CR 114984

REPORT NO. GDC-DBB70-002
CONTRACT NAS9-11193

OPEN

FACILITY FORM 602

N71 24824	
(ACCESSION NUMBER)	(THRU)
114	00
(PAGES)	(CODE)
CR-114984	31
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

SPACE SHUTTLE SYNTHESIS PROGRAM (SSSP)

VOLUME I, PART 2 • PROGRAM OPERATING INSTRUCTIONS
FINAL REPORT

GENERAL DYNAMICS
Convair Aerospace Division

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VOLUME I, PART 2 • PROGRAM OPERATING INSTRUCTIONS

FINAL REPORT

December 1970

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Prepared Under
Contract NAS9-11193

Submitted to
National Aeronautics and Space Administration
MANNED SPACECRAFT CENTER
Houston, Texas

Prepared by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
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FOREWORD

Volume I, Part 2: Program Operating Instructions

The SSSP documentation is presented in two volumes. Volume I contains the basic user's manual text and all of the simulation input and output description as well as a complete listing of the computer program FORTRAN V source deck. Volume II contains a compilation of statistical data on previous aircraft, missiles and space systems to serve as background information and program inputs to the weight/volume portion of the program.

This report is the second of three documents for Volume I. Part I contains the engineering and programming discussions and Part 3 describes the program output and contains all of the Volume I appendices.

SUMMARY

The Space Shuttle Synthesis Program (SSSP) automates the trajectory, weights and performance computations essential to predesign of the Space Shuttle system for earth-to-orbit operations. The two-stage Space Shuttle system is a completely reusable space transportation system consisting of a booster and an orbiter element. The SSSP's major parts are a detailed weight/volume routine, a precision three-dimensional trajectory simulation, and the iteration and synthesis logic necessary to satisfy the hardware and trajectory constraints.

The SSSP is a highly useful tool in conceptual design studies where the effects of various trajectory configuration and shuttle subsystem parameters must be evaluated relatively rapidly and economically. The program furnishes sensitivity and tradeoff data for proper selection of configuration and trajectory predesign parameters. Emphasis is placed upon predesign simplicity and minimum input preparation. Characteristic equations for describing aerodynamic and propulsion models and for computing weights and volumes are kept relatively simple. The synthesis program is designed for a relatively large number of two-stage Space Shuttle configurations and mission types, but avoids the complexity of a completely generalized computer program that would be unwieldy to use and/or modify.

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4.0 PROGRAM OPERATION INSTRUCTIONS

This section contains a discussion of the general program operation information, the input deck setup, the input parameters, and the basic synthesis operation.

SSSP has numerous possible input parameters. With the exception of a few table input parameters, the input parameters have internally compiled values which are assumed unless input with different values. The data is input via an input/output selection card (IOS card), cards containing the user's run title (TITLES card), and NAMELIST blocks ($DATA1, $DATA2, $DATA3). Input requirements are simplified by using NAMELIST input blocks. Each NAMELIST block contains three elements: (1) The appropriate NAMELIST name ($DATA1, $DATA2, $DATA3), (2) the input parameters (both name and numerical value), and (3) the terminator ($). Some important NAMELIST characteristics are enumerated below for the user's convenience:

1) Card column 1 is unused
2) The $ preceding the NAMELIST name must be in card column 2
3) For each parameter there must be its name, value, decimal point (omitted for fixed point numbers), and a comma following the input value.
4) Serial input for arrays may be simplified by inputting the acronym of only the first element of the series. Groups of input parameters may be stacked several to a card or condensed to one input acronym, if the values are the same for serial input data slots, by symbolically multiplying the value by the number of successive slots it will occupy; see the following example.

Examples

Expanded Input Method	Simplified Method
C2(3, 6, 3) = 1.03,	C2(3, 6, 3) = 1.03, 1.05, 1.10, 1.23,
C2(4, 6, 3) = 1.05,	
C2(5, 6, 3) = 1.10,	
C2(6, 6, 3) = 1.23,	
TWD1(5) = 5.,	TWD1(5) = 4*5.,
TWD1(6) = 5.,	
TWD1(7) = 5.,	
TWD1(8) = 5.,	

5) The input may start on the same card as the NAMELIST name.

6) The terminator ($) may appear as the last item on a card containing input data.

The systems requirements for the UNIVAC 1108 consists of:

Hardware

1. Card punch (optional)
2. Card reader
3. Printer
4. One tape drive (for CUR tape). It is possible to execute from cards in which case no tape drive is necessary.
5. 70000 octal words of central memory

Software

1. EXEC 11 LEVEL 6 operating system.
2. FORTRAN V
3. Ability to execute from a CUR tape (optional)

4.1 DECK SETUP

Figure 4-1 depicts the groups of cards and their order which are necessary to execute an SSSP case for the MSC system using a UNIVAC 1108 digital computer. The following paragraphs discuss the deck setup in terms of control cards, input/output selection (IOS) card, TITLES card, orbiter and booster data decks, synthesis data deck, and GTSII data deck.

4.1.1 CONTROL CARDS

The following control cards are necessary to effect execution of an SSSP case(s) for the MSC system currently used for the Univac 1108 digital computer.

```
1111111111222222222233333333334444444444
12345678901234567890123456789012345678901234567890
   RUN CARD
78N MSG   FILE REQ  TAPE 1  FH432 0 FS  RN 0
78 ASG A=34456
78 XQT CUR
       TRW A
       IN  A
       REL A
78 XQT MSCI                      ...
```

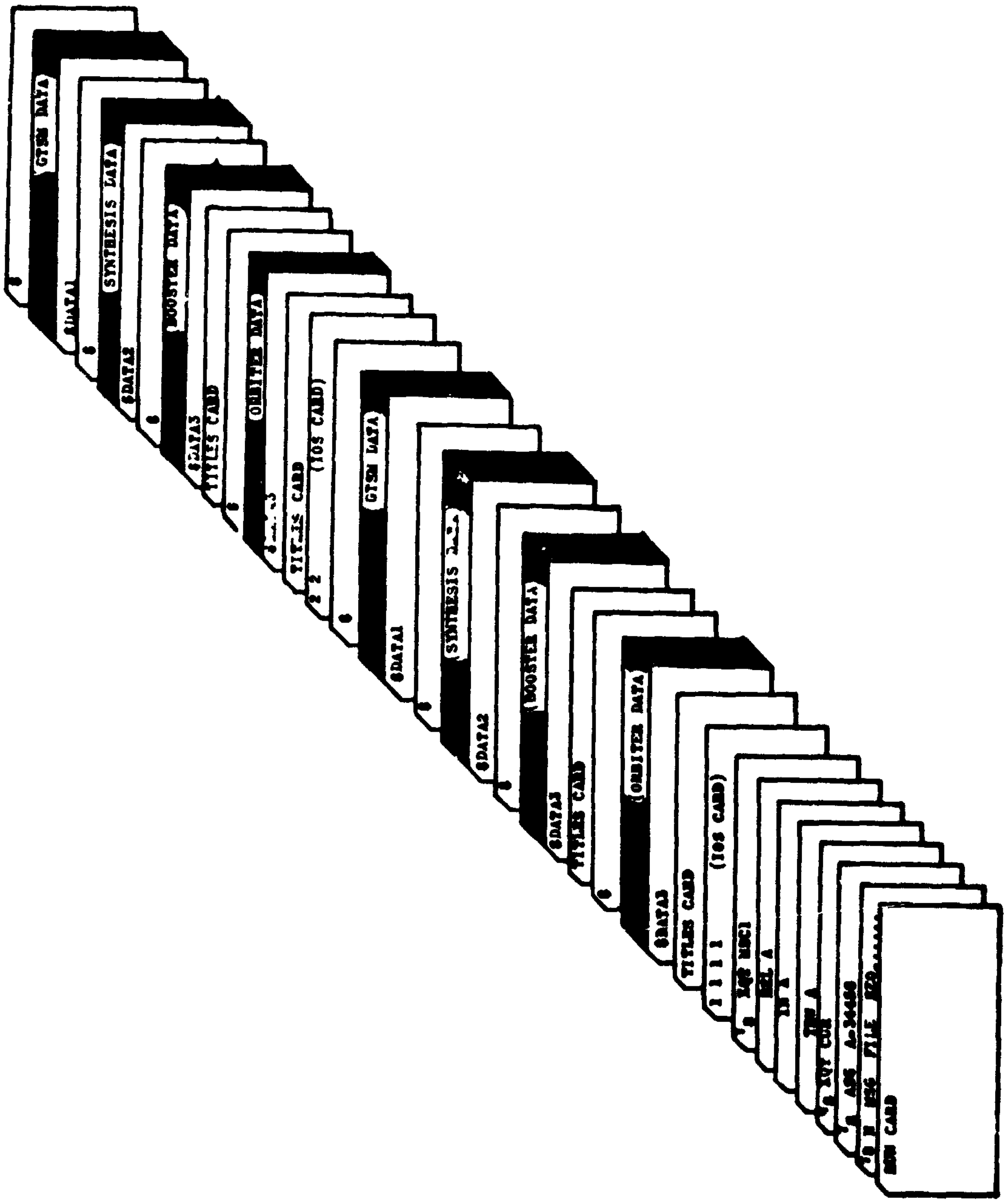


Figure 4-1. Deck Setup

4.1.2 IOS CARD

The input/output selection card (IOS) is the first card of the data package. Six program flags, JO, JB, MPRNTO, MPRNTB, MPNCHO and MPNCHB in a 6 I 2 format are necessary.

4.1.2.1 JO and JB. JO is the flag controlling the reading of weight/volume input data ($DATA3) for the orbiter element, and JB serves the same purpose for the booster element. These flags may assume the following values to perform the indicated function:

0	use stored data, no changes from a preceding case of a multiple run
1	read input data, the SETO subroutine is activated
2	read changes to input data for a case of multiple run

For example, the user would choose the values 1 1 for the first case of a multiple run in order to fully define the input parameters for the orbiter and booster elements; and then choose the values 2 0 for the second case which would allow the program to accept changes to the orbiter weight/volume parameters while retaining the booster parameters from the preceding case.

In addition to the proper setting of the flags JO and JB, the user must also set the parameter MULT in the GTSM data deck ($DATA1) to the proper value:

MULT = 0 for the final case

MULT = 1 if another case is to follow current case

JO and JB are the first and second words, respectively, on the IOS card.

4.1.2.2 MPRNTO and MPRNTB. The printing of the weight/volume input data ($DATA3) is controlled by the flag MPRNTO for the orbiter and by MPRNTB for the booster. MPRNTO and MPRNTB are the third and fourth words respectively, appearing on the IOS card in the 6 I 2 format. The printing of the input data is obtained by inputting a 1 for these flags. Printing is suppressed by entering zero in the appropriate slot. The $DATA2 ("synthesis") input is either printed or suppressed according to the value of MPRNT. MPRNT is an internal flag which is set to either the value of MPRNTO or MPRNTB depending on the value of JO and JB as shown.

JO	JB	MPRNT
1 or 2	1 or 2	MPRNTB
0	1 or 2	MPRNTB
1 or 2	0	MPRNTO
0	0	0

For example, the IOS card of the first case of a multiple run might contain 1 1 1 1 which would cause the printing of the orbiter and booster input weight/volume data ($DATA3) and the "synthesis" data ($DATA2). The IOS card of the second case might contain 2 2 0 2 which would suppress the printing of $DATA3 and $DATA2 input data. Note: the print of $DATA1 is handled by PRNTX(1), see Sec. 4.2.2)

4.1.2.3 MPNCHO and MPNCHB. MPNCHO and MPNCHB are the fifth and sixth words, respectively on the IOS card and cause punched output of the input weight/volume data for the orbiter (MPNCHO) and booster (MPNCHB). By inputting a 1 the user will obtain punched card output of the input (useful for "cleaning up" a NAMELIST block); a zero will suppress the punching. For example, an IOS card containing 1 1 1 1 1 0 would yield a punched deck of the weight/volume input for the orbiter but none for the booster.

4.1.3 TITLES Card.

The TITLES card must precede each $DATA3 deck (see Fig. 4-1). The hollerith information contained in card columns 2 through 60 is printed as the user's run title. (The user may insert a blank card). Although a TITLES card must be present before both the orbiter and booster $DATA3 decks, only that information appearing on the one preceding the booster $DATA3 deck is retained and printed as the user's run title.

4.1.4 DATA DECKS.

Four blocks of data are necessary to execute a single case or the first case of a multiple run. These blocks with their corresponding NAMELIST names and order of input are

$DATA3	Orbiter weight/volume data
$DATA3	Booster weight/volume data
$DATA2	"Synthesis" data
$DATA1	GTSM (trajectory) data

For multiple cases, the user may choose to omit the orbiter and/or booster data if the changes do not affect orbiter and/or booster input. If the "synthesis" data and/or GTSM data is to remain unchanged for succeeding cases, the user must still input the $DATA2, $DATA1 and terminating $ cards even though no new data appears in these input blocks.

