TAPE IS BEING USED TO OBTAIN POSITION AND VELOCITY VECTORS.
```

Figure 2. Sample Initial Conditions Printout

```
      5501 IS DREF FOR 1972  9 23

BEGTIM =  0.2160000E 06 ENDTIM =  0.3312000E 06

START APOGEE SEARCH TIME =  0.2160000D 06

ELCOMP FOUND  7 STATIONS AVAILABLE FOR COVERAGE AT TIME,ST =  0.2230217D 06

INERTIAL TO ORBITAL FRAME TRANSFORMATION MATRIX

  -0.33    -0.87     0.37
 -0.18     0.45     0.88
 -0.93     0.22    -0.30

RAORBF  -0.1562500E-01 -0.1562500E-01  0.2410805E 06 VAORBF   0.3012848E 00  0.0          -0.1909211E-04

VBOOST =  0.9845988E 00 VC =  0.1285847E 01 DELVR =  0.9845619E 00

FIRING MODE IS 3

VCI =  0.1285725E 01 VCJ =  0.1771324E-01

ORBITAL TO INERTIAL FRAME TRANSFORMATION MATRIX

  -0.33    -0.18    -0.93
 -0.87     0.45     0.22
  0.37     0.88    -0.30

DVBIJK     0.9844398E 00  0.1771324E-01  0.1909211E-04

DVB   -0.3239051E 00 -0.8466687E 00  0.3842823E 00

ATTITUDE AT TIME,ST =  0.2230217D 06 IS  ALPHA =  69.06491 DELTA = -22.97273

SENSITIVITY TO ALPHA =-.0021 SENSITIVITY TO DELTA =-.0003
NEGATIVE PERTURBATIONS  NGDELA = -0.2200644E-02 NGDELD = -0.4504174E-03

DELTA SMA = -0.9141875E 03 DELTA INCLINATION = -0.1597443E 00

TANOMR =  0.0            TANOMT =  0.1799985E 03
```

Figure 3. Sample Debug Printout for Ignition-Time "case"

```
CASE NO.   1 OF APOGEE NUMBER   1 IS AN EXCESS ENERGY CASE. THE FIRING TIME IS 1972  9 25 AT 13 HR 57 MIN  2 SEC.
REFNO.         1

THE FIRING ATTITUDE IS ALPHA =   69.065 DEG  DELTA =  -22.973 DEG  DERIVED.

INERTIAL POSITION(KM)      = -223908.875    53014.539   -71931.375
         VELOCITY(KM/SEC) =    -0.098300    -0.261503     0.112808

ORBITAL POSITION(KM)      =        -0.016       -0.016   241080.500  MAGNITUDE =   241080.500 KM
        VELOCITY(KM/SEC) =         0.301        0.0          -0.000  MAGNITUDE =        0.301 KM/SEC =      988.458 FT/SEC

RADII(KM)  APOGEE =  244174.875  PERIGEE =   6625.527 OF THE TRANSFER ORBIT.

VC(KM/SEC) =     1.28585 VBOOST(KM/SEC) =   0.98460 DELVR(KM/SEC) =   0.98456
VC(FT/SEC) =     4218.61 VBOOST(FT/SEC) =   3230.28 DELVR(FT/SEC) =   3230.16

DELTA V APPLIED(INERTIAL) =   -0.32391   -0.84667    0.38428
               (ORBITAL) =    0.98444    0.01771    0.00002

INCLINATION CHANGE IS DIRECTED ALONG +J AXIS IN ORBIT FRAME SYSTEM

ANGLE BETWEEN POSITION AND VELOCITY VECTORS(RDOTV) =   89.974 DEG.  TRUE ANOMALY OF TRANSFER ORBIT =  179.999 DEG.


ORBITAL ELEMENTS OF MISSION ORBIT

SMA = 233914.188 KM  ECC = 0.030636  INCL =   29.230 DEG  M ANOM =  179.902 DEG  OMEGA =  142.433 DEG  RA NODE =  200.643DEG

INERTIAL POSITION(KM)      = -223915.000    52997.922   -71923.938
         VELOCITY(KM/SEC) =    -0.415527    -1.091140     0.489393

DELTA(TARGET - MISSION)  SMA =  -914.188 KM  INCL =   -0.160 DEG

RADII(KM)  APOGEE =  241080.313  PERIGEE =  226747.938 OF THE MISSION ORBIT.

SENSITIVITY OF ECCENTRICITY  TO ALPHA =  -0.002114 PER DEG(+)  TO DELTA = -0.000257 PER DEG(+)
                             TO ALPHA =  -0.002201 PER DEG(-)  TO DELTA = -0.000450 PER DEG(-)

STATIONS    ELEVATION(DEG)
 SNTAGO          62.849
 LIMAPU          55.567
 QUITOE          53.849
 FTMYRS          33.309
 FCSMAN          26.046
 NEWFLD          23.313
 JOBURG          19.439
```

Figure 4. Sample Ignition-Time "Case" Results

```
*****   SPECIAL   CASES   *****

CASE NO.  16 RESULTS IN A MINIMUM DELTA INCLINATION.

CASE NO.  18 RESULTS IN A MINIMUM DELTA SEMI-MAJOR AXIS.

CASE NO.  16 RESULTS IN A MINIMUM SENSITIVITY OF ECCENTRICITY TO ALPHA.

CASE NO.   1 RESULTS IN A MINIMUM SENSITIVITY OF ECCENTRICITY TO DELTA.
```

Figure 5. Sample "Special Case" Summary

```
                INTEGRATING IMPMOT FDS MANAGER REPORT NC.  1
OLVL   C ALVL   C AOLV   C TOTAL NUMBER OF FIRING TIMES PROCESSED  18

EPOCH ORBIT A 125400.3 E 0.94716 I  28.646 M   0.044 W 141.259 N 201.641
INPUT ATTITUDE  AW   0.0   DW   0.0   EAW   1.000 EDW   1.000