The first case of a run would consist of the following cards:

```
1 1 1 1 0 0          IOS card
TRIAL RUN            TITLES Card
$DATA3
                     Orbiter weight/volume data
$
TRIAL RUN            TITLES Card
$DATA3
                     Booster weight/volume data
$
$DATA2               "Synthesis" input data

$

$DATA1               GTSM (trajectory) data
    MULT=1.,
$
```

While the second case, requiring only changes to the "synthesis" and GTSM data, could consist of the cards:

```
2 2 0 0 0 0          IOS card
  SECOND CASE        TITLES Card

$DATA3
                     Orbiter
$

  SECOND CASE        TITLES Card

$DATA3
                     Booster
$

$DATA2
                     "Synthesis" data changes

$

$DATA1
    MULT=0.,         GTSM data changes

$
```

4.2 INPUT PARAMETERS

The basic input data blocks required for an SSSP setup, as discussed above, are:

$DATA3 - Orbiter weight/volume data
$DATA3 - Booster weight/volume data
$DATA2 - Synthesis driver data
$DATA1 - Basic trajectory simulation data

The $DATA3 input blocks contain the scaling coefficients, fixed weight/volume items and basic estimates necessary to synthesize the orbiter and booster stages, respectively. This data is read-in under identical input acronyms or names since the identical set of scaling equations (subroutine WTSCH) are utilized to size each stage. Because of the wide range of design parameters and the many possible design solutions in any area of either the orbiter or booster design, these equations of necessity are compiled in general terms and therefore are used for both stages in the SSSP. It is the responsibility of the user to select those items which comprise his specific design application for each stage and to reflect these differences in the input to each respective $DATA3 block. (The input parameters for each stage are internally stored under special data arrays to differentiate between the stages during the synthesis process, however). The Weight/Volume Handbook contains a complete description of the scaling equations in terms of these general $DATA3 input terms and only differentiates between the stages when use of an equation requires a special orbiter or booster input parameter to be specified.

The $DATA2 input block contains the basic parameters which drive the operation of the synthesis process. These parameters include the synthesis option flags, initial estimates necessary to start the process, and fixed items for each SSSP run such as the stage specific impulses to be used for each ascent flight simulation section. Many of the parameters input to this data block either "override" the basic input to the $DATA3 or $DATA1 blocks due to an option that has been specified or must be utilized in conjunction with certain input parameters to the $DATA3 and $DATA1 blocks for a particular SSSP run. In addition certain parameters which are normally input to the $DATA1 block and necessary to drive the ascent simulation are computed internally during the synthesis process and hence are not known, a priori. These computed parameters are then "supplied" to the GTSM subprogram and therefore, also "override" the $DATA1 input. Use of the $DATA2 input parameters are discussed in Section 2.3, Synthesis Techniques and are operationally summarized in Section 4.3, Basic Synthesis Operation.

The $DATA1 input block contains the basic parameters necessary to simulate the baseline ascent trajectory (GTSM subprogram) and, if the option is utilized, to simulate the booster entry trajectory from the staging point on the ascent trajectory. Section 2.3.1.2 discusses the baseline ascent trajectory profile compiled into the SSSP. Necessary parameters which drive this ascent profile fall into two basic categories (1) synthesis computed, and (2) $DATA1 required input. Examples that fall into the first category include the following basic items which are supplied automatically to GTSM:

1) Stage gross weights, propellants, jettison weights
2) Propulsion characteristics: thrust levels, propellant flow rates
3) Theoretical wing areas for use as reference areas for the fixed aerodynamic characteristics

Necessary $DATA1 input includes such basic items as:

1) Initial conditions: launch pad coordinates, launch azimuth, etc.
2) Iteration and integration controls
3) Atmospheric data
4) Aerodynamic characteristics
5) Parking orbit insertion conditions
6) Maximum axial load allowed during ascent

The basic $DATA1 input items either have built-in default values in the GTSM subprogram, e.g., the atmosphere model, Appendix III, or are compiled at fixed values which fix the ascent profile prior to GTSM entry.

The following sub sections describe the basic input parameters for each data block and, in the cases of $DATA3 and $DATA1 input, flag those input parameters which are supplied from the synthesis process. Due to the large number of required input for operating the SSSP, it is strongly suggested that the user initially setup a configuration with the minimum required input parameters and then proceed to build upon this basis as necessary. As a new configuration is being developed for analyses, it is also suggested that the basic data deck setup developed for a previous configuration be utilized as its foundation. This process not only assists the user in the SSSP operation but also minimizes the number of aborted computer runs. Lack of a necessary input parameter is one of the most frequent causes of aborted SSSP runs particularly during the initial phases of developing a new configuration.

4 $DATA3

The NAMELIST input data block $DATA3 supplies the basic scaling coefficients, fixed items and basic scaling estimates necessary to size each stage in the subroutine WTSCH. It also includes certain option flags used to define the design philosophy required within WTSCH such as (1) specifying a fixed wing loading or a fixed theoretical wing area, and (2) specifying what portion of the total wetted area is to be covered by the thermal protection system, etc. The $DATA3 input is read in twice, first the orbiter then the booster. This data is read-in under identical input acronyms, by the subroutine READY and are stored in appropriate arrays in the subroutine STORE. This possessing is accomplished for ease of data handling when transferring from one OVERLAY to another during the synthesis iteration process and to differentiate between orbiter and booster data. The Weight/ Volume Handbook, Volume II contains a complete description of the use of these input parameters in the general $DATA3 format and differentiates between the orbiter and booster input where necessary.

This section contains a complete list and brief description of the $DATA3 input in the general data format (orbiter or booster) and points to those input parameters which are either (1) controlled by the synthesis driver input ($DATA2) or (2) computed internally during synthesis process. In the first case input for certain parameters are necessary in order to parallel a particular synthesis option. This is discussed in Section 4.3, Basic Synthesis Operation. In the second case certain input parameters are either internally computed thereby overriding the $DATA3 input or are recomputed during the synthesis process as described in Section 2.3, Synthesis Techniques. The basic scaling coefficients are input in subscripted arrays and acronym names. The principal arrays and their internal dimensions are: C(300) and K(30). These arrays are internally initialized at a value of 0, for both the orbiter and booster data. Therefore if a parameter is not input, its value will be internally stored at 0. Where an array parameter is not shown in the following list, it has been reserved for future use in expanding the SSSP and also has an internally stored value of 0. The remaining $DATA3 input parameters are read-in under acronym names and primarily consist of fixed items or initial estimates used in WTSCH sizing process for each stage. These parameters are also internally initialized at a value of 0. for each stage. Since the data for both the orbiter and booster are input under the same parameter names, it is important to place the respective input in the proper $DATA3 input data block as outlined in Section 4.1 above. Misplacement of orbiter data to the booster $DATA3 and vice versa is one of the most frequent causes of aborted SSSP runs.

The brief descriptions following the $DATA3 input list are utilized in this volume only for reference. The numbers preceding the input parameters refer to the list of comments succeeding the $DATA3 list.

$DATA3 INPUT COEFFICIENTS

TERMS	DESCRIPTION	UNITS
C(1)	WING WEIGHT COEFFICIENT (INTERCEPT)	--
C(2)	WING WEIGHT COEFFICIENT F(GROSS AREA)	LBS/FT2
C(3)	FIXED WING WEIGHT	LBS
C(4)	VERTICAL FIN WEIGHT COEFFICIENT	LBS/FT2
C(5)	FIXED VERTICAL FIN WEIGHT	LBS
C(6)	HORIZONTAL STABILIZER WEIGHT COEF.	--
C(7)	FIXED HORIZONTAL STABILIZER WEIGHT	LBS
C(8)	UNIT WEIGHT OF FAIRING OR SHROUD	LBS/FT2
C(9)	FIXED WEIGHT OF FAIRING OR SHROUD	LBS
C(10)	INTEGRAL FUEL TANK WEIGHT COEFFICIENT	LBS/FT2
C(11)	FIXED INTEGRAL FUEL TANK WEIGHT	LBS
C(12)	WING WEIGHT COEFFICIENT (SLOPE)	--
C(13)	BASIC BODY WEIGHT COEFFICIENT F(AREA)	LBS/FT2
C(14)	BASIC BODY WEIGHT COEFFICIENT F(VOL.)	LBS/FT3
C(15)	FIXED BASIC BODY WEIGHT	LBS
C(16)	NOT USED	--
C(17)	NOT USED	--
C(18)	NOT USED	--
C(19)	NOT USED	--
C(20)	NOT USED	--
C(21)	NOT USED	--
C(22)	NOT USED	--
C(23)	SECONDARY STRUCTURE WEIGHT COEF.	LBS/FT2
C(24)	VERTICAL FIN WEIGHT COEF. F(FIN AREA)	LBS/FT2
C(25)	HORIZONTAL WEIGHT COEF. F(HORIZ. AREA)	LBS/FT2
C(26)	FIXED INSULATION WEIGHT	LBS
C(27)	FIXED COVER PANEL WEIGHT	LBS
C(28)	GIMBAL SYSTEM WEIGHT COEF. (INTERCEPT)	--
C(29)	PRIME POWER SOURCE TANKAGE WT. COEF	--
C(30)	LANDING GEAR WEIGHT COEF. F(WLAND)	--
C(31)	FIXED LANDING GEAR WEIGHT	LBS
C(32)	ROCKET ENGINE WEIGHT COEF.	--
C(33)	FIXED ROCKET ENGINE WEIGHT	LBS
C(34)	NOT USED	--
C(35)	NOT USED	--
C(36)	NACELLE,PODS AND PYLONS WEIGHT COEF.	--
C(37)	FIXED NACELLE,PODS AND PYLONS WEIGHT	LBS
C(38)	POWER SOURCE PROPELLANT WEIGHT COEF.	--
C(39)	FUEL TANK WEIGHT COEF. (NON-STRUCTURAL)	LBS/FT3
C(40)	FIXED FUEL TANK WEIGHT (NON-STRUCTURAL)	LBS
C(41)	OXID TANK WEIGHT COEF. (NON-STRUCTURAL)	LBS/FT3
C(42)	FIXED OXID TANK WEIGHT (NON-STRUCTURAL)	LBS
C(43)	FUEL TANK INSULATION UNIT WEIGHT	LBS/FT2
C(44)	FIXED PROPELLANT TANK INSULATION WEIGHT	LBS
C(45)	FUEL SYSTEM WT COEF. F(THRUST)	--
C(46)	FUEL SYSTEM WT COEF F(LENGTH)	LBS/FT
C(47)	FIXED FUEL SYSTEM WEIGHT	LBS

INPUT COEFFICIENTS (CONT)

TERMS	DESCRIPTION	UNITS
C(48)	OXID SYSTEM WT COEF F(THRUST)	--
C(49)	OXID SYSTEM WT COEF F(LENGTH)	LBS/FT
C(50)	FIXED OXID SYSTEM WEIGHT	LBS
C(51)	FUEL TANK PRESSURE SYSTEM WEIGHT COEF	LBS/FT3
C(52)	OXID TANK PRESSURE SYSTEM WEIGHT COEF	LBS/FT3
C(53)	NOT USED	--
C(54)	NOT USED	--
C(55)	AERODYNAMIC CONTROL SYSTEM WEIGHT COEF	--
C(56)	FIXED AERODYNAMIC CONTROL SYSTEM WEIGHT	LBS
C(57)	NOT USED	--
C(58)	NOT USED	--
C(59)	NOT USED	--
C(60)	FIXED PRIME POWER SOURCE TANKAGE WEIGHT	LBS
C(61)	NOT USED	--
C(62)	ELECTRICAL SYSTEM WEIGHT COEF.	--
C(63)	ELECTRICAL SYSTEM WEIGHT COEF.	--
C(64)	FIXED ELECTRICAL SYSTEM WEIGHT	LBS
C(65)	HYDRAULIC/PNEUMATIC SYSTEM WEIGHT COEF	--
C(66)	HYDRAULIC/PNEUMATIC SYSTEM WEIGHT COEF	--
C(67)	FIXED HYDRAULIC/PNEUMATIC SYSTEM WEIGHT	LBS
C(68)	FIXED GUIDANCE AND NAVIG. SYSTEM WEIGHT	LBS
C(69)	INSTRUMENTATION SYSTEM WEIGHT COEF	LBS/FT
C(70)	FIXED INSTRUMENTATION SYSTEM WEIGHT	LBS
C(71)	COMMUNICATION SYSTEM WEIGHT COEF.	--
C(72)	FIXED COMMUNICATION SYSTEM WEIGHT	LBS
C(73)	FIXED ACS RESERVE PROPELLANT WEIGHT	LBS
C(74)	EQUIPMENT ECS WEIGHT COEF.	--
C(75)	CREW PROVISIONS WEIGHT COEF.	--
C(76)	FIXED CREW PROVISIONS WEIGHT	LBS
C(77)	OXID TANK INSULATION UNIT WEIGHT	LBS/FT2
C(78)	FIXED ICE AND FROST WEIGHT	LBS
C(79)	NOT USED	--
C(80)	NOT USED	--
C(81)	NOT USED	--
C(82)	NOT USED	--
C(83)	NOT USED	--
C(84)	NOT USED	--
C(85)	NOT USED	--
C(86)	NOT USED	--
C(87)	NOT USED	--
C(88)	NOT USED	--
C(89)	NOT USED	--
C(90)	NOT USED	--
C(91)	NOT USED	--
C(92)	NOT USED	--
C(93)	NOT USED	--
C(94)	NOT USED	--
C(95)	NOT USED	--
C(96)	CONTINGENCY AND GROWTH COEF.	--

INPUT COEFFICIENTS (CONT)

TERMS	DESCRIPTION	UNITS
C(97)	CREW WEIGHT COEF.	--
C(98)	FIXED CREW WEIGHT	LBS
C(99)	NOT USED	--
C(100)	NOT USED	--
C(101)	NOT USED	--
C(102)	PAYLOAD/CARGO WEIGHT COEF.	--
(1) C(103)	FIXED PAYLOAD/CARGO WEIGHT	LBS
C(104)	PASSENGER WEIGHT COEFFICIENT	--
(2) C(105)	FIXED PASSENGER WEIGHT	LBS
C(106)	FUEL TANK GASEOUS WEIGHT COEF.	LBS/FT3
C(107)	OXID TANK GASEOUS WEIGHT COEF.	LBS/FT3
C(108)	FIXED PRESSURE AND PURGE GASEOUS WEIGHT	LBS
C(109)	TRAPPED FUEL WEIGHT COEF. F(FUEL WT.)	--
C(110)	FIXED TRAPPED FUEL WEIGHT	LBS
C(111)	TRAPPED OXID WEIGHT COEF. F(OXID WT.)	--
C(112)	FIXED TRAPPED OXID WEIGHT	LBS
C(113)	TRAPPED SERVICE ITEMS WEIGHT COEF.	--
C(114)	FIXED TRAPPED SERVICE ITEMS WEIGHT	LBS
C(115)	FUEL RESERVE WEIGHT COEF.	--
C(116)	FIXED RESERVE FUEL WEIGHT	LBS
C(117)	OXID RESERVE WEIGHT COEF.	--
C(118)	FIXED RESERVE OXIDIZER WEIGHT	LBS
C(119)	POWER SOURCE RESERVE PROPELLANT WT COEF	--
C(120)	FIXED RESERVE POWER SOURCE PROPELLANT	LBS
C(121)	RESERVE SERVICE ITEMS WEIGHT COEF.	--
C(122)	FIXED RESERVE SERVICE ITEMS	LBS
C(123)	VENTED FUEL WEIGHT COEF. F(TOTAL FUEL)	--
C(124)	FIXED VENTED FUEL WEIGHT	LBS
C(125)	VENTED OXID WEIGHT COEF. F(TOTAL OXID)	--
C(126)	FIXED VENTED OXID WEIGHT	LBS
C(127)	FIXED POWER SOURCE PROPELLANT WEIGHT	LBS
C(128)	NOT USED	--
(3) C(129)	FIXED MAIN THRUST PER ENGINE	LBS
C(130)	SERVICE ITEM LOSSES WEIGHT COEF.	--
C(131)	FIXED SERVICE ITEM LOSSES	LBS
C(132)	FIXED THRUST BUILD-UP FUEL WEIGHT	LBS
C(133)	FIXED THRUST BUILD-UP OXID WEIGHT	LBS
C(134)	FIXED PRE-IGNITION LOSSES	LBS
C(135)	VERTICAL FIN WEIGHT COEF.	--
C(136)	FIXED SECONDARY FUEL SYSTEM WEIGHT	LBS
C(137)	FIXED SECONDARY OXID SYSTEM WEIGHT	LBS
C(138)	INTEGRAL OXID TANK WEIGHT COEF.	LBS/FT3
C(139)	FIXED INTEGRAL OXID TANK WEIGHT	LBS
C(140)	SECONDARY ROCKET ENGINE WEIGHT COEF.	--
C(141)	FIXED SECONDARY ROCKET ENGINE WEIGHT	LBS
C(142)	NOT USED	--
C(143)	LAUNCH GEAR WEIGHT COEF.	--
C(144)	FIXED LAUNCH GEAR WEIGHT	LBS
C(145)	DEPLOYABLE AERODYNAMIC DEVICES WT COEF	--

INPUT COEFFICIENTS (CONT)

TERMS	DESCRIPTION	UNITS
C(146)	FIXED DEPLOYABLE AERODYNAMIC DEVICES WT	LBS
C(147)	DOCKING STRUCTURE WEIGHT COEF.	--
C(148)	FIXED DOCKING STRUCTURE WEIGHT	LBS
C(149)	AIRBREATHING ENGINE THRUST PER ENGINE	LBS
C(150)	NOT USED	--
C(151)	NOT USED	--
C(152)	NOT USED	--
C(153)	SEPARATION SYSTEM WEIGHT COEF.	--
C(154)	FIXED SEPARATION SYSTEM WEIGHT	LBS
C(155)	ACS SYSTEM WEIGHT COEF.	--
C(156)	ACS SYSTEM WEIGHT COEF.	--
C(157)	FIXED ACS SYSTEM WEIGHT	LBS
C(158)	FIXED SECONDARY THRUST	LBS
C(159)	NOT USED	--
C(160)	GIMBAL SYSTEM WEIGHT COEF.	--
C(161)	FIXED GIMBAL SYSTEM WEIGHT	LBS
C(162)	FIXED CONTINGENCY AND GROWTH WEIGHT	LBS
C(163)	FIXED THRUST STRUCTURE WEIGHT	LBS
C(164)	ACS TANK WEIGHT COEF.	--
C(165)	FIXED ACS TANK WEIGHT	LBS
C(166)	THRUST DECAY PROPELLANT WEIGHT COEF.	--
C(167)	FIXED THRUST DECAY PROPELLANT WEIGHT	LBS
C(168)	THRUST STRUCTURE WEIGHT COEF.	--
C(169)	FIXED SECONDARY STRUCTURE WEIGHT	LBS
C(170)	SECONDARY FUEL SYSTEM WEIGHT COEF.	LBS/FT3
C(171)	SECONDARY OXID SYSTEM WEIGHT COEF.	LBS/FT3
C(172)	ACS RESERVE PROPELLANT WEIGHT COEF.	--
C(173)	ACS PROPELLANT WEIGHT COEF. F(WTO)	--
C(174)	ACS PROPELLANT WEIGHT COEF. F(WWAIT(4))	--
C(175)	FIXED ACS PROPELLANT WEIGHT	LBS
C(176)	HORIZONTAL STABILIZER WEIGHT COEF.	--
C(177)	NOT USED	--
C(178)	NOT USED	--
C(179)	NOT USED	--
C(180)	INSULATION UNIT WEIGHT	LBS/FT2
C(181)	COVER PANEL UNIT WEIGHT	LBS/FT2
C(182)	LANDING GEAR WEIGHT COEF. F(WLAND)	--
C(183)	ENGINE MOUNT WEIGHT COEF.	--
C(184)	FIXED ENGINE MOUNT WEIGHT	LBS
C(185)	AERODYNAMIC CONTROL SYSTEM WEIGHT COEF	--
C(186)	NOT USED	--
C(187)	FIXED PRESSURIZATION SYSTEM WEIGHT	LBS
C(188)	NOT USED	--
C(189)	FUEL TANK WEIGHT COEF. (JP)	--
C(190)	FIXED FUEL TANK WEIGHT	LBS
C(191)	FUEL DIST. SYSTEM-PART 1 WEIGHT COEF.	--
C(192)	NOT USED	--
C(193)	NOT USED	--
C(194)	NOT USED	--

INPUT COEFFICIENTS (CONT)

	TERMS	DESCRIPTION	UNITS
	C(195)	NOT USED	--
	C(196)	NOT USED	--
	C(197)	NOT USED	--
	C(198)	NOT USED	--
	C(199)	NOT USED	--
	C(200)	NOT USED	--
	C(201)	NOT USED	--
	C(202)	NOT USED	--
	C(203)	NOT USED	--
	C(204)	NOT USED	--
	C(205)	NOT USED	--
	C(206)	NOT USED	--
	C(207)	NOT USED	--
	C(208)	NOT USED	--
	C(209)	NOT USED	--
	C(210)	AIRBREATHING ENGINE WEIGHT COEF.	--
	C(211)	FIXED AIRBREATHING ENGINE WEIGHT	LBS
	C(212)	AIRBREATHING TANKAGE + SYSTEM WT. COEF	--
	C(213)	FIXED AIRBREATHING TANKAGE + SYST. WT.	LBS
(4)	C(214)	FLYBACK MASS RATIO MINUS 1.0	--
	C(215)	FIXED FLYBACK PROPELLANT WEIGHT	LBS
	C(216)	NOT USED	--
	C(217)	NOT USED	--
	C(218)	NOT USED	--
	C(219)	ROCKET ENGINE WT. COEF. F(THRUST AREA)	--
	C(220)	ROCKET ENGINE AREA RATIO	--
	C(221)	ROCKET ENGINE AREA RATIO EXPONENT	--
	C(222)	NOT USED	--
	C(223)	NOT USED	--
	C(224)	NOT USED	--
	C(225)	TRAPPED FUEL WEIGHT COEF F(PROPELLANT)	--
	C(226)	TRAPPED FUEL WEIGHT COEF F(THRUST)	--
	C(227)	TRAPPED OXID WEIGHT COEF F(PROPELLANT)	--
	C(228)	TRAPPED OXID WEIGHT COEF F(THRUST)	--
	C(229)	VENTED FUEL WEIGHT COEF F(PROPELLANT)	--
	C(230)	VENTED OXID WEIGHT COEF F(PROPELLANT)	--

$DATA3 INPUT TERMS

TERMS	DESCRIPTION	UNITS
ANENGS	NUMBER OF AIRBREATHING ENGINES	--
ANTANK	NUMBER OF AIRBREATHING FUEL TANKS (JP)	--
ASRATO	WING ASPECT RATIO	--
ASWEEP	WING LEADING EDGE SWEEP ANGLE	DEG
CBBODY	BODY WIDTH OR COEFFICIENT	FT
CFUEL(1)	THRUST BUILD-UP MIXTURE RATIO	--
CFUEL(2)	NOT USED	--
CFUEL(3)	MAIN IMPULSE MIXTURE RATIO	--
CFUEL(4)	MAIN IMPULSE RESERVE MIXTURE RATIO	--
CFUEL(5)	SECONDARY IMPULSE MIXTURE RATIO	--
CFUEL(6)	NOT USED	--
CHBODY	BODY HEIGHT OR COEFFICIENT	FT
CLBODY	BODY LENGTH OR COEFFICIENT	FT
CSBODY	TOTAL BODY WETTED AREA OR COEFFICIENT	FT2
CSFAIR	FAIRING PLANFORM AREA OR COEFFICIENT	FT2
CSFUTK	FUEL TANK SURFACE AREA COEFFICIENT	--
CSHORZ	HORIZONTAL STAB. PLANFORM AREA OR COEF.	FT2
CSOXTK	OXID TANK SURFACE AREA COEFFICIENT	--
CSPLAN	BODY PLANFORM AREA OR COEFFICIENT	FT2
CSVERT	VERTICAL FIN PLANFORM AREA OR COEF.	FT2
(5) CSWING	WING PLANFORM AREA	FT2
CTHRST	VACUUM THRUST TO LIFT-OFF WEIGHT RATIO	--
CTHST2	SECONDARY PROPULSION T/W RATIO	--
FXWOVS	FIXED WING LOADING	LBS/FT2
ISP(1)	THRUST BUILD-UP PROPELLANT ISP	SEC
ISP(2)	NOT USED	--
(6) ISP(3)	MAIN IMPULSE PROPELLANT ISP	SEC
(7) ISP(4)	MAIN IMPULSE RESERVE PROPELLANT ISP	SEC
ISP(5)	SECONDARY PROPULSION PROPELLANT ISP	SEC
ISP(6)	NOT USED	--
ITPS	TPS FLAG	--
K(1)	FUEL TANK ULLAGE VOLUME COEFFICIENT	--
K(2)	OXIDIZER TANK ULLAGE VOLUME COEFFICIENT	--
K(3)	AVERAGE FUEL TANK INSULATION THICKNESS	FT
K(4)	FIXED PROPELLANT TANK INSULATION VOLUME	FT3
K(5)	CREW VOLUME COEFFICIENT	--
K(6)	FIXED CREW VOLUME	FT3
K(7)	FIXED SECONDARY FUEL TANK VOLUME	FT3
K(8)	FIXED SECONDARY OXID TANK VOLUME	FT3
K(9)	FIXED CARGO BAY VOLUME	FT3
K(10)	AVERAGE BODY STRUCTURAL DEPTH	FT
K(11)	FIXED BODY STRUCTURAL VOLUME	FT3
K(12)	LANDING GEAR BAY VOLUME COEFFICIENT	FT3/LB
K(13)	FIXED LANDING GEAR BAY VOLUME	FT3

INPUT TERMS (CONT)

TERMS	DESCRIPTION	UNITS
K(14)	NOT USED	--
K(15)	NOT USED	--
K(16)	PROPULSION BAY VOLUME COEFFICIENT	FT3/LB
K(17)	FIXED PROPULSION BAY VOLUME	FT3
K(18)	MISCELLANEOUS VOLUME COEFFICIENT	--
K(19)	FIXED MISCELLANEOUS VOLUME	FT3
K(20)	NOT USED	--
K(21)	FIXED FUEL TANK VOLUME	FT3
K(22)	NOT USED	--
K(23)	BODY VOLUME INTERCEPT (K(18) SCALING)	FT3
K(24)	NOT USED	--
K(25)	AVERAGE OXID TANK INSULATION THICKNESS	FT
K(26)	NOT USED	--
K(27)	NOT USED	--
K(28)	MAIN FUEL TANK VOLUME FOR FLYBACK	FT3
K(29)	FIXED OXIDIZER TANK VOLUME	FT3
K(30)	NOT USED	--
KIN	NOT USED	--
LF	ULTIMATE LOAD FACTOR	--
MR(1)	THRUST BUILD-UP MASS RATIO OR ΔV	--
MR(2)	NOT USED	--
(8) MR(3)	MAIN IMPULSE MASS RATIO	--
MR(4)	MAIN IMPULSE RESERVE MASS RATIO OR ΔV	--
MR(5)	SECONDARY IMPULSE MASS RATIO OR ΔV	--
MR(6)	NOT USED	--
NCREW	NUMBER OF CREW MEMBERS	--
NENGS	TOTAL NUMBER OF ENGINES PER STAGE	--
NLISTO	NAME LIST OUTPUT FLAG	--
NPASS	NUMBER OF PASSENGERS	--
NWL	WING LOADING FLAG	--
PCHAM	MAIN ROCKET ENGINE CHAMBER PRESSURE	PSIA
(9) Q	MAXIMUM DYNAMIC PRESSURE	PSIA
RHOFU	FUEL DENSITY	LBS/FT3
RHOFU2	SECONDARY FUEL DENSITY	LBS/FT3
RHOX	OXIDIZER DENSITY	LBS/FT3
RHOX2	SECONDARY OXIDIZER DENSITY	LBS/FT3
(10) SBODY	TOTAL BODY WETTED AREA	FT2
TOL	GROSS WEIGHT ITERATION TOLERANCE	LBS
TOVERC	WING THICKNESS OVER CHORD RATIO	--
TPRATO	WING TAPER RATIO	--
TYTAIL	NOT USED	--
(10) VBODY	TOTAL BODY VOLUME	FT3
(10) WGROSS	GROSS WEIGHT	LBS

$DATA3 Comments

1. For the orbiter this input is the fixed system payload or cargo for the mission excluding the weight of furnishings and support equipment for the passengers, if any. The weight of the passengers is handled separately. If a fixed booster gross weight (liftoff weight) is to be specified (see Section 4.3.5), this input is used as the initial estimate for the system payload.