251357 2 A  69.06 D -22.97 S233914. I  29.23 N 200.64 RA241080. P226748.
251357 2 A  69.78 D -21.02 S233914. I  28.00 N 202.69 RA241080. P226748.
251352 2 A  69.21 D -22.86 S233914. I  29.14 N 200.78 RA241080. P226748.
251352 2 A  69.82 D -21.19 S233914. I  28.09 N 202.53 RA241080. P226748.
251347 2 A  69.40 D -22.64 S233913. I  28.98 N 201.04 RA241079. P226747.
251347 2 A  69.82 D -21.48 S233913. I  28.25 N 202.26 RA241079. P226747.
251342 2 A  69.70 D -22.09 S233910. I  28.61 N 201.64 RA241078. P226742.
2514 2 2 A  68.95 D -23.01 S233914. I  29.27 N 200.58 RA241080. P226748.
2514 2 2 A  69.71 D -20.93 S233914. I  27.96 N 202.76 RA241080. P226748.
2514 7 2 A  68.85 D -22.99 S233914. I  29.28 N 200.57 RA241079. P226748.
2514 7 2 A  69.62 D -20.89 S233914. I  27.95 N 202.77 RA241079. P226748.
251412 2 A  68.77 D -22.91 S233912. I  29.25 N 200.62 RA241078. P226746.
251412 2 A  69.51 D -20.91 S233912. I  27.98 N 202.72 RA241078. P226747.
251417 2 A  68.73 D -22.76 S233910. I  29.17 N 200.74 RA241076. P226745.
251417 2 A  69.38 D -20.99 S233910. I  28.06 N 202.59 RA241076. P226744.
251422 2 A  68.71 D -22.51 S233908. I  29.03 N 200.96 RA241073. P226742.
251422 2 A  69.21 D -21.18 S233908. I  28.19 N 202.35 RA241073. P226742.
251427 2 A  68.87 D -21.82 S233905. I  28.61 N 201.65 RA241070. P226739.
```

Figure 6. Sample FDS Manager Summary Report

IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 57 2	AW .DW	69.065	-22.973	233914.	0.03064	29.230	179.502	142.433	200.643	241080.	226748.	1
	AW -1E.DW 1E	69.065	-23.973	233861.	0.03170	29.986	166.420	156.108	199.483	241275.	226446.	2
	AW -1E.DW 0E	68.065	-22.973	233897.	0.03284	29.412	158.617	162.651	200.357	241577.	226216.	3
	AW -1E.DW -1E	68.065	-21.973	233908.	0.03459	28.844	151.516	168.462	201.263	241999.	225817.	4
	AW 0E.DW 1E	69.065	-23.973	233878.	0.03109	29.803	188.116	135.481	199.757	241149.	226608.	5
	AW 0E.DW 0E	69.065	-22.973	233914.	0.03064	29.230	179.502	142.433	200.643	241080.	226748.	6
	AW 0E.DW -1E	69.065	-21.973	233926.	0.03089	28.662	171.639	149.402	201.561	241153.	226699.	7
	AW 1E.DW 1E	70.065	-23.973	233875.	0.03461	29.625	208.002	116.668	200.028	241968.	225782.	8
	AW 1E.DW 0E	70.065	-22.973	233911.	0.03275	29.092	201.297	122.109	200.926	241571.	226250.	9
	AW 1E.DW -1E	70.065	-21.973	233923.	0.03146	28.485	193.870	128.240	201.657	241282.	226564.	10
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 57 2	AW .DW	69.780	-21.021	233914.	0.03064	28.001	179.502	140.638	202.688	241080.	226748.	15
	AW -1E.DW 1E	68.780	-22.021	233923.	0.03150	28.740	165.859	154.943	201.432	241291.	226556.	16
	AW -1E.DW 0E	68.780	-21.021	233911.	0.03284	28.179	158.273	161.204	202.379	241593.	226230.	17
	AW -1E.DW -1E	68.780	-20.021	233876.	0.03477	27.624	151.449	166.667	203.361	242008.	225744.	18
	AW 0E.DW 1E	69.780	-22.021	233926.	0.03087	28.562	188.056	133.613	201.728	241147.	226704.	19
	AW 0E.DW 0E	69.780	-21.021	233914.	0.03064	28.001	179.902	140.638	202.688	241080.	226748.	20
	AW 0E.DW -1E	69.780	-20.021	233879.	0.03109	27.447	171.803	147.372	203.683	241150.	226607.	21
	AW 1E.DW 1E	70.780	-22.021	233908.	0.03453	28.388	208.301	114.640	202.021	241986.	225830.	22
	AW 1E.DW 0E	70.780	-21.021	233896.	0.03287	27.828	201.556	120.052	202.994	241585.	226207.	23
	AW 1E.DW -1E	70.780	-20.021	233860.	0.03178	27.275	194.171	126.068	204.004	241293.	226427.	24
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 52 2	AW .DW	69.211	-22.862	233914.	0.03064	29.140	179.842	142.345	200.784	241080.	226748.	29
	AW -1E.DW 1E	68.211	-23.862	233872.	0.03167	29.895	166.296	156.088	199.617	241278.	226465.	30
	AW -1E.DW 0E	68.211	-22.862	233908.	0.03281	29.322	158.511	162.609	200.497	241581.	226234.	31
	AW -1E.DW -1E	68.211	-21.862	233920.	0.03456	28.754	151.428	168.397	201.409	242004.	225835.	32
	AW 0E.DW 1E	69.211	-23.862	233878.	0.03108	29.713	188.033	135.419	199.892	241147.	226609.	33
	AW 0E.DW 0E	69.211	-22.862	233914.	0.03064	29.140	179.842	142.345	200.784	241080.	226748.	34
	AW 0E.DW -1E	69.211	-21.862	233926.	0.03089	28.574	171.604	149.285	201.708	241153.	226699.	35
	AW 1E.DW 1E	70.211	-23.862	233863.	0.03464	29.535	207.916	116.610	200.165	241964.	225763.	36
	AW 1E.DW 0E	70.211	-22.862	233900.	0.03279	28.963	201.236	122.023	201.069	241569.	226230.	37
	AW 1E.DW -1E	70.211	-21.862	233912.	0.03151	28.397	193.837	128.120	202.006	241281.	226542.	38
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 52 2	AW .DW	69.822	-21.191	233914.	0.03063	28.089	179.843	140.808	202.535	241080.	226748.	43
	AW -1E.DW 1E	68.822	-22.191	233925.	0.03149	28.829	165.817	155.089	201.286	241291.	226558.	44
	AW -1E.DW 0E	68.822	-21.191	233921.	0.03281	28.267	158.216	161.369	202.228	241595.	226246.	45
	AW -1E.DW -1E	68.822	-20.191	233892.	0.03471	27.710	151.371	166.860	203.205	242011.	225772.	46
	AW 0E.DW 1E	69.822	-22.191	233919.	0.03090	28.651	187.984	133.990	201.580	241146.	226691.	47
	AW 0E.DW 0E	69.822	-21.191	233914.	0.03063	28.089	179.843	140.808	202.535	241080.	226748.	48
	AW 0E.DW -1E	69.822	-20.191	233885.	0.03107	27.534	171.743	147.548	203.525	241151.	226620.	49
	AW 1E.DW 1E	70.822	-22.191	233891.	0.03458	28.477	208.174	114.871	201.871	241978.	225804.	50
	AW 1E.DW 0E	70.822	-21.191	233887.	0.03290	27.916	201.456	120.260	202.639	241581.	226192.	51
	AW 1E.DW -1E	70.822	-20.191	233858.	0.03178	27.362	194.095	126.260	203.843	241290.	226425.	52
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 47 2	AW .DW	69.399	-22.636	233913.	0.03064	28.978	179.784	142.151	201.044	241079.	226747.	57
	AW -1E.DW 1E	68.399	-23.636	233885.	0.03163	29.730	166.139	156.000	199.865	241282.	226488.	58
	AW -1E.DW 0E	68.399	-22.636	233919.	0.03278	29.158	158.366	162.482	200.755	241586.	226252.	59
	AW -1E.DW -1E	68.399	-21.636	233929.	0.03454	28.593	151.337	168.228	201.677	242008.	225849.	60
	AW 0E.DW 1E	69.399	-23.636	233879.	0.03107	29.549	187.948	135.260	200.142	241145.	226614.	61
	AW 0E.DW 0E	69.399	-22.636	233913.	0.03064	28.978	179.784	142.151	201.044	241079.	226747.	62
	AW 0E.DW -1E	69.399	-21.636	233923.	0.03091	28.413	171.579	149.050	201.979	241153.	226693.	63
	AW 1E.DW 1E	70.399	-23.636	233853.	0.03466	29.373	207.852	116.431	200.417	241959.	225747.	64
	AW 1E.DW 0E	70.399	-22.636	233887.	0.03284	28.802	201.192	121.814	201.331	241567.	226206.	65
	AW 1E.DW -1E	70.399	-21.636	233896.	0.03157	28.238	193.826	127.871	202.278	241280.	226512.	66
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 47 2	AW .DW	69.822	-21.476	233913.	0.03064	28.249	179.784	141.084	202.259	241079.	226747.	71
	AW -1E.DW 1E	68.822	-22.476	233922.	0.03150	28.991	165.807	155.307	201.023	241291.	226554.	72
	AW -1E.DW 0E	68.822	-21.476	233928.	0.03278	28.427	158.181	161.622	201.956	241595.	226261.	73
	AW -1E.DW -1E	68.822	-20.476	233909.	0.03465	27.869	151.297	167.162	202.923	242013.	225805.	74

Figure 7. Sample Ignition Time and Attitude Scan Table

IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 57 2	AW .DW	69.065	-22.973	233914.	0.03064	29.230	175.902	142.433	200.643	241080.	226748.	1
	AW .DW-EDW	69.065	-21.973	233926.	0.03089	28.662	171.639	149.402	201.561	241153.	226699.	11
	AW+EAW.DW	70.065	-22.973	233911.	0.03275	29.052	201.297	122.109	200.926	241571.	226250.	12
	AW .DW+EDW	69.065	-23.973	233878.	0.03109	29.803	188.116	135.481	199.757	241149.	226608.	13
	AW-EAW.DW	68.065	-22.973	233897.	0.03284	29.412	158.617	162.651	200.357	241577.	226216.	14
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 57 2	AW .DW	69.780	-21.021	233914.	0.03064	28.001	179.902	140.638	202.688	241080.	226748.	15
	AW .DW-EDW	69.780	-20.021	233879.	0.03109	27.447	171.803	147.372	203.683	241150.	226607.	25
	AW+EAW.DW	70.780	-21.021	233896.	0.03287	27.828	201.556	120.052	202.994	241585.	226207.	26
	AW .DW+EDW	69.780	-22.021	233926.	0.03087	28.562	188.056	133.813	201.728	241147.	226704.	27
	AW-EAW.DW	68.780	-21.021	233911.	0.03284	28.179	158.273	161.204	202.379	241593.	226230.	28
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 52 2	AW .DW	69.211	-22.862	233914.	0.03064	29.140	175.842	142.345	200.784	241080.	226748.	29
	AW .DW-EDW	69.211	-21.862	233926.	0.03089	28.574	171.604	149.285	201.708	241153.	226699.	39
	AW+EAW.DW	70.211	-22.862	233900.	0.03279	28.963	201.236	122.023	201.069	241569.	226230.	40
	AW .DW+EDW	69.211	-23.862	233878.	0.03108	29.713	188.033	135.419	199.892	241147.	226609.	41
	AW-EAW.DW	68.211	-22.862	233908.	0.03281	29.322	158.511	162.609	200.497	241581.	226234.	42
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 52 2	AW .DW	69.822	-21.191	233914.	0.03063	28.089	175.843	140.808	202.535	241080.	226748.	43
	AW .DW-EDW	69.822	-20.191	233885.	0.03107	27.534	171.743	147.548	203.525	241151.	226620.	53
	AW+EAW.DW	70.822	-21.191	233887.	0.03290	27.916	201.458	120.250	202.839	241581.	226192.	54
	AW .DW+EDW	69.822	-22.191	233919.	0.03090	28.651	187.984	133.990	201.580	241146.	226691.	55
	AW-EAW.DW	68.822	-21.191	233921.	0.03281	28.267	158.216	161.369	202.228	241595.	226246.	56
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 47 2	AW .DW	69.399	-22.636	233913.	0.03064	28.978	175.784	142.151	201.044	241079.	226747.	57
	AW .DW-EDW	69.399	-21.636	233923.	0.03091	28.413	171.579	149.050	201.979	241153.	226693.	67
	AW+EAW.DW	70.399	-22.636	233887.	0.03284	28.802	201.192	121.814	201.331	241567.	226206.	68
	AW .DW+EDW	69.399	-23.636	233879.	0.03107	29.549	187.948	135.260	200.142	241145.	226614.	69
	AW-EAW.DW	68.399	-22.636	233919.	0.03278	29.158	158.386	162.482	200.755	241586.	226252.	70
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 47 2	AW .DW	69.822	-21.476	233913.	0.03064	28.249	175.784	141.084	202.259	241079.	226747.	71
	AW .DW-EDW	69.822	-20.476	233895.	0.03103	27.692	171.675	147.644	203.239	241151.	226638.	81
	AW+EAW.DW	70.822	-21.476	233877.	0.03291	28.075	201.347	120.591	202.560	241575.	226180.	82
	AW .DW+EDW	69.822	-22.476	233908.	0.03094	28.813	187.915	134.267	201.313	241144.	226671.	83
	AW-EAW.DW	68.822	-21.476	233928.	0.03278	28.427	158.181	161.622	201.556	241595.	226261.	84
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 13 42 2	AW .DW	69.704	-22.086	233910.	0.03064	28.613	175.723	141.661	201.644	241078.	226742.	85
	AW .DW-EDW	69.704	-21.086	233909.	0.03096	28.052	171.581	148.476	202.602	241151.	226666.	95
	AW+EAW.DW	70.704	-22.086	233868.	0.03292	28.438	201.184	121.271	201.937	241566.	226171.	96
	AW .DW+EDW	69.704	-23.086	233886.	0.03102	29.180	187.851	134.826	200.720	241142.	226631.	97
	AW-EAW.DW	68.704	-22.086	233930.	0.03275	28.791	158.207	162.111	201.348	241592.	226268.	98
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 14 2 2	AW .DW	68.947	-23.009	233914.	0.03064	29.272	175.962	142.456	200.578	241080.	226748.	99
	AW .DW-EDW	68.947	-22.009	233924.	0.03090	28.704	171.681	149.444	201.493	241152.	226696.	109
	AW+EAW.DW	69.947	-23.009	233922.	0.03271	29.093	201.368	122.120	200.861	241574.	226270.	110
	AW .DW+EDW	68.947	-24.009	233881.	0.03108	29.846	188.196	135.481	199.694	241150.	226611.	111
	AW-EAW.DW	67.947	-23.009	233886.	0.03287	29.454	158.709	162.643	200.292	241573.	226199.	112
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 14 2 2	AW .DW	69.712	-20.925	233914.	0.03063	27.960	175.961	140.541	202.760	241080.	226748.	113
	AW .DW-EDW	69.712	-19.925	233873.	0.03111	27.406	171.857	147.277	203.757	241149.	226597.	123
	AW+EAW.DW	70.712	-20.925	233906.	0.03285	27.786	201.646	119.923	203.068	241589.	226223.	124
	AW .DW+EDW	69.712	-21.925	233931.	0.03085	28.520	188.131	133.702	201.798	241148.	226714.	125
	AW-EAW.DW	68.712	-20.925	233902.	0.03287	28.137	158.341	161.097	202.450	241590.	226213.	126
IGNITION TIME	ATTITUDE SCAN	ALPHAW	DELTAW	A	E	I	M	W	N	APOGEE	PERIGEE	REFNO
72 9 25 14 7 2	AW .DW	68.850	-22.987	233914.	0.03063	29.277	180.021	142.428	200.570	241079.	226748.	127
	AW .DW-EDW	68.850	-21.987	233919.	0.03091	28.709	171.729	149.428	201.484	241150.	226688.	137
	AW+EAW.DW	69.850	-22.967	233931.	0.03268	29.098	201.448	122.072	200.854	241577.	226286.	138
	AW .DW+EDW	68.850	-23.987	233883.	0.03107	29.651	188.274	135.434	199.698	241150.	226616.	139
	AW-EAW.DW	67.850	-22.987	233875.	0.03290	29.460	158.790	162.593	200.284	241569.	226181.	140

Figure 8. Sample Ignition Time and Attitude Scan Table (attitude uncertainty only)

SECTION 4

JOB CONTROL LANGUAGE

The Job Control Language (JCL) required to execute the IMPMOT Program on the IBM 360 series computer system at GSFC is presented in this section. For the purpose of discussion, it is assumed that an object file of the IMPMOT program resides on the first file of a nine-track, standard-labeled magnetic tape, YOURTAPE.

The examples presented in the following subsections are the ones which the user is most likely to encounter. Additional combinations can be formed, using the examples as a guide, if the user keeps in mind the following rules

1. DD names FT10F001 and FT50F001 are used for the FDS Manager Summary Report. FT10F001 defines a scratch sequential data set. FT50F001 identifies the FDS Manager Summary Report assigned to the IMPMOT Program.
2. DD name FT11F001 is reserved for the sequential excursion file.
3. DD names FT17F001 and GENTAP are used in conjunction with ORB1 and EPHEM tapes (see Section 2.11.1 for the internal flags which must be set).
    - A. If a seven-track ORB1 tape is used, it is entered via GENTAP. The program will convert the seven-track tape to nine-track format and store the result on FT17F001.

B. If a nine-track ORB1 tape is used, it is entered directly via FT17F001.

C. If a nine-track EPHEM tape is used, it is entered via FT17F001.

4. DD name FT20F001 defines the FDS Orbit File.

5. DD name FT25F001 defines the FDS Attitude File.

6. DD name FT36F001 defines the SPINAT tape.*

Seven examples are presented.

1. JCL using the Orbit File and the Attitude File
2. JCL using an ORB1 tape and the Attitude File
3. JCL using an EPHEM tape and the Attitude File
4. JCL using the Brouwer propagator and the Attitude File
5. JCL using the Orbit File and a SPINAT tape
6. JCL using the Orbit File without the Attitude File
7. JCL without the FDS Manager Summary Report

In examples one through six, it is assumed that the FDS Manager Summary Report will be generated. For these examples it is further assumed that:

1. The Attitude File data set, with data set name, ATTITUDE. FILE, resides on a disk.
2. The Orbit File data set, with data set name, ORBIT. FILE, resides on a disk.

*The SPINAT tape indicated above, refers to the attitude prediction tape mentioned in Section 2.11.

3. The SPINAT tape is a nine-track non-labeled magnetic tape with volume serial number SPINAT.

4. The EPHEM tape is a nine-track non-labeled magnetic tape with volume serial number EPHEM.

5. The FDS Manager Summary Report file, with data set name FDS. MANAGER. SUMMARY, is a preallocated data set residing on a disk.

6. The Sequential Excursion File, with data set name, EXFILE, is a preallocated data set residing on a disk. This file is assumed to be generated for each example presented in this section.

4.1 JCL Using the Orbit and Attitude Files