2. For the booster this input is unavailable. Internally this parameter is set equal to the gross weight of the orbiter and hence, the "payload" of the booster.

3. For the orbiter this input is the vacuum thrust per engine (unit thrust). If a fixed vacuum thrust/gross weight is desired for the orbiter (see Section 4.3.1), this parameter must be input as 0. For the booster this parameter is internally computed and the input value is ignored.

4. For the orbiter this input is the fixed value of the cruise performance mass ratio minus one which is used to calculate the weight of airbreathing fuel, if any. Typically the orbiter makes use of airbreathing engines only for a powered approach and landing with go-around capability. For the booster this input is an initial estimate (see section 4.3.4) since the booster also utilizes its airbreathing engines to perform the subsonic cruise to the landing site with the cruise range requirement being specified internally.

5. For the orbiter or the booster, this input is the fixed specified theoretical (gross) wing area and the wing loading is computed internally (set FXWOVS=0.,) at a selected design condition. If the wing is to be specified (FXWOVS) at a selected design condition, this input is used as an initial estimate for the theoretical wing area.

6. For the orbiter this parameter is internally set equal to the $DATA2 input IVACO(5) and therefore need not be input. For the booster this parameter is internally computed (see Section 2.3.1, Basic Synthesis Iteration) as a function of the $DATA2 inputs ISLB(1), IVACB(2), and PERISP, and therefore need not be input.

7. For the orbiter this parameter is internally set equal to the $DATA2 input (IVACO(5)) and therefore need not be input.

8. For the orbiter this parameter is internally computed as an initial estimate to start the synthesis process (see Section 2.3.1, Basic Synthesis Iteration) and therefore need not be input. For the booster this input is the fixed main impulse mass ratio utilized during the synthesis process. If a fixed orbiter gross weight or fixed orbiter propellant weight is to be specified (see Sections 4.3.5.2 and 4.3.5.3, respectively), this input is used as the initial estimate for the booster main impulse mass ratio.

9. For the orbiter and the booster, this parameter is internally computed by the maximum dynamic pressure attained during simulation of the ascent trajectory and therefore need not be input. Internally the initial estimate for this parameter is equal to the $DATA2 input estimate CMAX.

10. For the orbiter and the booster, this input is used as an initial estimate to start the synthesis process.

4.2.2 $DATA2

The NAMELIST input data block $DATA2 primarily controls the basic operation of the SSSP. It contains the basic synthesis drive. parameters and option flags necessary to interface the two major operational portions of the program: the WTVOL and GTSM subprograms. It also includes estimates for the various synthesis options and control flags for printing output during the synthesis iterations. These inputs are read in from the subroutine VEHDF and are stored in subscripted arrays for ease of data handling when transferring from one OVERLAY to another during the basic synthesis iteration process described in Section 2.3, Synthesis Techniques. These subscripted arrays are also utilized to store internally computed data necessary to drive the synthesis iterations. A complete list of these arrays and their definitions is discussed in Appendix VI. Use of the $DATA2 input parameters for driving the basic SSSP procedures is discussed in Section 4.3, Basic Synthesis Operation.

Input Parameter	Internal Parameter	Compiled Value	
IDVEL	SV(2)	—	Total characteristic velocity estimate to parking orbit insertion (fps) see Section 2.3.1
COPIES	SV(29)	6.	No. of copies of summary sheet (see Program Output, Section 5)
ISLB(1)	SE(3)	390.	Booster sea level specific impulse (sec) for ascent flight simulation sections 1 thru 4*
ISLB(2)	SE(13)	390.	
ISLB(3)	SE(31)	390.	
ISLB(4)	SE(35)	390.	
IVACB(1)	SE(1)	450.	Booster vacuum specific impulse (sec) for ascent flight simulation sections 1 thru 4*
IVACB(2)	SE(11)	450.	
IVACB(3)	SE(29)	450.	
IVACB(4)	SE(33)	450.	
ISLO(1)	SE(4)	390.	Orbiter sea level specific impulse (sec) for ascent flight simulation sections 1 thru 4*√
ISLO(2)	SE(14)	390.	
ISLO(3)	SE(32)	390.	
ISLO(4)	SE(36)	390.	
ISLO(5)	SE(16)	390.	
ISLO(6)	SE(18)	390.	
ISLO(7)	SE(20)	390.	

*Values used for sections 3 and 4 are used for print purposes where the value for the parameter in Section 3 is considered the nominal and Section 4 the uprated value.

√ Values for Sections 1 and 2 are not used unless FIRE=1.

IVACO(1)	SE(2)	450.	Orbiter vacuum specific impulse (sec) for ascent flight simulation sections 1 thru 7* ✓
IVACO(2)	SE(12)	450.	
IVACO(3)	SE(30)	450.	
IVACO(4)	SE(34)	450.	
IVACO(5)	SE(15)	450.	
IVACO(6)	SE(17)	450.	
IVACO(7)	SE(19)	450.	
TFCTRB(1)	SE(26)	1.	Booster multiplicative thrust factors for ascent flight simulation sections 1 thru 4*, see Section 2.3.1.2, Trajectory Simulation Driver.
TFCTRB(2)	SE(27)	1.	
TFCTRB(3)	--	1.	
TFCTRB(4)	SE(37)	1.	
TFCTRO(1)	SE(21)	1.	Orbiter multiplicative thrust factors for ascent flight simulation sections 1 thru 7* ✓, see Section 2.3.1.2, Trajectory Simulation Driver.
TFCTRO(2)	SE(22)	1.	
TFCTRO(3)	--	1.	
TFCTRO(4)	SE(38)	1.	
TFCTRO(5)	SE(23)	1.	
TFCTRO(6)	SE(24)	1.	
TFCTRO(7)	SE(25)	1.	
FIRE	SE(5)	2.	Flag for stage ascent burn sequence: Sec. 4.3.2 = 1., for simultaneous stage burns = 2., for sequential stage burns
BOOTW	SE(6)	0.	Flag for propulsion option: Sec. 4.3.1 = 0., for fixed booster thrust or fixed liftoff thrust/weight with common engines = 1., for fixed liftoff thrust-to-weight (non common engines)
QMXS	SE(7)	900.	Slope used for QMAX adjustment (psf) when liftoff thrust/weight varies during the synthesis iterations, see Sec. 2.3.2.1, Fixed Booster Thrust
FBPAR	SE(8)	250.	Estimate of slope for adjusting the booster cruise parameter if WOREQ >0. or WPOREQ >0., see Special Note, Sec. 2.3.4.2.

QMAX	SE(9)	550.	Estimate of maximum dynamic pressure (psf) during ascent flight used for sizing of stage components, see Volume II, Weight/Volume Handbook.
NXFOB	SE(39)	0.	Flag for cross-feed of propellants from booster tanks to orbiter engines at liftoff if FIRE=1., see Section 4.3.2.2. = 1., for no crossfeed
SYNIT	SW(3)	5.	Number of allowable basic synthesis iterations, see Section 2.3.1.
TOLMU	SW(5)	.0005	Convergence tolerance for orbiter main impulse mass ratio during basic synthesis iteration process, see Section 2.3.1.
TRATIO	SW(6)	1.	Ratio of booster to orbiter engine vacuum thrust if BOOTW=0., common engines, see Section 4.3.1.
PERISP	SW(7)	.81	Parameter used to estimate the effective booster specific impulse in calculating the booster characteristic velocity requirement in sizing, see Section 2.3.1.
CLVG	SW(9)	1.0	Correlation factor used to adjust reference cruise range requirement if FLYBCK=1., see Section 2.3.4.1. (Adjustment not used if CLVG=1.)
ALD SFC VCRUSE	SW(11) SW(12) SW(14)	6. .2 300.	Booster subsonic lift/drag ratio, specific fuel consumption (lb/lb-hr) and cruise velocity (fps) respectively for determining cruise performance parameter if FBFUEL = 1., see Section 2.3.4.2.
SLVOUT	SW(13)	0.	Flag for printout of weight sizing iterations during booster and orbiter weight synthesis (see Section 2.3.1.1 for iteration process) = 0., for no printout 2., for printout of final iteration = 3., for printout of each iteration

WTOUT	SW(16)	0.	Flag for intermediate printout of weight data and trajectory simulation during basic synthesis iteration process (see Section 2.3.1 for iteration process) = 0., no printout = 1., for intermediate printout
TWLO	SW(17)	1.371	Desired liftoff thrust/weight ratio if BOOTW=0., and TWLOI >0., see Section 2.3.2.2 Common Stage Engines.
TOLTW	SW(18)	.001	Tolerance on TWLO for iteration process, see Section 2.3.2.2, Common Stage Engines.
TWLOI	SW(19)	-1.	Maximum allowable number of iterations to obtain TWLO, see Section 2.3.2.2 Common Stage Engines.
PRNTX(1)	SQ(1,1)	1.	Non zero value allows printout of basic $DATA1 input as controlled by $DATA1 input parameter YOUT (see Section 4.2.3).
PRNTX (2)	SQ(1,2)	0.	Non zero value allows printout of ascent trajectory during synthesis iterations as controlled by $DATA1 input parameters XOUT, etc. (see Section 4.2.3).
PRNTX(3)	SQ(1,3)	1.	Not used.
FSEC	SQ(2,1)	0.	Final simulation section of ascent trajectory for use of a constant integration step size (from section 1 through section FSEC). The constant step utilized is the one specified by $DATA1 input of "STEP" for each section through FSEC (see Section 4.2.3). Use of a constant integration step size during section 1 smooths the convergence of the trajectory iteration scheme to a specified staging condition (dynamic pressure or flight path angle), therefore FSEC should be input = 1., with a typical STEP(1)=2., as an input value.

WOREQ	SQ(10,1)	0.	Required orbiter gross weight (lb), see Section 2.3.2.4. If WOREQ ≤ 0., the option is not used (also see Section 4.3.5.2).
DRNG	SQ(10,3)	0.	Additive range increment (n. mi) to bias results of booster cruise reference range requirement see Section 2.3.4.
WPOREQ	SQ(13,1)	0.	Required orbiter total impulse propellants (lb) see Section 2.3.2.5. If WPOREQ ≤0., the option is not used (also see Section 4.3.5.3).
GWREQ	SQ(16,1)	3500000.	Required booster gross weight (lb), see Section 2.3.2.3. If GWREQ ≤0., the option is not used (also see Section 4.3.5.1)
FLYBCK	SQ(19,5)	2.	Flag for desired method of calculating reference cruise range requirement for booster, see Sections 2.3.4.1 and 4.3.3: = 1., for parametric flyback range data = 2., for staging Q function range = 3., for constant range = 4., for ballistic impact range = 5., for entry trajectory simulation range
SOLID	SQ(20,1)	0.	Required number of solid rocket strap-on motors, see Section 2.3.3.3. If SOLID <0., the option is not used (also see Section 4.3.5.4).
AS	SQ(20,2)	0.	Constant (lb), slope (lb/sec), inert weight (lb), and exit area (in^2) per solid rocket, respectively, if SOLID > 0., see Section 2.3.3.3.
BS	SQ(20,3)	0.	
SINERT	SQ(20,5)	0.	
SAE	SQ(21,1)	0.	
SISP	SQ(20,4)	0.	Constant vacuum specific impulse (sec) and total burn time (sec) for solid rockets, respectively, if SOLID >0., see Section 2.3.3.3.
TSBO	SQ(21,2)	0.	

FBFUEL	SQ(32, 1)	1.	Flag for desired method of calculating booster cruise performance parameter, see Sec. 2.3.4.2: = 1., for single segment cruise = 2., for four segment cruise option 1 = 3., for four segment cruise option 2
CA	SQ(32, 2)	0.	Percent of the current booster weight at initiation of idle descent and final descent, respectively, to be used as cruise fuel during these cruise flight phases when FBFUEL=2., see Sec. 2.3.4.2.
CB	SQ(32, 3)	0.	
WFLYX	SQ(32, 4)	0.	Weight additive term (lb) used in calculating the booster cruise performance parameter, see Section 2.3.4.2.
RT	SQ(32, 5)	0.	Range decrements (n. mi) for transition, idle descent and final descent, respectively, when FBFUEL=2., or 3., see Sec. 2.3.4.2.
R1	SQ(33, 1)	0.	
R3	SQ(33, 2)	0.	
ALD2	SQ(34, 2)	1.	Booster subsonic lift/drag ratio, specific fuel consumption (lb/lb-hr) and cruise velocity (fps) respectively, for determining fuel expended during cruise phase when FBFUEL=2., or 3., see Section 2.3.4.2.
SFC2	SQ(33, 4)	0.	
VFLY2	SQ(34, 5)	1.	
ALD1	SQ(34, 1)	1.	Booster subsonic lift/drag ratio, specific fuel consumption (lb/lb-hr) and cruise velocity (fps) respectively, for determining fuel expended during idle descent phase when FBFUEL=3., see Section 2.3.4.2.
SFC1	SQ(33, 3)	0.	
VFLY1	SQ(34, 4)	1.	
ALD3	SQ(34, 3)	1.	Booster subsonic lift/drag ratio, specific fuel consumption (lb/lb-hr) and cruise velocity (fps) respectively, for determining fuel expended during final descent phase when FBFUEL=3., see Section 2.3.4.2.
SFC3	SQ(33, 5)	0.	
VFLY3	SQ(35, 1)	1.	

4.2.3 $DATA1

The trajectory simulation technique which is used in the SSSP program is accomplished with a special version of the General Trajectory Simulation Module (GTSM) (Reference 1). With the exception of a few input parameters required for the ascent portion of the flight, the input to the trajectory simulation part of the SSSP program is identical to that of the standard GTSM input and is accomplished via the "NAMELIST" block "$DATA1." These differences in input arise because the SSSP program assumes a fixed ascent profile and because the SSSP synthesis segments internally determine vehicle weights, propulsion parameters, and other vehicle characteristics. $DATA1 has numerous possible input parameters which provide a means to simulate a large variety of aerospace vehicles and trajectory profiles. With the exception of a few table parameters, the input parameters have internally compiled values (compiled via DATA statements) which are assumed unless specifically input with different values, or unless set or computed subsequent to the reading of the $DATA1 input. These parameters are identified in the following paragraphs (paragraphs 4.2.3.1 to 4.2.3.7) by underlining the tabulated compiled-in value; a complete list of these parameters is presented in Appendix V.

This section lists all the $DATA1 input parameters together with their definitions and stored values. For convenience, a complete index of these parameters is presented in Section 4.2.3.7. For input parameters with subscripts, these subscripts are defined:

I	First independent variable table position number
J	Second independent variable table position number
K	Simulation section number
L	Table number
M	General iteration block number
N	Denotes first or second independent variable table argument

Four quantities, each in parentheses, appear at the end of each input parameter definition. These are:

a. The input parameter code number

b. The internally compiled value. This is the value which is compiled via the DATA statement and is the value which is assumed unless specifically input with a different value, or unless redefined subsequently. Those parameters which are subject to internal redefinition are identified by underlining this internally compiled value as it appears at the bottom of its associated input parameter definition. These parameters are also identified in the Input Parameter Index (Sec. 4.2.3.7). A complete list of these parameters is presented in Appendix V.

c. The units of the parameter

d. The corresponding internal parameter

All input parameters are floating point regardless of their first letter. For those input parameters ending with a "0", the "0" is a numeric zero. When the "O" is not the last symbol in the acronym, the "O" is an alphabetic O. Even though some of these input parameters are used as "flags" to control the program logic, it is not necessary to be concerned with the floating point to integer truncation as the required logic has been provided internally in the input processing portion of subroutine TRAJA.

4.2.3.1 Initial Conditions. Initial Conditions input parameters define the initial state of the vehicle, the program control parameters which apply to the entire trajectory or which initiate the trajectory, and the required constants.

Vehicle State.

ALP Initial pitch angle of attack (output parameter 12) about the vehicle pitch axis (η axis) with algebraic sign in accordance with right handed rotations of the standard $\xi - \eta - \zeta$ coordinate system (pitch up is positive).

(62) (0.) (deg) (V(62))

ALT0 Initial altitude above the central body surface (see "ALTF" which appears later in this section).

(8) (0.) (ft) (V(8))

AZM The initial relative azimuth measured clockwise from north.

(4) (270.) (deg) (V(40)

GAM The initial relative flight angle.

(3) (90.) (deg) (V(3))

LAM Initial yaw angle of attack (output parameter 13) about the vehicle yaw axis (ζ axis) with algebraic sign in accordance with right-handed rotations of the standard $\xi - \eta - \zeta$ coordinate system (yaw right is positive).

(63) (0.) (deg) (V(63))

LAT Initial geocentric latitude - positive in the northern hemisphere

(5) (34.5815)* (deg) (V(5))

*Western Test Range (WTR) coordinates.

LNG Initial geocentric longitude - positive to the east of the Greenwich meridian.

(6) (-120.6233)* (deg) (V(6))

PLD Payload. This weight is added to the initial weight ("WGH"), the simulation section termination weights if any ("STGV(K)" if, and only if, "STGC(K) = 7.," for simulation section "K"), and the simulation section initial weights if any (if and only if "JETW(K-1)" ≤ -0.00001 for simulation K).

(10) (0.) (lb) (V(10))

PSI Initial relative pitch attitude (output parameter 43). This angle is measured from the initial geocentric radius vector (up sense) to the initial vehicle roll axis ($\hat{\xi}$ axis).

(60) (0.) (deg) (V(60))

RAD Initial geocentric radius magnitude (see "ALTF" which appears later in this section.

(1) (0.) (ft) (V(1))

SIG Initial roll (bank) angle (output parameter 11) about the vehicle roll axis ($\hat{\xi}$ axis) with algebraic sign in accordance with right-handed rotations of the standard $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ coordinate system (roll (bank) right is positive).

(61) (0.) (deg) (V(61))

T0 Initial time. The time at the initiation of simulation Section 1.

(51) (0.) (sec) (V(51))

VEL The initial relative velocity.

(2) (0.) (ft/sec) (V(2))

WGH Initial Weight. The value of "WGH" does not include payload (the value of PLD)

(7) (0.) (lb) (V(7))

Program Control.

AGQ The relative flight path angle - relative azimuth time derivative cutoff parameter. The state kinetic equation of motion which defines the time rate of change of relative azimuth ($\dot{\beta}$) is undefined for relative flight path angle (γ) values of ± 90 deg[illegible]. To prevent the expression for $\dot{\beta}$ from being arbitrarily large in [illegible]nitude (it is meaningless for $\gamma = \pm 90$ deg) it is possible to zero out this expression

If $|\gamma| > AGQ$, $\dot{\beta} = 0$

If $|\gamma| \leq AGQ$, $\dot{\beta}$ = state kinetic equation of motion value

subject to the logic associated with "ATQ" and "VELQ".

(41) (85.) (deg) (V(41))

ALTF The initial altitude - initial radius flag

If ALTF = 0., assume the input value of "ALT0" and compute "RAD".

If ALTF = 1., assume the input value of "RAD" and compute "ALT0".

(71) (0.) (none) (V(71))

ALTQ The altitude above which it is assumed there is no atmosphere. Above this altitude, "ALTQ", no atmosphere definition is made and no aerodynamic calculations are performed.

(47) (300000.) (ft) (V(47))

ATQ The absolute time - relative azimuth time delay parameter. It is possible to assume that the time rate of change of relative azimuth ($\dot{\beta}$) is zero until after a specified absolute time (t)

If t < ATQ, $\dot{\beta} = 0$ and the value of γ is unconstrained (e.g., γ can assume values which are greater in magnitude than 90 degrees).

If t ≥ ATQ, $\dot{\beta}$ = state kinetic equation of motion value subject to the logic associated with "AGQ" and "VELQ". γ is constrained such that $-90° \leq \gamma \leq 90°$ if V ≥ "VELQ".

(42) (0.) (sec) (V(42))

AZMF The automatic initial relative azimuth predictor flag which is used in conjunction with latitude-longitude targeting.
See Section 4.2.3.3 Targeting.

If AZMF = 0.,, assume the input value of "AZM"

If 1., ≤ AZMF ≤ 4.,, approximately determine "AZM" to yield the shortest (less than 180 degree) trajectory to "TLAT(AZMF)" and "TLNG(AZMF)".

If 5., ≤ AZMF ≤ 8., approximately determine "AZM" to yield the longest (greater than 180 degrees) trajectory to "TLAT(AZMF-4)" and "TLNG(AZMF-4)".

(72) (0.) (none) (V(72))

AZMI Relative azimuth of the first axis ($\hat{J}_1$) of the $\hat{J}_1 - \hat{J}_2 - \hat{J}_3$ inertial coordinate system used with the "Optional Vector Components".

If AZMI $<$ 900.,, the input value of "AZMI" is assumed.

If AZMI $\geq$ 900.,, the value of "AZMI" is reset to the current value of the initial direction parameter, "AZM".

(75) (1000.) (deg) (V(75))

GTIP Angle between the initial geocentric radius vector and the third axis ($\hat{J}_3$) of the $\hat{J}_1 - \hat{J}_2 - \hat{J}_3$ inertial coordinate system used with the "Optional Vector Components".

If GTIP $<$ 900.,, the input value of "GTIP" is assumed.

If GTIP $\geq$ 900.,, the value of "GTIP" is reset (computed internally) to the geodetic tip angle corresponding to the initial latitude, "LAT".

(76) (1000.) (deg) (V(76))

MULT Multiple Run Flag

If MULT = 0.,, no additional cases will be processed; execution terminates after the current case is completed.

If MULT = 1.,, an additional case is processed upon completion of the current case. "MULT" is then reset to zero, consequently it is necessary to input "MULT = 1.," in <u>each</u> case after which a subsequent multiple run is desired. Execution will terminate upon completion of the first case for which "MULT = 1.," has not been specifically input.

(64) (0.) (none) (V(64))

PRNT Iteration Print Option Flag

If PRNT = 0.,, brief summary information which indicates the simulation sections which have been successfully entered is output during the iteration. Upon completion of the iteration block (either successful or otherwise) the normal detailed trajectory parameters are printed for the simulation sections which comprise the iteration block.

If PRNT = 1.,, a complete output group of the detailed trajectory parameters is output at the beginning and end of each simulation section which is successfully entered during the iteration. Upon completion of the iteration block (either successful or otherwise) the normal detailed trajectory parameters are printed for the simulation sections which comprise the iteration block.

If PRNT = 2.,, complete normal detailed trajectory parameters are printed at all times during and upon completion of all iteration blocks.

(66) (0.) (none) (V(66))

PSIF The initial pitch angle of attack-pitch attitude flag

If PSIF = 0.,, the input value of "ALP" is assumed and "PSI" is then computed

If PSIF = 1.,, the input value of "PSI" is assumed and "ALP" is then computed

(67) (1.) (none) (V(67))

RFCN This parameter defines the simulation section at the end of which the total propulsive ideal velocity (Z(17)) is stored in SV(3) for subsequent use

(74) (0.) (none) (V(74))

SEC Total number of simulation sections including those required if a numerically integrated booster return trajectory is specified. The ascent trajectory always requires exactly 7 simulation sections. Any integrated return sections follow the last ascent section, consequently the first return section is Section 8. Up to 8 return sections are available and correspondingly "SEC ≤15.

(9) (7.) (none) (V(9))

STPF Minimum Integration Stepsize Option Flag

If STPF = 0.,, if the required stepsize is less than the input minimum acceptable stepsize ("HMIN(K)"), a diagnostic is printed and the integration continues with the preceding stepsize.

If STPF = 1.,, if the required stepsize is less than the input minimum acceptable stepsize "(HMIN(K)"), a diagnostic is printed and the case is terminated. (Subsequent cases are still processed.)

(48) (0.) (none) (V(48))

TWE Estimated trajectory time from the initiation of simulation section 1 to passage through "TLAT(M)" and "TLNG(M)" used in conjunction with the automatic initial relative azimuth predictor option described under "AZMF".

(73) (1800.) (sec) (V(73))

VELQ The angular time derivative cutoff parameter. The state kinetic equations of motion which define the time rate of change of relative flight path angle ($\dot{\gamma}$) and the time rate of change of relative azimuth ($\dot{\beta}$) have the relative velocity (V) in the denominator. As V approaches zero, γ and β become meaningless. In order to provide continuity in the functional values of these equations, it is possible to assume a value of V in the denominator of these equations. (Numerator values of V are not affected.)

If $|V| <$ "VELQ", V = "VELQ" is assumed in the denominator of the state kinetic equations of motion for $\dot{\gamma}$ and β and the value of γ is unconstrained (e.g., γ can assume values which are greater in magnitude than 90 degrees).

If $|V| \geq$ "VELQ", the state kinetic equations for $\dot{\gamma}$ and $\dot{\beta}$ are defined conventially. γ is constrained such that $-90° \leq \gamma \leq 90°$ if $t \geq$ "ATQ".

(65) (10.) (ft/sec) (V(65))

VGAI This parameter is NOT available to the user DO NOT attempt to input.

(77) (0.) (none) (V(77))

YOUT Table output suppression flag. The value of "YOUT" controls the printing of the input tables in accordance with Table 4-1a.

(78) (0.) (none) (V(78))

ZOUT Optional vector components output flag. See Section 5.2.2, "Optional Vector Components".

If ZOUT = 0.,, no "Optional Vector Components" are computed or output.

If ZOUT = 1.,, in addition to the regular output, "Option A" of the "Optional Vector Components" is computed and printed.

If ZOUT = 3.,, in addition to the regular output, "Option B" of the "Optional Vector Components" is computed and printed.

Do not attempt to input other values of ZOUT (e.g., 2., 4., etc.)

(86) (0.) (none) (V(86))

Table 4-1a. Input Table Printing Controlled by "YOUT"

"YOUT" Value	Print all Tables other than the Atmosphere Table		Print the Atmosphere Table	
	First Case	Subsequent Cases	First Case	Subsequent Cases
0.,	yes	yes	yes	yes
1.,	yes	yes	yes	no
2.,	yes	no	yes	no
3.,	yes	yes	no	no
4.,	no	no	no	no
5.,	yes	no	no	no

NOTE: Use of "YOUT" is used only in conjunction with the normal printing of the $DATA1 input which is obtained by setting the $DATA2 input flag "PRNTX(1)" to a non-zero value (see Section 4.2.2). This allows the GTSM subprogram to print the initial conditions, simulation section data, etc., in a special format. Special care should be used in interpreting this output since many of the simulation section conditions and initial conditions are computed during the synthesis process and therefore will be printed with only their internally initialized values (see Section 5.0).

Constants

A Equatorial surface radius, semi-major axis of the surface ellipsoid of the central body.

(49) (20925741.) (ft) (V(49))

B Polar surface radius, semi-minor axis of the surface ellipsoid of the central body.

(50) (20855591.) (ft) (V(50))

CK Gravitational field constant of the central body

(36) (1.407654×10^{16}) (ft^3/sec^2) (V(36))

CNV1 Conversion factor, 3.14159265 radians per 180 degrees.