```
//LINK EXEC LINKGO,REGION.GO=300K
//LINK.SYSLIN DD UNIT=2400-9,DISP=(OLD,KEEP),DSN=IMPMOT.OBJECT,
// LABEL=(1,SL),DCB=(LRECL=80,RECFM=FB,BLKSIZE=3200),VOL=SER=YOURTAPE
//GO.FT05F001 DD DDNAME=DATA5
//GO.FT06F001 DD SYSOUT=A,SPACE=(CYL,(3,2)),
// DCB=(LRECL=137,RECFM=VBA,BLKSIZE=7265)
//GO.FT08F001 DD SYSOUT=A,SPACE=(CYL,(3,2)),
// DCB=(LRECL=137,RECFM=VBA BLKSIZE=7265)
//GO.FT10F001 DD UNIT=2314,DISP=(NEW,DELETE),DSN=&&SCRATCH,
// SPACE=(CYL,(2,2)),DCB=(LRECL=72,RECFM=FB,BLKSIZE=7200)
//GO.FT11F001 DD UNIT=2314,DISP=SHR,DSN=EXFILE,
// DCB=(LRECL=164,RECFM=VBS,BLKSIZE=6564),VOL=SER=XXXXXX
//GO.FT17F001 DD DUMMY
//GO.FT20F001 DD UNIT=2314,DISP=SHR,DSN=ORBIT.FILE,VOL=SER=XXXXXX
//GO.FT25F001 DD UNIT=2314,DISP=SHR,DSN=ATTITUDE.FILE,VOL=SER=XXXXXX
//GO.FT36F001 DD DUMMY
//GO.FT50F001 DD UNIT=2314,DISP=SHR,DSN=FDS.MANAGER.SUMMARY,
// VOL=SER=XXXXXX
//GO.DATA5 DD*
//GO.GENTAP DD DUMMY
/* ENTER DATA CARDS HERE
```

4.2 JCL Using an ORB1 Tape and the Attitude File

An ORB1 tape may be in either a seven- or nine-track format. An example of each is presented below. Section 2.11.1.2 describes the use of ORB1 tapes.

4.2.1 Seven-Track ORB1

The changes to the JCL, as presented in Section 4.1, needed to execute with a seven-track ORB1 tape are as follows.