(44) (3.14159265) (rad/deg) (V(44))

CNV2 Conversion factor, 57.295780 degrees per radian

(45) (57.295780) (deg/rad) (V(45))

CNV3 Conversion factor, 6076.1033 feet per nautical mile.

(46) (6076.1033) (ft/n.mi.) (V(46))

CNV4 Conversion factor, 0.00030480061 kilometers per foot.

(79) (0.00030480061) (km/ft) (V(79))

D2 Second gravitational harmonic coefficient*

(38) (1062.30×10^{-6})† (none) (V(38))

D3 Third gravitational harmonic coefficient*

(39) (-2.30×10^{-6})† (none) (V(39))

D4 Fourth gravitational harmonic coefficient*

(40) (-1.80×10^{-6})† (none) (V(40))

---

*These coefficients are defined according to standard convention (Reference 5) and agree with Reference 12.

† Reference 6

G0 Reference gravitational surface acceleration used for mass to weight conversion

(35) (32.174049)* (ft/sec^2) (V(35))

P0 Reference sea level atmospheric pressure used for the atmospheric correction to the thrust level.

(43) (14.)* (lb/in^2) (V(43))

WE Rotational rate of the central body

(37) (0.0041780746)** (deg/sec) (V(37))

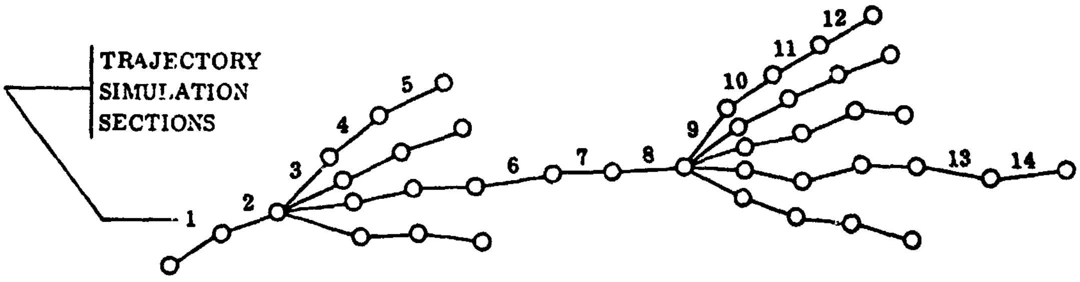
---

* Reference 9

** Reference 5

4.2.3.2 General Iteration.

A general iteration block (GIS block) is a group of simulation sections which are iterated to meet specified end conditions defined within the simulation sections of the block (see Figure 4-2). The primary* iteration control variables must also be selected from the simulation sections† contained within the iteration block, however the secondary* control variables need not be within the iteration block. This general iteration scheme (GIS) allows the selection of any of the "input parameters" which have a code number as members of iteration control variable groups for an iteration block. The end conditions may be any of the output parameters which are computed‡ in any section contained in the iteration block in question. The end condition value is the last computed value of the selected output parameter during the selected simulation section. One or two control variable groups - end conditions can be specified for each iteration



GIS Block 1: Simulation sections 3, 4, & 5
GIS Block 2: Simulation sections 9, 10, 11, & 12
O Denotes initiation or termination of a simulation section

Figure 4-2. Flight Profile with General Iteration Blocks (GIS Blocks)

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*It is possible to chain control variables such that a group of control variables act as a single control variable during iteration. In this case there is one primary control variable per control variable group. The other control variables in the group are secondary.

†Initial Conditions are considered as simulation Section 0.

‡If the desired end condition is an "Optional Output Parameter" (see Section 5/1.2.2. "Optional Output Parameters"), it is necessary to call for the containing group of optional parameters with appropriate input.

block, and up to four iteration blocks are available, however iteration blocks cannot overlap contained simulation sections.[*] It is possible to chain up to five like simulation section input parameters to form any or all of the control variable groups. Caution should be exercised to ensure that a reasonably continuous dependence exists between the selected end conditions and the control parameters.

The ascent trajectory uses the first two GIS blocks with some of the corresponding input being preset or defined internally (See Appendix V). Consequently only GIS blocks 3 and 4 are available during the integrated return trajectory, however these GIS blocks are general and accept all the input listed in this section.

CVC1(M)	Input parameter code number of all the parameters comprising the first control variable group			
	(11)	(0.)	(none)	(V(11), VQ(1, M))
CVC2(M)	Same as "CVC1(M)" except for the second control variable group.			
	(12)	(0.)	(none)	(V(12), VQ(2, M))
CVC3(M)	Not available to user.			
	(13)	(0.)	(none)	(V(13), VQ(3, M))
CVL1(M)	The minimum value allowed for the primary control variable of the first control variable group. If the iteration procedure predicts a value of the primary control variable which is algebraically lower than "CVL1(M)", the iteration process is terminated with appropriate diagnostics.			
	(29)	(0.)	(C. V. Units)[‡]	(V(29), VQ(19, M))
CVL2(M)	Same as "CVL1(M)" except for the second control variable group.			
	(30)	(0.)	(C. V. Units)[‡]	(V(30), VQ(20, M))
CVL3(M)	Not available to user.			
	(31)	(0.)	(none)	(V(31), VQ(21, M))

---

[*] The simulation sections where secondary control variables are defined are not necessarily contained in the general iteration block.

[†] Same code number.

[‡] Control variable units.

CVM1(M) The maximum value allowed for the primary control variable of the first control variable group. If the iteration procedure predicts a value of the primary control variable which is algebraically greater than "CVM1(M)", the iteration process is terminated with appropriate diagnostics.

(26) (0.) (C.V. Units)* (V(26), VQ(16, M))

CVM2(M) Same as "CVM1(M)" except for the second control variable group.

(27) (0.) (C.V. Units)* (V(27), VQ(17, M))

CVM3(M) Not available to user.

(28) (0.) (none) (C(28), VQ(18), M))

CVN1(M) The simulation section numbers of the simulation sections for which the control variables of the first control variable group are defined. Only simulation section input parameters (input parameters with a "K" subscript) may be chained, that is, have more than one parameter to a control variable group. Non-simulation section parameters must be solo members of control variable groups and are consequently considered the primary control variable for the purposes of these definitions. For control variable groups consisting of simulation section input parameters, there must be one and only one primary control variable and there can be from 0 to 4 secondary control variables. The primary control variable value is the one used in evaluating the iteration derivatives and the predicted control variable increments. The secondary control variables which must have the same input parameter code number can have values different from the primary variable and from each other. The secondary variables are incremented whenever the primary variable is and by the same amount. The simulation section where the primary control variable is defined is contained in the GIS block; this is not necessary for secondary control variables, that is, the secondary control variables can be defined in any simulation section before, within, and after the GIS block which contains the primary control variable. The value of "CVN1(M)" defines the simulation sections in which the primary and secondary control variables for the first control variable group are defined. The general form of "CVN1(M)" is:

$$\mathrm{CVN1(M)} = [100000000 \cdot B_4 + 1000000 \cdot B_3 + 10000 \cdot B_2 + 100 \cdot B_1 + A].,$$

---

*Control variable units.

where: "A" is the simulation section number in which the primary control variable is defined. For non-simulation section input parameters (input parameters with no "K" subscript) "A" is assumed to be zero. B_1, B_2, B_3, and B_4 are the simulation section numbers of the simulation sections in which the secondary control variables are defined. If any "B" is zero, it is assumed that there is no corresponding secondary control variable for that particular "B" position.

<u>Examples:</u>

1. If the first control variable group of the 3rd GIS block is comprised of simulation section input parameters from simulation sections 9,13,10, and 8, and the parameter from simulation sec 13 is to be the primary control variable then "CVN1(2)" can have the following values:

```
          CVN1(3)  =    9100813.,
or
          CVN1(3)  =    8091013.,
or
          CVN1(3)  =  908001013.,
or
          CVN1(3)  = 1009080013.,
or
                            -
 -
                            -
 -
                            -
 -
                            -

                            -
```

Any permutation of 00, 08, 09, and 10 is acceptable providing 13 always occupies the tens and units positions reserved for "A".

2. If the first control variable group of the 4th GIS block is comprised of one input parameter from simulation section 9, then "CVN1(4)" = 9.,

(14) <u>(0.)</u> (none) (V(14), VQ(4,M))

CVN2(M) Same as "CVN1(M)" except for the second control variable group.

(15) (0.) (none) (V(15), VQ(5, M))

CVN3(M) Not available to user.

(16) (0.) (none) (V(16), VQ(6, M))

DCV1(M) First control variable increment for all elements of the first control variable group used to determine the iteration partial derivatives.

(23) (0.) (C. V. Units)* (V(23), VQ(13, M))

DCV2(M) Second control variable increment for all the elements of the second control variable group used to determine the iteration partial derivatives.

(24) (0.) (C. V. Units)* (V(24), VQ(14, M))

DCV3(M) Not available to user.

(25) (0.) (none) (V(25), VQ(15, M))

EC1(M) The required value of the first end condition.

(52) (0.) (E. C. Units)† (V(52), VQ(25, M))

EC2(M) The required value of the second end condition.

(53) (0.) (E. C. Units)† (V(53), VQ(26, M))

EC3(M) Not available to user.

(54) (0.) (none) (V(54), VQ(27, M))

ECC1(M) Output parameter code number for the first end condition.

(17) (0.) (none) (V(17), VQ(7, M))

ECC2(M) Output parameter code number for the second end condition.

(18) (0.) (none) (V(18), VQ(8, M))

ECC3(M) Not available to user.

(19) (0.) (none) (V(19), VQ(9, M))

---

*Control variable units.

†End condition units.

ECN1(M) Simulation section number of the simulation section in which the first end condition is defined.

(20) (0.) (none) (V(20), VQ(10, M))

ECN2(M) Same as "ECN1(M)" except for the second end condition.

(21) (0.) (none) (V(21), VQ(11, M))

ECN3(M) Not available to user.

(22) (0.) (none) (V(22), VQ(12, M))

ECT1(M) First end condition iteration tolerance. Acceptable first end condition values for convergence must be within this tolerance of the required end condition.

(32) (0.) (E.C. Units)* (V(32), VQ(22, M))

ECT2(M) Same as "ECT1(M)" except for the second end condition.

(33) (0.) (E.C. Units)* (V(33), VQ(23, M))

ECT3(M) Not available to user.

(34) (0.) (none) (V(34), VQ(24, M))

GIS(M) Iteration control flag. The value of "GIS(M)" determines what type iteration, if any, will be accomplished. *

(55) (0.) (none) (V(55), VQ(28, M))

HANM Orbiter targeting flag. If HANM ≤ the orbiter vehicle is not targeted to an orbit with a specific injection true anomaly, perigee altitude and apogee altitude. If HANM > 0 the option to target the orbiter vehicle to specific orbit is used. In this option, the "target" orbit is defined by the value of its apogee and perigee altitudes with the other orbital elements being left free to be a function of the ascent trajectory. The injection condition is a specified true anomaly. This targeting option is flagged whenever HANM >0. The option then takes the value of HANM as that of the required apogee altitude

(none) (0.) (n. mi) (SQ(3, 1), HANM))

* GIS(K) = 0., 1., or 4., denotes no iteration, single variable iteration, or two variable iteration

HPNM	The required perigee altitude for the orbiter targeting option (see HANM described above)			
	(none)	(0.)	(n. mi)	(SQ(3, 2), HPNM))
ITT1(M)	Maximum number of iterations allowed for the (1 x 1), or (2 x 2) iterations respectively. If the number of iterations during an iteration exceeds ITT1(M), an appropriate diagnostic is printed and the iteration is terminated.			
	(57)	(10.)	(none)	(V(57), VQ(29, M))
ITT2(M)	Not available to user			
	(58)	(10.)	(none)	(V(58), VQ(30, M))
ITT3(M)	Not available to user			
	(59)	(10.)	(none)	(V(59), VQ(31, M))
TRANOM	The required injection true anomaly for the targeting option (see HANM described above)			
	(none)	(0.)	(deg)	(SQ(3, 3), TRANOM))

4.2.3.3 Targeting. It is possible to reference a geocentric radius vector of any magnitude (see Figure 4-3) which is defined by its geocentric latitude ("TLAT(M)") and longitude("TLNG(M)") in order to compute the current cross range at each integration step from the plane which passes through this reference geocentric radius vector (called the "target vector") and the initial geocentric radius vector which is defined by "LAT" and "LNG". A target landing or other reference point can then be any point along this target radius vector and would be defined by its radius or its altitude (usually introduced in a simulation as a simulation section termination parameter). The significance of this option is the capability to compute the "target miss angle" (output position parameter code number 50) and the "target miss angle" (output position parameter code number 51). This option together with the option to automatically determine the downrange angle between the initial and the target vectors to use as required end conditions in GIS blocks 3 or 4 greatly simplifies the iteration procedure and eliminates parameter crosscoupling which can occur when iterating to a latitude and longitude within a GIS block. In this case, the required downrange end condition value (corresponding iteration end condition code number is set equal to 49.,) can be internally computed, and the required crossrange end condition value (corresponding code number is set equal to 50.,) is identically equal to zero. In addition, a radar or landing site can be located along the target vector by specifying it altitude above the central body surface ("RDALT(M)") for the purpose of computing the position of the vehicle in radar coordinates from this site (see "WOUT(K)") in Section 4.2.3.5).

*end condition units

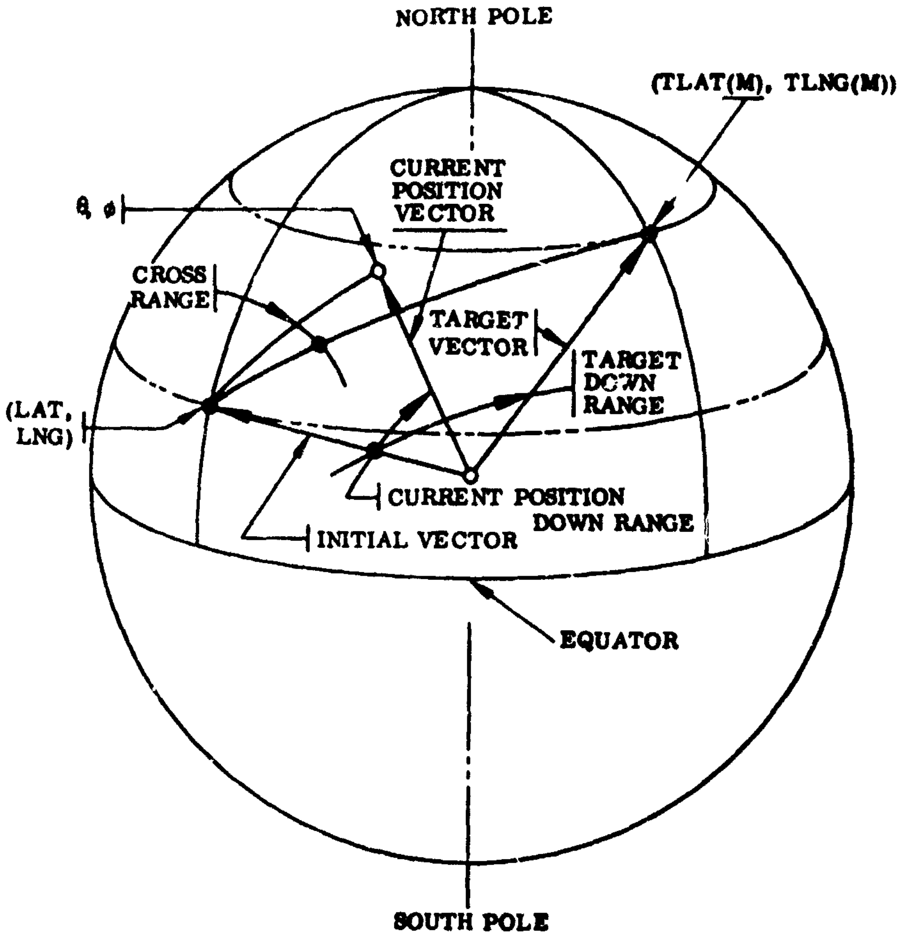

Figure 4-3. Downrange, Crossrange, and Targeting

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CRGF(M) Crossrange-downrange targeting control flag.

If CRGF(M) = 0., for all possible "M" values (1., 2., 3., and 4.,) the output parameters 50., and 51., are not computed.

If CRGF(M) = 1., same as if "CRGF(M)" = 4., except the first iteration end condition required value of the Mth GIS block ("EC1(M)") is internally set equal to the range angle between (LAT", "LNG") and ("TLAT(M)", "TLNG(M)"). The range angle can be either the smallest or the largest great circle subtended by these two points (greater than or less than 180 degrees). This selection is based on the <u>input</u> value of "AZM", even if the automatic initial relative azimuth prediction option ("AZMF") is used, and is defined in Table 4-1

If CRGF(M) = 2., same as if "CRGF(M) = 1.," except "EC2(M)" is set equal to the appropriate range angle between ("LAT", "LNG") and ("TLAT(M)", "TLNG(M)").

If CRGF(M) = 3., Not available to user. DO NOT attempt to input.

Table 4-1. Definition of Great Circles

Direction of the Smallest Great Circle between ("LAT","LNG"), and ("TLAT(M)", ("TLNG(M)")	Desired Great Circle Angle between ("LAT","LNG") and ("TLAT(M)", "TLNG(M)")	"AZM" (Input Value)
Easterly	Less then 180 degrees	0° ≤ "AZM" ≤ 180°
Easterly	Greater than 180 degrees	180° < "AZM" < 360°
Westerly	Less than 180 degrees	180° < "AZM" < 360°
Westerly	Greater than 180 degrees	0° ≤ "AZM" ≤ 180°

CRGF(M) Crossrange-downrange targeting control flag.

If CRGF(M) = 0., for all possible "M" values (1., 2., 3., and 4.,) the output parameters 50., and 51., are not computed.

If CRGF(M) = 1., same as if "CRGF(M)" = 4., except the first iteration end condition required value of the Mth GIS block ("EC1(M)") is internally set equal to the range angle between (LAT", "LNG") and ("TLAT(M)", "TLNG(M)"). The range angle can be either the smallest or the largest great circle subtended by these two points (greater than or less than 180 degrees). This selection is based on the <u>input</u> value of "AZM", even if the automatic initial relative azimuth prediction option ("AZMF") is used, and is defined in Table 4-1

If CRGF(M) = 2., same as if "CRGF(M) = 1.," except "EC2(M)" is set equal to the appropriate range angle between ("LAT", "LNG") and ("TLAT(M)", "TLNG(M)").

If CRGF(M) = 3., Not available to user. DO NOT attempt to input.

Table 4-1. Definition of Great Circles

Direction of the Smallest Great Circle between ("LAT","LNG"), and ("TLAT(M)", ("TLNG(M)")	Desired Great Circle Angle between ("LAT","LNG") and ("TLAT(M)", "TLNG(M)")	"AZM" (Input Value)
Easterly	Less than 180 degrees	0° ≤ "AZM" ≤ 180°
Easterly	Greater than 180 degrees	180° < "AZM" < 360°
Westerly	Less than 180 degrees	180° < "AZM" < 360°
Westerly	Greater than 180 degrees	0° ≤ "AZM" ≤ 180°

if CRGF(M) = 4., for any or all possible "M" values (1., 2., 3., and 4.,) and if there are no GIS iteration blocks in the simulation ("GIS(M) = 0.," for M = 1, 2, 3, and 4), the highest "M" for which "CRGF(M)" > 0.5, is the "M" used to define "CRGF(M)", "TLAT(M)", "TLNG(M)", and "RDALT(M)" and to compute the corresponding crossrange angle and target miss angle values (output parameters 50., and 51.,) at each integration step during all the trajectory simulations; see Figure 4-4A for example. If any or all GIS iteration blocks ("GIS(M)" > 0.5 for "M" = 1, and/or 2, and/or 3, and/or 4) are used, the current "M" which defines all the iteration parameters (all that are subscripted with "M") for the Mth GIS block also defines "CRGF(M)", "TLAT(M)", "TLNG(M)" and "RDALT(M)". This current "M" not only defines the above parameters during the simulation sections of the Mth GIS block, but also for all the simulation sections between the Mth GIS block and the immediately previously defined block if one exists. If there are no previous GIS blocks, these parameters are defined from and including the first simulation section to the last simulation section of the Mth GIS block. The last defining "M" value is assumed for any simulation sections following the last GIS block. See Figure 4-4B

(68) (0.) (none) (V(68), VQ(32, M))

RDALT(M) Altitude of the radar site above the central body surface

(80) (0.) (ft) (V(80), VQ(35, M))

TLAT(M) Geocentric latitude of the target vector

(69) (0.) (deg) (V(69), VQ(33, M))

TLNG(M) Geocentric longitude of the target vector

(70) (0.) (deg) (V(70, VQ(34, M))

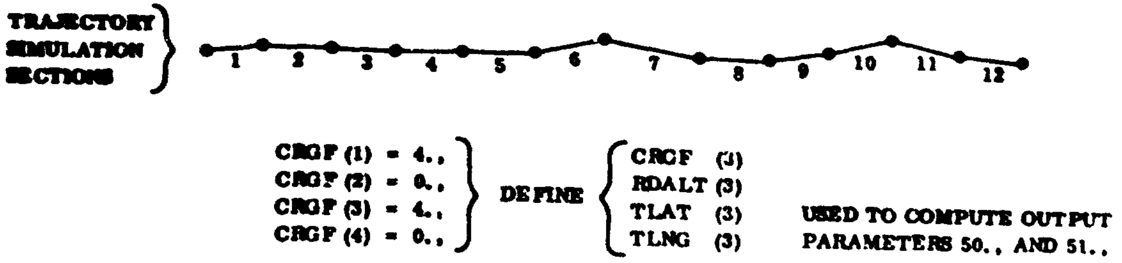

Figure 4-4A. No GIS Blocks ("GIS(M) = 0.," for M = 1, 2, 3, and 4)

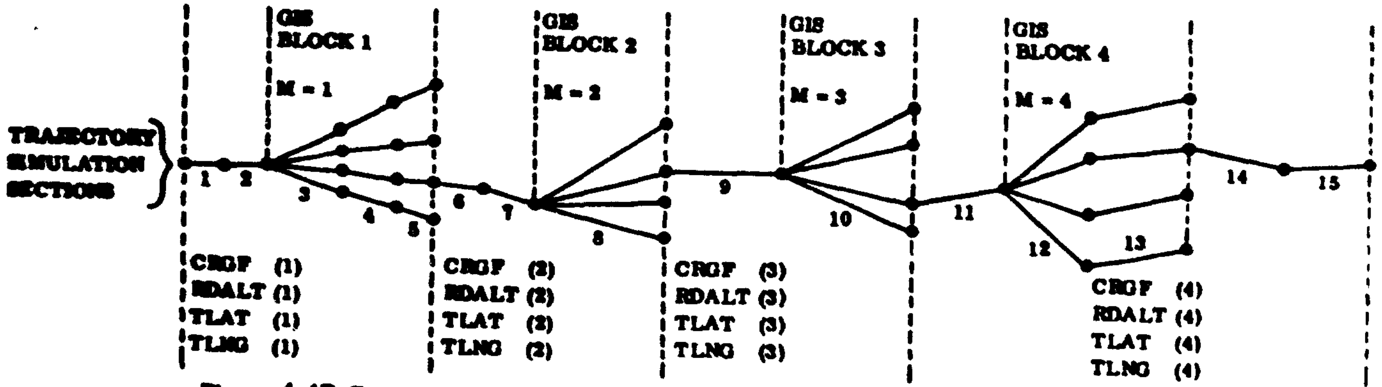

Figure 4-4B Targeting with GIS Blocks 3, and 4 ("GIS(M)" > 0.5 for M = 1, 2, 3, and 4)

Figure 4-4. Targeting - Iteration Control Relationships

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4.2.3.4 Integration Control

The efficient Kutta-Merson variable stepsize numerical integration technique is used to integrate the twelve state equations which define the three degree-of-freedom vehicle motion, vehicle mass, ideal velocity, velocity losses, and heating parameter. These twelve state equations define the time rate of change of the following parameters:

a. Geocentric Radius Magnitude
b. Relative Velocity
c. Relative Flight Path Angle
d. Relative Azimuth
e. Geocentric Latitude
f. Geocentric Longitude
g. Vehicle Weight
h. Total Ideal Velocity
i. Relative Velocity Loss due to Gravity
j. Relative Velocity Loss due to Aerodynamic Forces
k. Relative Velocity Loss due to Thrust Misalignment
l. Heating Parameter

The Kutta-Merson integration technique requires the evaluation of five sequenced polynomials, each (except the first) dependent on the preceding one, to integrate over a single step. Ideally the values of these polynomials should converge to the correct integrated value at the end of the integration step. The integration error has been shown to be 0.20 times the magnitude of the difference between the fourth and fifth polynomial and is a measure of the integration accuracy during a single step. The relative values of the lower and upper integration tolerances and the current integration error are used to control the integration stepsize. To expand the stepsize, the integration error must be less than the corresponding lower integration tolerance for all the state variables: stepsize contraction is caused if the integration error for any state variable is greater than its corresponding upper integration tolerance. If all the integration error values are less than their corresponding upper integration tolerances but at least one is greater than its corresponding lower integration tolerance, the integration stepsize remains unchanged. The units used for the integration errors, lower tolerances, and upper tolerances are the same as those of the corresponding state variables. This variable stepsize procedure is illustrated in Table 4-2.

TABLE 4-2. VARIABLE STEPSIZE PROCEDURE

Error Condition	Number of State Variables for which the Condition Exists	Effect on Stepsize and Integration Procedure
Error < lower tol.	All	Stepsize is expanded for starting the next integration step
Error > upper tol.	One or more	Stepsize is reduced and the current integration step is reattempted
Error < upper tol. Error > lower tol.	All One or more	Stepsize is unchanged for starting the next integration step

HCOEF(K) Integration stepsize expansion coefficient.

If the lower integration tolerances are met for all the state variables, the integration stepsize is expanded by "HCOEF(K)" times the current stepsize value.

(40) (2.0) (none) (Q(40, K))

HMIN(K) The minimum acceptable integration stepsize. Failure to meet any of the upper integration tolerances results in halving the stepsize to reattempt the integration step. This halving process is continued as required until either the upper tolerances are met or the required stepsize is less than "HMIN(K)". In the latter event, after appropriate diagnostics are printed, the case can be either continued by using the nearest halved stepsize above "HMIN(K)" or terminated. The option which is exercised depends on the value of the initial conditions-program control input parameter "STPF" which is described in Section 4.2.3.2.

(39) (0.05) (sec) (Q(39, K))

HTL1(K) Lower integration tolerance used for the geocentric radius magnitude.

(15) (0.10) (ft) (Q(15, K))

HTL2(K) Lower integration tolerance used for the relative velocity, total ideal velocity, velocity loss due to gravity, velocity loss due to aerodynamic forces, and velocity loss due to thrust misalignment.

(16) (0.05) (ft/sec) (Q(16, K))

HTL3(K) Lower integration tolerance used for the relative flight path angle.

(17) (0.01) (deg) (Q(17,K))

HTL4(K) Lower integration tolerance used for the relative azimuth.

(18) (0.01) (deg) (Q(18,K))

HTL5(K) Lower integration tolerance used for the geocentric latitude.