```
                                                                Card Ref.
                                                                   No.

//GO.FT17F001 DD UNIT=2314,DISP=(NEW,DELETE),DSN=&&NINE,            13
// SPACE=(CYL,(5,2)),DCB=(LRECL=5608,RECFM=VS,BLKSIZE=5616)         13A
// GO.FT20F001 DD DUMMY                                             14
//GO.GENTAP DD UNIT=2400-7,DISP=(OLD,KEEP),DSN=SEVEN,               20
// LABEL=(1,BLP),DCB=(DEN=1,RECFM=V, BLKSIZE=4250),VOL=SER=TAPE     20A
//GO.FT20F001
```

Where DD name GENTAP points to the seven-track double-precision ORB1 tape.

4.2.2 Nine-Track ORB1

The changes to the JCL presented in Section 4.1 which are required to execute with a nine-track single-precision ORB1 tape are as follows

```
                                                                        Card Ref.
                                                                           No.

//GO.FT17F001 DD UNIT=2400-9,DISP=(OLD,KEEP),DSN=NINE,                      13
// LABEL=(,BLP),DCB=(LRECL=5608,RECFM=VS,BLKSIZE=5616),VOL=SER=TAPE         13A
//GO.FT20F001 DD DUMMY                                                      14
```

4.3 JCL Using an EPHEM Tape and the Attitude File

If an EPHEM tape is desired, the changes to the JCL presented in Section 4.1 are:

	Card Ref. No.
//GO.FT17F001 DD UNIT=2400-9,DISP=(OLD,KEEP),DSN=EPHEM,	13
// LABEL=(1,BLP),DCB=(DEN=2,LRECL=2808,RECFM=VS,BLKSIZE=2816),VOL=SER=EPHEM	13A
//GO.FT20F001 DD DUMMY	14

4.4 JCL Using the Brouwer Propagator and the Attitude File

The changes to the JCL presented in Section 4.1 when using the Brouwer propagator are:

	Card Ref. No.
//GO.FT20F001 DD DUMMY	14

4.5 JCL Using the Orbit File and SPINAT Tape

The changes to the JCL presented in Section 4.1 when using the SPINAT tape in lieu of the Attitude File are as follows:

	Card Ref. No.
//GO.FT25F001 DD DUMMY	15
//GO.FT36F001 DD UNIT=2400-9,DISP=(OLD,KEEP),DSN=SPINAT,	16
// LABEL=(1,BLP),VOL=SER=SPINAT,DCB=(LRECL=2808,RECFM=VS,BLKSIZE=5616)	16A

4.6 JCL Using the Orbit File Without the Attitude File

The change to the JCL presented in Section 4.1 necessary to delete the Attitude File is presented below.

	Card Ref. No.
//GO.FT25F001 DD DUMMY	15

4.7 JCL Without the FDS Manager Summary Report

The changes to the JCL in Section 4.1 required if the FDS Manager Summary Report is not requested are:

	Card Ref. No.
//GO.FT10F001 DD DUMMY	9
//GO.FT50F001 DD DUMMY	17

SECTION 6

REFERENCES

1. "Applications Technology Satellite Programming System," NAS5-10022, International Business Machine Corporation, Scientific Satellite Systems Department.

2. "Solution of the Problem of Artificial Satellite Theory Without Drag," Dirk Brouwer, Astronomical format 64, No. 1274.

3. "APMTR2 RAE Integrating Apogee Motor Program," NAS5-10022 International Business Machine Corporation, Scientific Satellite Systems Department, November 1968.

APPENDIX A

INITIAL VELOCITY GUIDANCE TECHNIQUE

This appendix describes the logical sequence followed when the initial velocity guidance technique is employed. The major computational steps which the program follows are presented below.

1. Compute the satellite state vector at apogee of the transfer trajectory
2. Compute the satellite state vector at the ignition time
3. Compute the apogee motor firing attitude
4. Propagate the satellite state vector through the apogee motor burn*
5. Perform the attitude excursion*
6. Superimpose the attitude uncertainties upon the attitude computed in Step 3*
7. Increment the ignition time
8. Repeat Steps 2 through 7 until the ignition time scan is satisfied

Whenever the desired firing time is input (see Section 2.8), Step 1 is replaced by:

1A. Compute the satellite state vector at the input firing time. In addition, Steps 7 and 8 are bypassed.

---

*If the user requests that the sequential excursion file be generated, the satellite state vector (as defined by both the position and velocity vectors and the osculating orbital elements) are stored on this file at each of these steps.

A. 1 Satellite State Vector at Apogee

The IMPMOT Program has four sources of satellite ephemeris information in the transfer trajectory

1. FDS Orbit File
2. ORB1 tape
3. EPHEM tape
4. Card input for use in the Brouwer propagator

Each of these sources provide the osculating orbital elements at epoch (a_o, e_o, i_o, m_o, ω_o, and Ω_o) as well as satellite position and velocity vectors as a function of time.**

From a_o and e_o, the program makes an initial estimate of the satellite position and velocity at apogee (R_a and V_a, respectively).

$$R_a = a_o (1 + e_o)$$
$$V_a = \sqrt{\mu\left(\frac{2}{R_a} - \frac{1}{a_o}\right)}$$

The program begins its search for apogee of the transfer trajectory at the input begin time (see parameter IBGRUN on input Card 9). The satellite position and velocity vectors at the begin time are obtained and a comparison is made:

**In the case of the FDS Orbit File and the Brouwer propagator, the satellite position and velocity vectors as a function of time involve additional calculations but are nevertheless available.

$$\left| |\vec{R}| - R_a \right| \leqslant 200. \quad \text{kilometers} \qquad \text{A-1}$$

$$\left| |\vec{V}| - V_a \right| \leqslant 0.2 \quad \text{kilometers per second} \qquad \text{A-2}$$

where:

$\vec{R}$ - is the satellite position vector at time t

$\vec{V}$ - is the satellite velocity vector at time t.

If both tests A-1 and A-2 are failed, the time, t, is incremented by:

$$t = t + \Delta t \qquad \text{A-3}$$

where:

Δt - is the input time increment DELTIM (see Card 3B).

The position and velocity vectors at this new time are obtained and tests A-1 and A-2 are repeated.

If either test A-1 or A-2 is passed, the satellite is in the vicinity of apogee and an additional test is made

$$\cos^{-1}\left\{\frac{\vec{R}\cdot\vec{V}}{|\vec{R}|\,|\vec{V}|}\right\} \geqslant \pi/_2 \qquad \text{radians} \qquad \text{A-4}$$

If test A-4 is failed, equation A-3 is used to increment the time and the search is continued. If test A-4 is passed, the satellite has reached or passed apogee. If the equality portion of A-4 is met, apogee has been found and the search is terminated. If the inequality portion of A-4 is met, the satellite has passed apogee in which case one time increment is subtracted (i. e. $t = t - \Delta t$). The time increment is then reduced by the input parameter IDIVID (see Card 10).

$$\Delta t = \text{DELTIM/IDIVID} \qquad \text{A-5}$$

where

IDIVID is the time reduction factor (see Card 10)

The time is then incremented according to equation A-3 with the new time increment described in equation A-5. The search continues (i. e. $\vec{R}$ and $\vec{V}$ are obtained at the new time and comparisons A-1, A-2 and A-4 are made as indicated above) until A-4 is again satisfied. Once A-4 has been satisfied for the second time, with the reduced time increment, the apogee search is terminated. It is noted that the time increment was reduced only once during the apogee search scheme.

Once the apogee search scheme has been satisfied, the satellite position and velocity vectors at apogee ($\vec{R}_A$ and $\vec{V}_A$, respectively) are available as well as the time at which the satellite reaches apogee of the transfer trajectory (t_A). If the desired firing time is input, the apogee search logic described above is circumvented. The satellite position and velocity vectors at the desired ignition time ($\vec{R}_f$ and $\vec{V}_f$, respectively) are obtained at the requested firing time (t_f).

A. 2 Satellite State Vector at the Ignition Time

The Program assumes that the apogee time, t_A, is the desired burn-out time (if the firing time is input, the burn-out time is assumed to be t_f). The apogee motor ignition time, t_{ig}, is computed from the burn-out time by:

$$t_{ig} = t_{Bo} - (t_B + t_D) \qquad \text{A-6}$$

where:

t_B is the apogee motor burn time (see parameter TBOOST on Card 4B)

t_D is the burn delay time (see parameter BRNDLY on Card 4B)

t_{Bo} is the desired burn-out time (either t_A or t_f)

The satellite position and velocity vectors ($\vec{R}_i$ and $\vec{V}_i$, respectively) at time t_{ig} are then obtained from one of the four sources indicated in Section A. 1.

A. 3 Compute Firing Attitude

The initial velocity guidance scheme applies the thrust vector in the direction defined by $\vec{V}_i$. Hence a unit vector along the positive spin axis, $\hat{e}_s$, is defined by (note that the thrust vector is assumed to be aligned along the negative spin axis):

$$\hat{e}_s = \frac{\vec{V}_i}{|\vec{V}_i|} \qquad \text{A-7}$$

where:

$$e_s \Rightarrow (e_{sx}, e_{sy}, e_{sz})$$

The spin axis right ascension, α, and declination, δ, (which define the firing attitude) are computed by:

$$\alpha_D = \tan^{-1}\left\{ e_{sy} / e_{sx} \right\} \qquad \text{A-8}$$

$$\delta_D = \sin^{-1}\left\{ e_{sz} \right\} \qquad \text{A-9}$$

A. 4 Propagate the Satellite State Vector Through the Apogee Motor Burn

The satellite state vector is propagated through the apogee motor burn by using an 8^{th} order Runga-Kutta technique to integrate the satellite equations of motion during the burn. (Reference 3 presents the satellite equations of motion) The satellite position and velocity vector at the beginning of the burn are $\vec{R}_i$ and $\vec{V}_i$, respectively. The thrust vector, $\vec{T}$, acting upon the satellite is defined by:

$$\vec{T} = -T \cdot \hat{e}_s \qquad \text{A-10}$$

where:

T - is generally a function of time and is computed based upon the input thrust coefficients (see Section 2. 2)

A. 5 Perform the Attitude Excursion

If the user requests the attitude excursion, each combination of spin axis right ascension, α, and declination, δ, in the following range will be taken for the apogee motor firing attitude.

$$\alpha_D - n \cdot \sigma_\alpha \leqslant \alpha \leqslant \alpha_D + n \cdot \sigma_\alpha$$

$$\delta_D - m \cdot \sigma_\delta \leqslant \delta \leqslant \delta_D + m \cdot \sigma_\delta$$

where

α_D - is defined by equation A-8

δ_D - is defined by equation A-9

σ_α - is the increment for the excursion upon right ascension (see parameter SIGALP on Card 3B)

σ_δ - is the increment for the excursion upon declination (see parameter SIGDEL on Card 3B)

m and n are arbitrary integers (see parameters NSIGAL and NSIGDE on Card 3B)

The unit vector along the spin axis is defined by:

$$\hat{e}_s \Rightarrow (\cos\alpha\cos\delta, \sin\alpha\cos\delta, \sin\delta) \qquad \text{A-11}$$

For each firing attitude in the range described above, the integration described in Section A. 4 is performed.

A. 6 Examine Attitude Uncertainties

The effects of attitude uncertainties upon the orbit resulting from the apogee motor burn are determined by superimposing these uncertainties upon the firing attitude computed by equations A-7, A-8 and A-9. Four cases are examined.

$$\alpha = \alpha_D + U_\alpha \;, \; \alpha = \delta_D$$

$$\alpha = \alpha_D - U_\alpha \;, \; \delta = \delta_D$$

$$\alpha = \alpha_D \;, \; \delta = \delta_D + U_\delta$$

$$\alpha = \alpha_D \;, \; \delta = \delta_D - U_\delta$$

where

α_D - is defined by equation A-8

δ_D - is defined by equation A-9

U_α - is the uncertainty in spin axis right ascension (see parameter DELA on Card 3B)

U_δ - is the uncertainty in spin axis declination (see parameter DELD on Card 3B).

For each firing attitude defined above, the integration described in Section A. 4 is performed.

A. 7 Increment Burn-Out Time

The apogee motor burn-out time, t_{B0}, is then incremented by an amount DELTIM (see Card 3B) and the sequence described in Sections A. 2 through A. 6 is repeated for each t_{B0} in the range:

$$t_A - \Delta t_s \leqslant t_{B0} \leqslant t_A + \Delta t_s$$

where

t_A - is the time at which the satellite reaches apogee of the transfer trajectory (see Section A. 1)

Δt_s - is the time period for the ignition time scan (see parameter DELSRM on Card 3B)

A. 8 Logical Flowchart

A descriptive flowchart illustrating the computational sequence described in Sections A. 1 through A. 7 is provided in Figures A-1 through A-5. Each of these figures is outlined below.

1. Figure A-1 illustrates the apogee search logic described in Section A. 1.
2. Figure A-2 presents the ignition time and firing attitude computations presented in Sections A. 2, A. 3 and A. 4.

3. The attitude excursion logic described in Section A. 5 is illustrated in Figure A-3.

4. Figure A-4 illustrates the attitude uncertainty logic described in Section A. 6.

5. The apogee motor ignition time scan logic is illustrated in Figures A-4 and A-5.

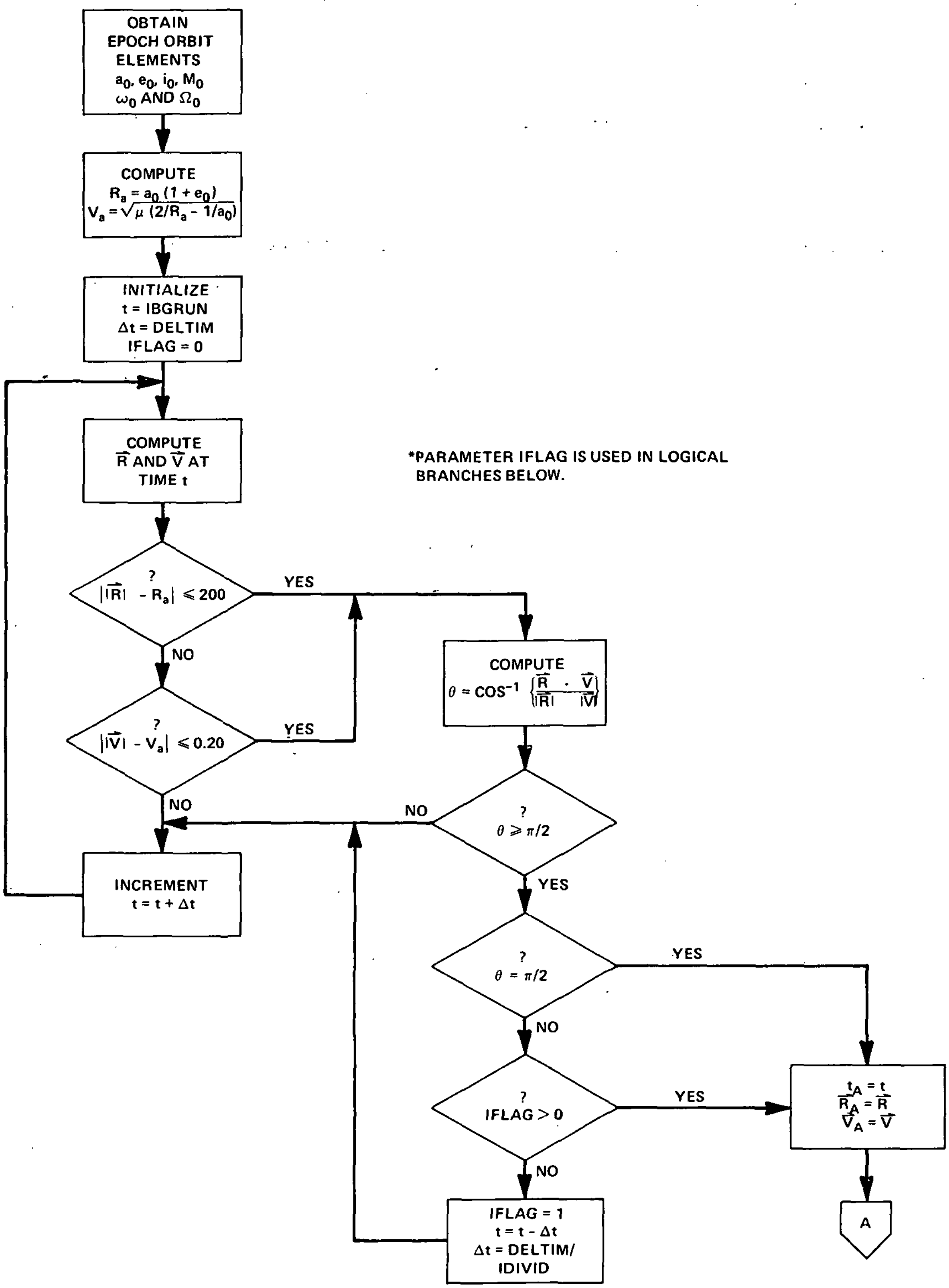

Figure A-1. Apogee Search

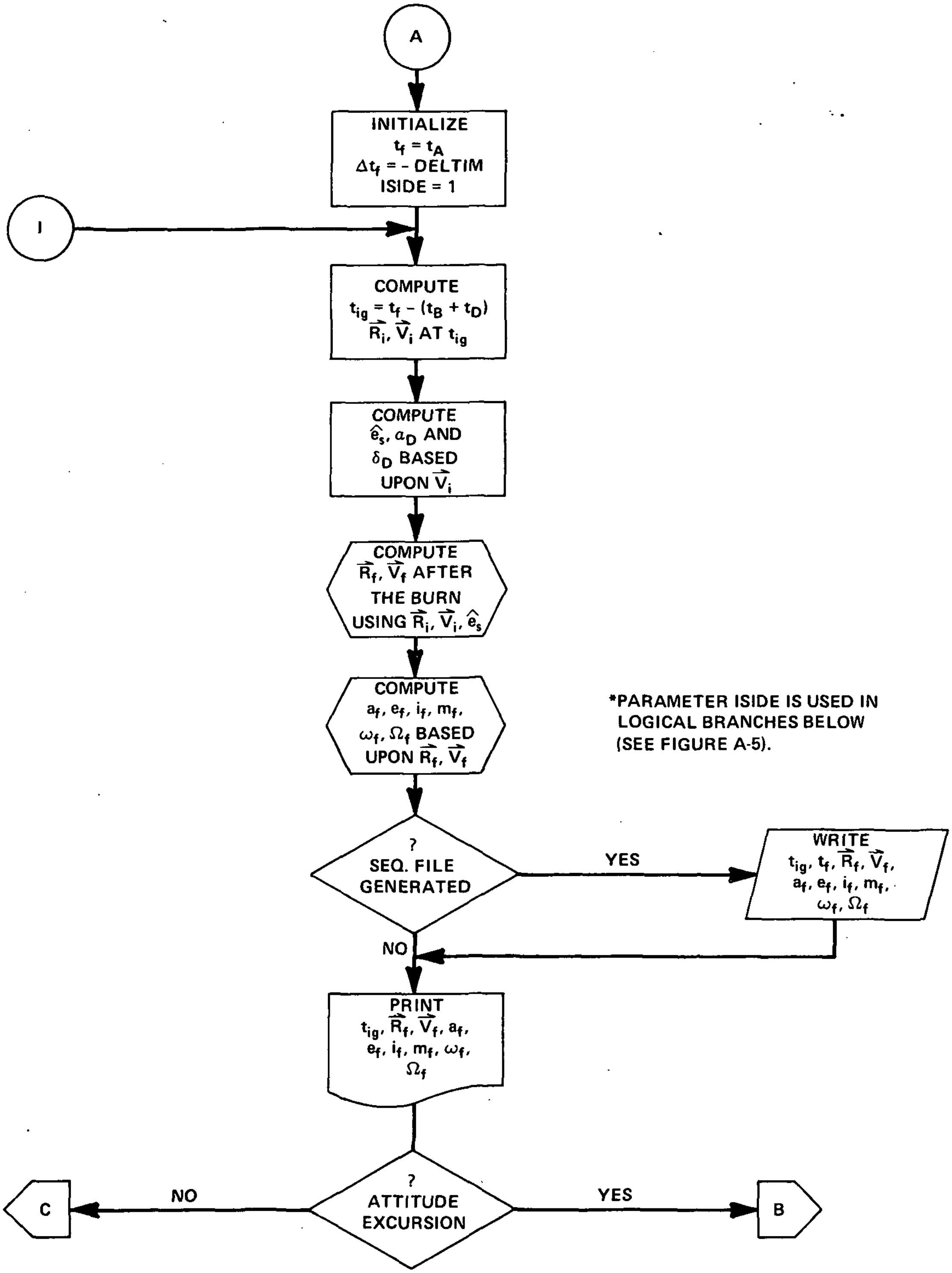

Figure A-2. Computed Ignition Time and Attitude

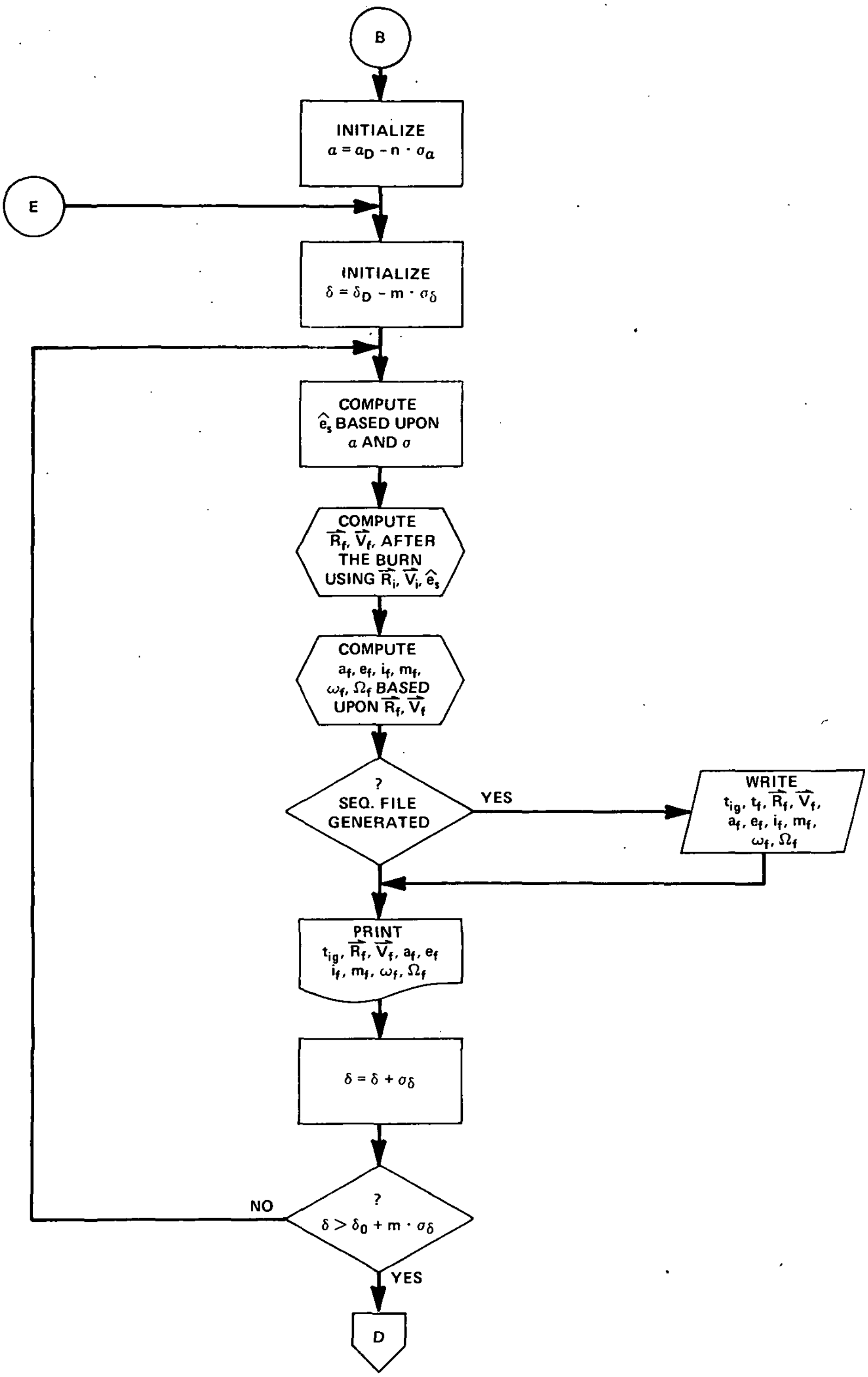

Figure A-3. Attitude Excursion (Sheet 1 of 2)

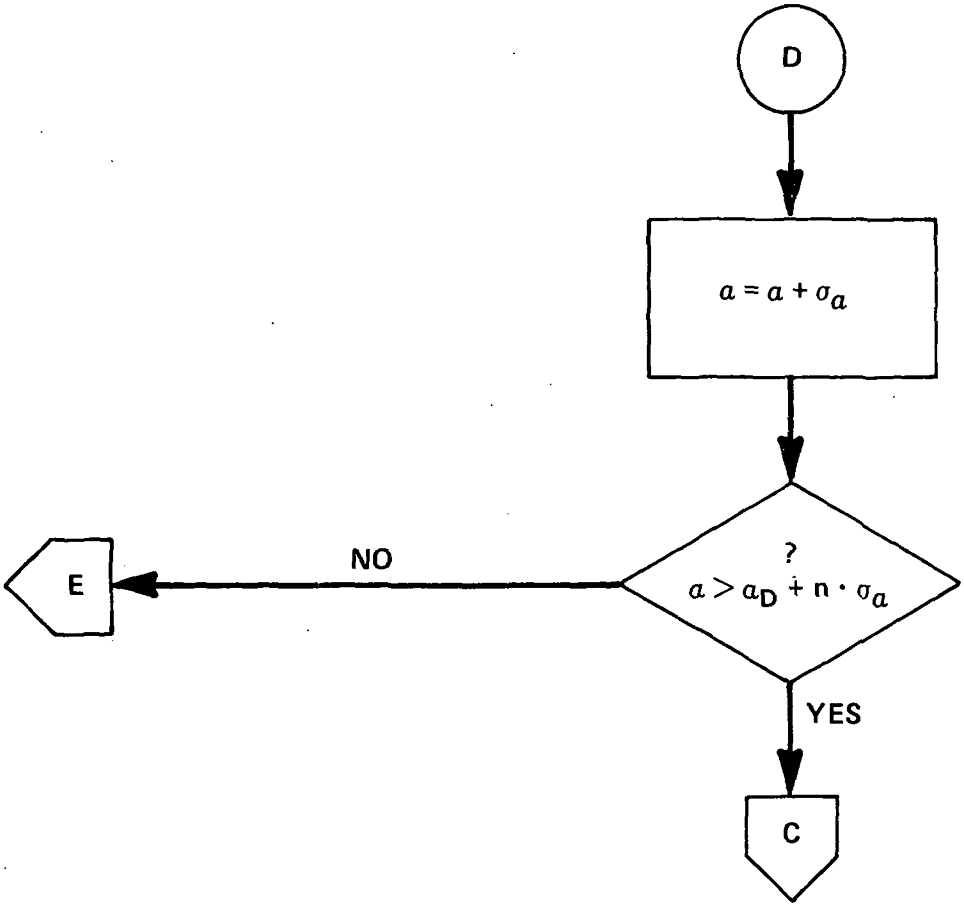

Figure A-3. Attitude Excursion (Sheet 2 of 2)

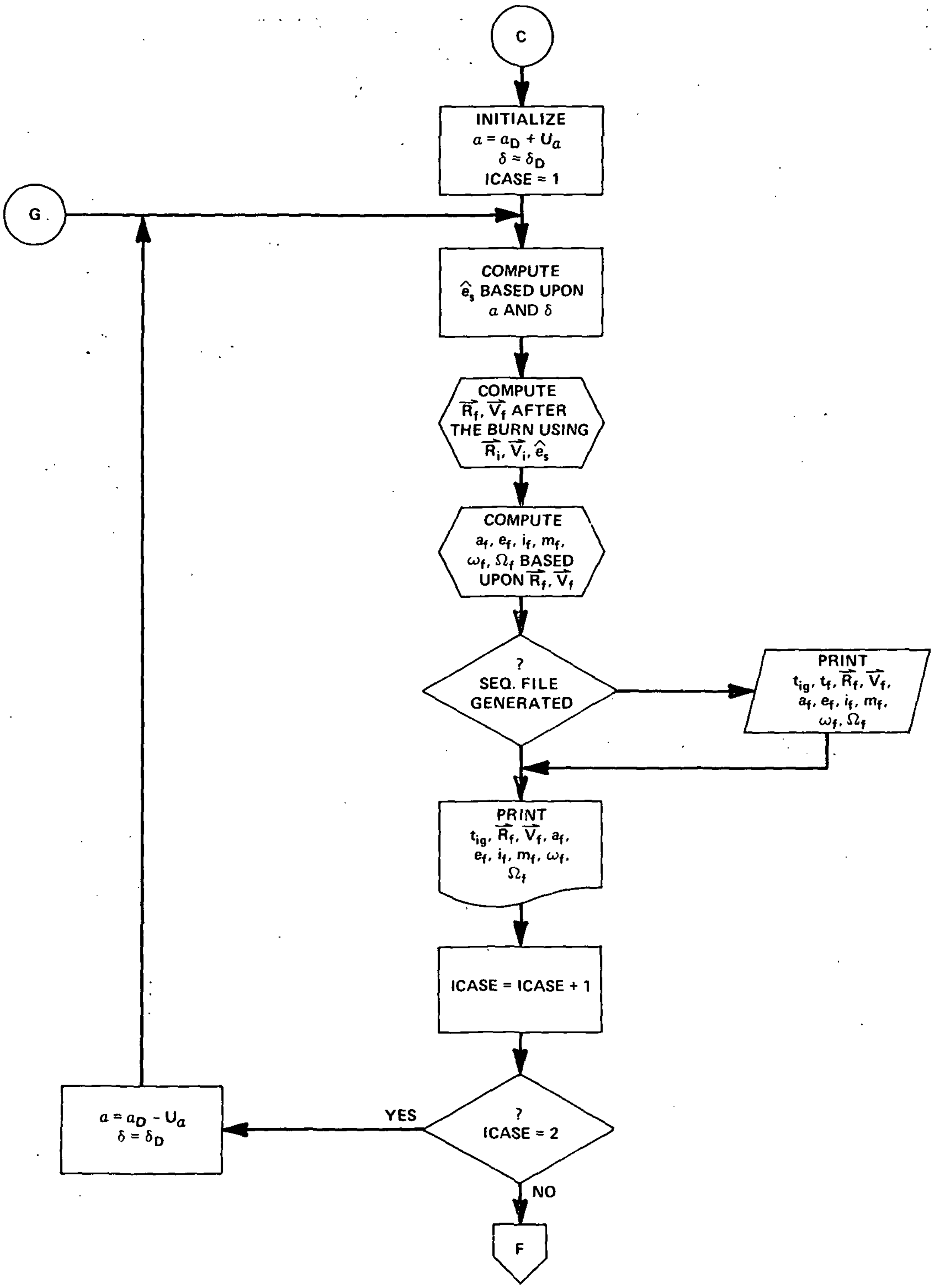

Figure A-4. Attitude Uncertainty (Sheet 1 of 2)

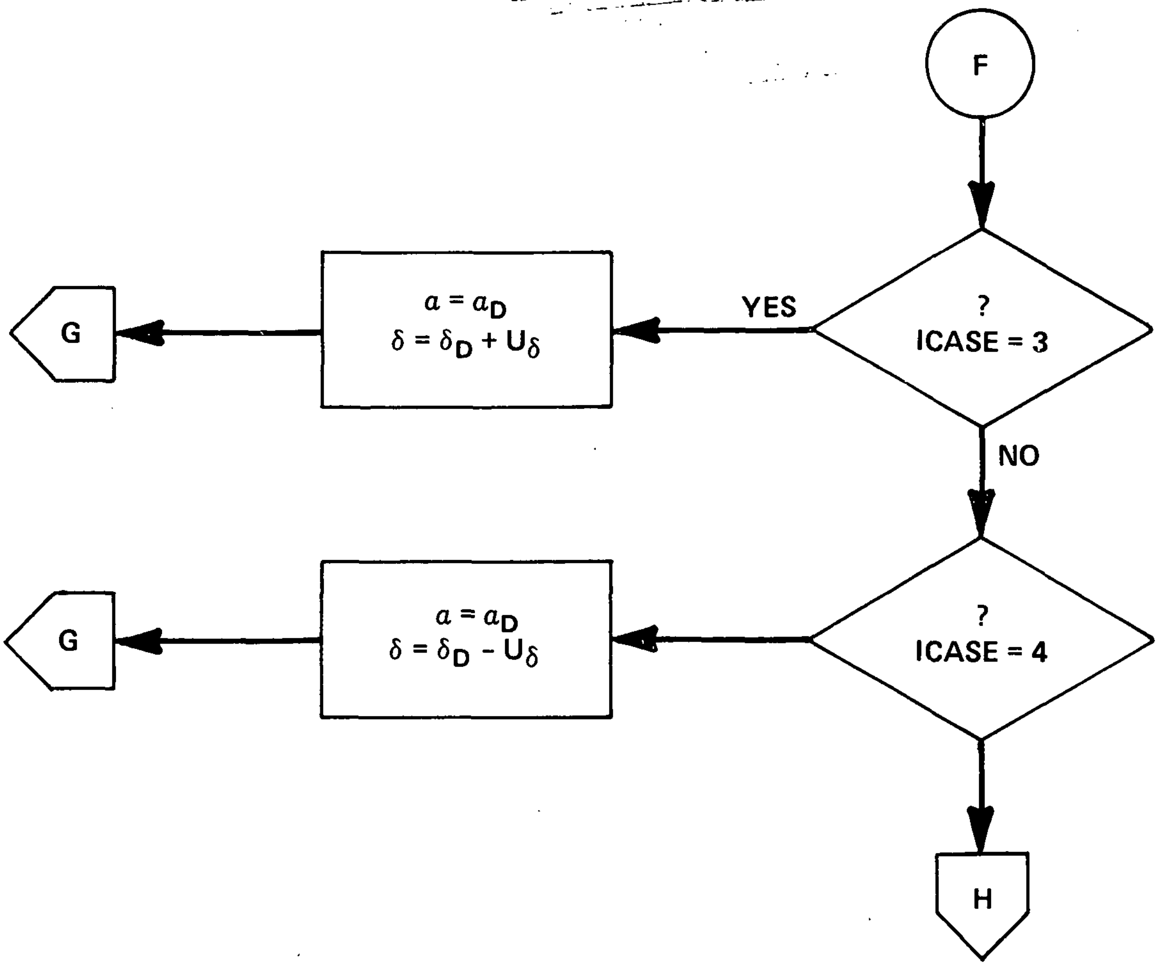

Figure A-4. Attitude Uncertainty (Sheet 2 of 2)

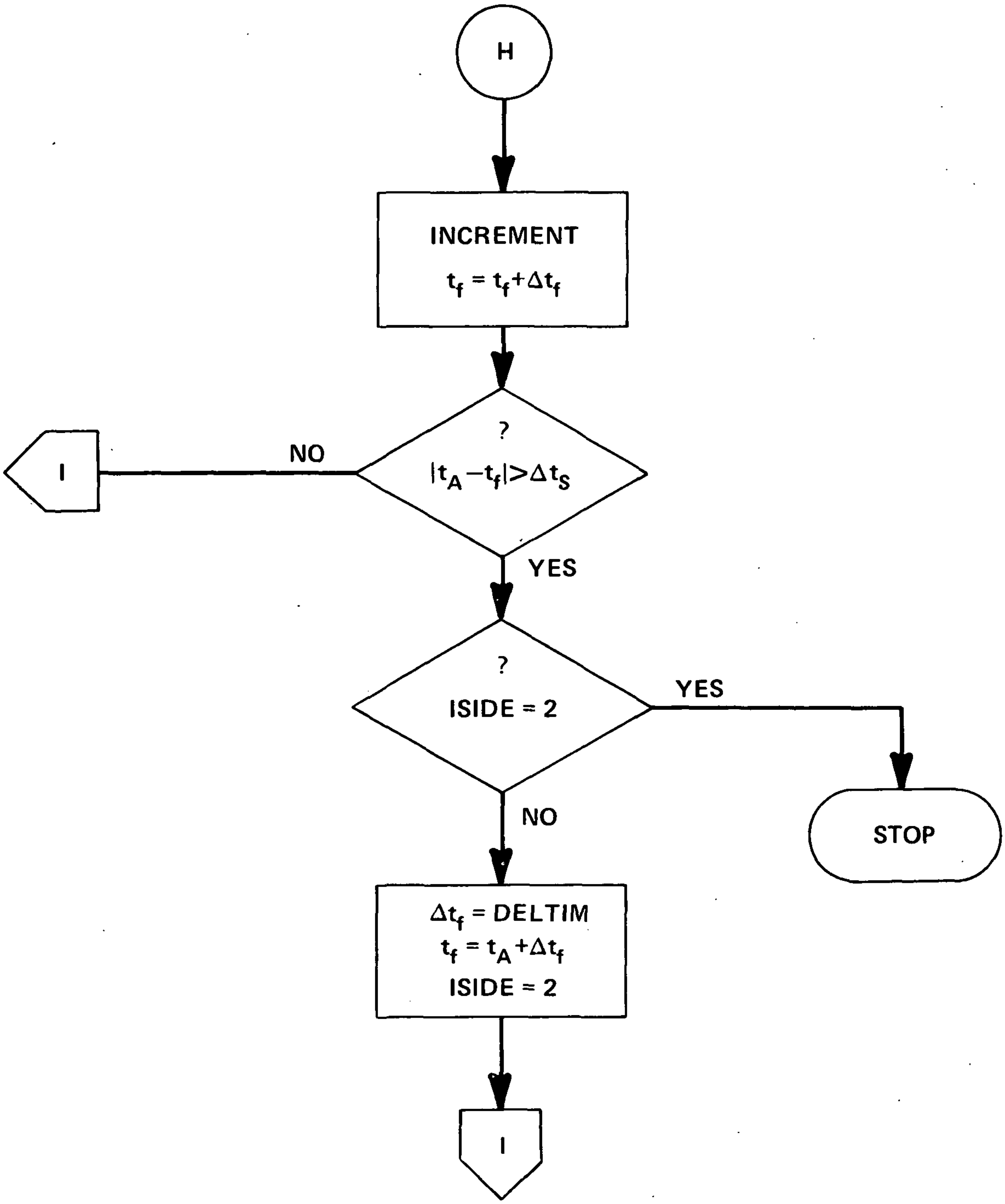

Figure A-5. Ignition Time Scan