(19) (0.01) (deg) (Q(19,K))

HTL6(K) Lower integration tolerance used for the geocentric longitude.

(20) (0.01) (deg) (Q(20,K))

HTL7(K) Lower integration tolerance used for the vehicle weight.

(21) (0.10) (lb) (Q(21,K))

HTL8(K) Lower integration tolerance used for the heating parameter.

(55) (10000000.) (lb/ft-sec) (Q(55,K))

RCOEF(K) Integration step size reduction coefficient. If an upper integration tolerance is exceeded for any state variable, the integration step size is reduced to a value which is equal to "RCOEF(K)" times the current step size subject to the logic associated with "HMIN(K)".

(72) (0.5) (none) (Q(72,K))

STEP(K) Stepsize which is used to start the integration process at the beginning of simulation Section "K" subject to the logic associated with "HMAX(K)".

(7) (2.0, 14 * 5.0) (sec) (Q(7,K))

TOL1(K) Upper integration tolerance used for the geocentric radius magnitude.

(8) (1.0) (ft) (Q(8,K))

TOL2(K) Upper integration tolerance used for the relative velocity, total ideal velocity, velocity loss due to gravity, velocity loss due to aerodynamic forces, and velocity loss due to misalignment.

(9) (0.5) (ft/sec) (Q(9,K))

TOL3(K) Upper integration tolerance used for the relative flight path angle.

(10) (0.1) (deg) (Q(10, K))

TOL4(K) Upper integration tolerance used for the relative azimuth.

(11) (0.1) (deg) (Q(11, K))

TOL5(K) Upper integration tolerance used for the geocentric latitude.

(12) (0.1) (deg) (Q(12, K))

TOL6(K) Upper integration tolerance used for the geocentric longitude.

(13) (0.1) (deg) (Q(13, K))

TOL7(K) Upper integration tolerance used for the vehicle weight.

(14) (1.0) (lb) (Q(14, K))

TOL8(K) Upper integration tolerance used for the heating parameter.

(54) (50000000.) (lb/(ft-sec)) (Q(54, K))

[illegible] Program Control

A trajectory simulation can be subdivided into several simulation sections, not to exceed 7 or 15 depending on whether a numerically integrated return trajectory is computed. The program control parameters are used to regulate these simulation sections by defining the conditions under which the sections are terminated, by specifying the additional computations of the instantaneous orbital elements and instantaneous impact conditions, by specifying a cycle check for the relative azimuth and geocentric longitude, by resetting the ideal velocity and associated velocity losses, and by defining the amount of output suppression.

BCKT(K) Backup time section termination flag.

If the normal simulation section termination logic has been initiated or if "STGC(K)" = -1., or 0., the backup time simulation section termination option is bypassed. The former condition occurs when the integration step results in the specified normal termination output parameter (defined by the value of "STGC(K)") passing through its specified termination value ("STGV(K)") in the specified direction ("STGD(K)"). Otherwise:

If BCKT(K) > 0.,, "BCKT(K)" is the section relative backup time. If the section relative time exceeds the value of "BCKT(K)", the simulation section is terminated at the section relative time equal to the value of "BCKT(K)".

If BCKT(K) < 0.,, "BCKT(K)" is the negative of the absolute backup time. If the absolute time exceeds the value of minus "BCKT(K)", the simulation section is terminated at the absolute time equal to the value of minus "BCKT(K)".

(41) (500.,) (sec) (Q(41,K))

BCKTT(K) Backup time termination tolerance.

If the backup time termination procedure has been initiated, the backup time termination is considered completed when the section relative or absolute (as appropriate) time is within "BCKTT(K)" of the value defined by "BCKT(K)".

(42) (0.001) (sec) (Q(42,K))

ORB(K) Orbital Elements Flag.

If ORB(K) = 0.,, no orbital elements are computed.

If ORB(K) = 1.,, the orbital elements (output parameters 66 to 77, 91, and 96 to 100)* are computed and printed.

---

*If the orbiter targeting option (see HANM in Section 4.2.3.2) is specified, output parameters [illegible] to 103 are also computed.

If ORB(K) [illegible]., the orbital elements (output parameters 66 to 77, 91, and 96 to 100)* and the instantaneous impact conditions** (output parameters 84 to and including 89) for an oblate central body (if modeled for the simulation) are computed and printed.

If ORB(K) = 3., the orbital elements (output parameters 66 to 77, 91, and 96 to 100)* and the instantaneous impact conditions** (output parameters 84 to and including 89) for a spherical central body with a surface radius equal to that at "LAT" are computed and printed.

(56) <u>(0.)</u> (none) (Q(56, K))

PRIF(K) Relative Azimuth, Longitude, and Argument of Perigee Cycle Check Flag.

If PRIF(K) = 0., the values of the relative azimuth, the longitude, and (if computed) the argument of perigee are kept between 0 and 360 degrees by adding or subtracting 360 degrees as appropriate.

If PRIF(K) = 1., the values of the relative azimuth, the longitude, and (if computed) the argument of perigee are not restricted to the 0 to 360 degree range, but are allowed to proceed outside this range when appropriate. This option is particularly useful when iterating to or terminating a simulation section on values of these parameters near 0 degree or an internal multiple (either positive or negative but less than 25 in magnitude) of 360 degrees as it provides numerical continuity in the values of these parameters.

(65) (0.) (none) (Q(65, K))

STGC(K) Section termination code number. The value of "STGC(K)" should be equivalent to the code number of the output parameter which is to be used to terminate simulation section "K".

(22) <u>(0.)</u> (none) (Q(22, K))

---

* If the orbiter targeting option (see HANM in Section 4.2.3.2) is specified, output parameters 101 to 103 are also computed.

** The instantaneous impact conditions are computed only if

1. $R_p \leq 0.999B$
2. $R_A \geq B$
3. $0.0001 \leq e \leq 0.9999$

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STGD(K) Section termination direction code number.

If STGD(K) = -1., simulation section "K" is to be terminated on the decreasing value of the termination output parameter

If STGD(K) = +1., simulation section "K" is to be terminated on the increasing value of the termination output parameter.

(25) (1.) (none) (Q(25, K))

STGT(K) Section termination tolerance.

If the value of the simulation section "K" termination output parameter is within "STGT(K)" of the specified simulation section "K" termination value ("STGV(K)") and if the termination parameter values have the right direction (see "STGD(K)") then the simulation section is terminated.

(24) (0.001) (S.T.P. Units*) (Q(24, K))

STGV(K) Section termination parameter value. This is the required value (the value of initial conditions input parameter "PLD" is internally added if "STGC(K)" = 7.,) of the section termination parameter at the end of simulation section "K" (see "STGT(K)"). Additionally, if the termination direction ("STGD(K)") and the termination value ("STGV(K)") are such as to indicate that this termination value would have been reached prior to simulation section "K" (the logic here assumes a continuous monotonic trajectory), then simulation section "K" is terminated immediately with an appropriate diagnostic, and the trajectory continues by starting the next simulation section.

(23) (0.) (S.T.P. Units*) (Q(23, K))

VINC(K) Ideal velocity increment parameter. See "VSET(K)" this section for usage.

(68) (0.) (ft/sec) (Q(68, K))

VSET(K) Ideal velocity reset flag. The values of the propulsion ideal velocity (Z(17)), the gravity relative velocity loss (Z(18)), the aerodynamic relative velocity

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*Same units as the corresponding section termination output parameter.

loss (Z(19)), and the thrust misalignment relative velocity loss (Z(20)) can be reset upon termination of simulation section "K" according to the following scheme.

If VSET(K) = 0., , there is no change in Z(17), Z(18), Z(19), and Z(20).

If VSET(K) = 1., , Z(17) is reset to "VINC(K)" and there is no change in Z(18), Z(19), and Z(20).

If VSET(K) = 2., , Z(17) is reset to "VINC(K)" and Z(18), Z(19), and Z(20) are reset to 0., .

If VSET(K) = 3., , Z(17) is reset to Z(17) + "VINC(K)" and there is no change in Z(18), Z(19), and Z(20).

If VSET(K) = 4., , Z(17), Z(18), Z(19), and Z(20) are reset by incrementing each value by "VINC(K)".

If VSET(K) = 5., , Z(17) is reset to Z(17) + "VINC(K)" and Z(18), Z(19), and Z(20) are reset to 0., .

(67) (0.) (none) (Q(67,K))

WOUT(K) Radar coordinate flag.

If WOUT(K) = 0., , the position of the vehicle is not computed in radar coordinates.

If WOUT(K) = 1., , the position of the vehicle is computed in radar coordinates from a radar site located at the initial coordinates specified by "LAT", "LNG", and "ALT0" or "RAD". The corresponding output parameters are 53, 79, and 80.

If WOUT(K) = 2., , same as when "WOUT(K) = 1.," except in addition if "CRGF(M)" > 0.5, the position of the vehicle is also computed in radar coordinates for a radar site located on the target vector at a point defined by "TLAT(M)", "TLNG(M)", and "RDALT(M)". The corresponding output parameters are 53, 79, 80, 81, 82, and 83.

If WOUT(K) = 3., , same as when "WOUT(K) = 2.," except in addition, the position of a landing site defined by "TLAT(M)," "TLNG(M)," and "RDALT(M)." The corresponding output parameters are 53, 79, 80, 81, 82, 83, 93, 94, and 95.

(69) (0.) (none) (Q(69,K))

XOUT(K) Section output suppression flag. The output parameters are printed once every "XOUT(K)"-th integration step and at the beginning and end of simulation section "K".

(53) (1.) (none) (Q(53,K))

4.2.3.6 Modeling Control

The modeling control parameters provide the means to select which of the available models are to be used to define the magnitude and direction of the applied forces on the vehicle during flight. The modeling categories include aerodynamics, vehicle attitude, and propulsion.

ATMOSPHERE MODEL. The atmosphere model is specified by defining the ambient pressure (lb/in^2) and the velocity of sound (ft/sec) as functions of altitude (ft). This is accomplished by means of a double two-dimensional table. In the event that the current altitude is outside the lower and upper bounds of the table altitude argument values (the lowest and the highest values of "ALT(I)"), an appropriate error diagnostic is printed and the trajectory case is terminated (subsequent cases are still processed) if and only if this error occurs at the successful completion of an integration step. Errors of this type occurring within an integration step do not cause termination.

The Cape Kennedy Reference Atmosphere (CKRA) also known as the 1963 Patrick Reference Atmosphere (Ref 9) is internally stored and is the model which is used unless another model is input by the parameters listed below. A listing of this computed atmosphere is presented in Appendix III.

ATMC(K) Atmosphere and GIMAC* weight flow rate flag.

If ATMC(K) = 0., the atmosphere table is not used or required, the ambient pressure is assumed to be zero, there are no aerodynamic calculations, and no GIMAC weight flow rates are computed.

If ATMC(K) = 1., the atmosphere table is used to define the ambient pressure and the velocity of sound as functions of altitude. No GIMAC weight flow rates are computed.

If ATMC(K) = 2., same as when "ATMC(K) = 1.," except in addition the GIMAC weight flow rates are computed.

(27) (0.) (none) (Q(27,K))

*** Gas injection maneuver and control.**

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ALT(I) Ith altitude argument of the atmosphere table. This parameter is the independent variable of the atmosphere table. See Figure 4-5.

(none) (See Appendix III) (ft) (ALT(I))

PRS(I) Ith atmospheric ambient pressure argument which corresponds to the Ith altitude argument of the atmosphere table. This parameter is one of the dependent variables of the atmosphere table. See Figure 4-5.

(none) (See Appendix III) (lb/in^2) (PRS(I))

XKA0 The number of altitude arguments (and likewise the number of ambient pressure and velocity of sound arguments) in the atmosphere table. The maximum number of arguments for these parameters is 200 and the minimum number is 2, consequently $2 \le$ XKA0 ≤ 200 if the table is called out.

(none) (193.) (none) (XNA0)

VLS(I) Ith velocity of sound argument which corresponds to the Ith altitude argument of the atmosphere table. This parameter is one of the dependent variables of the atmosphere table. See Figure 4-5.

(none) (See Appendix III) (ft/sec) (VLS(I))

AERODYNAMIC MODELS. GTSM has three-dimensional aerodynamic modeling capability which can be used to define the aerodynamic forces along the standard* pitch axis ($\hat{\eta}$ axis), roll axis ($\hat{\xi}$ axis), and yaw axis ($\hat{\zeta}$ axis).† Each of these models is specified by defining the appropriate aerodynamic coefficient (C_η, C_ξ and C_ζ) as a function of Mach number and the pitch angle of attack. This is accomplished by means of three-dimensional tables for each aerodynamic coefficient to be modeled. In the event that either the current Mach number or the angle of attack value is outside the lower and upper bounds of the table argument values of these parameters ("A2(J, L)" and "XM2"(I, L)" in the case of the Aerodynamic Axial Force Coefficient Table) an appropriate error diagnostic is printed and the trajectory case is terminated (subsequent cases are still processed) if and only if this error occurs at the successful completion of an integration step. Errors of this type occurring within an integration step do not cause termination. Up to five tables are available for each aerodynamic axis, however Tables 1 and 2 are reserved for the booster ascent portion of the trajectory (Sections 1, 2, and 3). In this case Table 1 for both C_ξ and C_ζ represents the powered booster aerodynamic coefficient while the booster is in the presence of the attached orbiter, while Table 2 represents the no thrust orbiter aerodynamic coefficient while the orbiter is attached to the booster. Table 3 is reserved for the powered orbiter solo (Sections 4, 5, 6, and 7) aerodynamic modeling (C_ξ and C_ζ) while Tables 4 and 5 are available for the integrated booster flyback (Sections 8 to 15) as appropriate.

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* See Figure 5-10, Section 5.1.2.1, Acceleration.

† Not available in the current version of SSSP.

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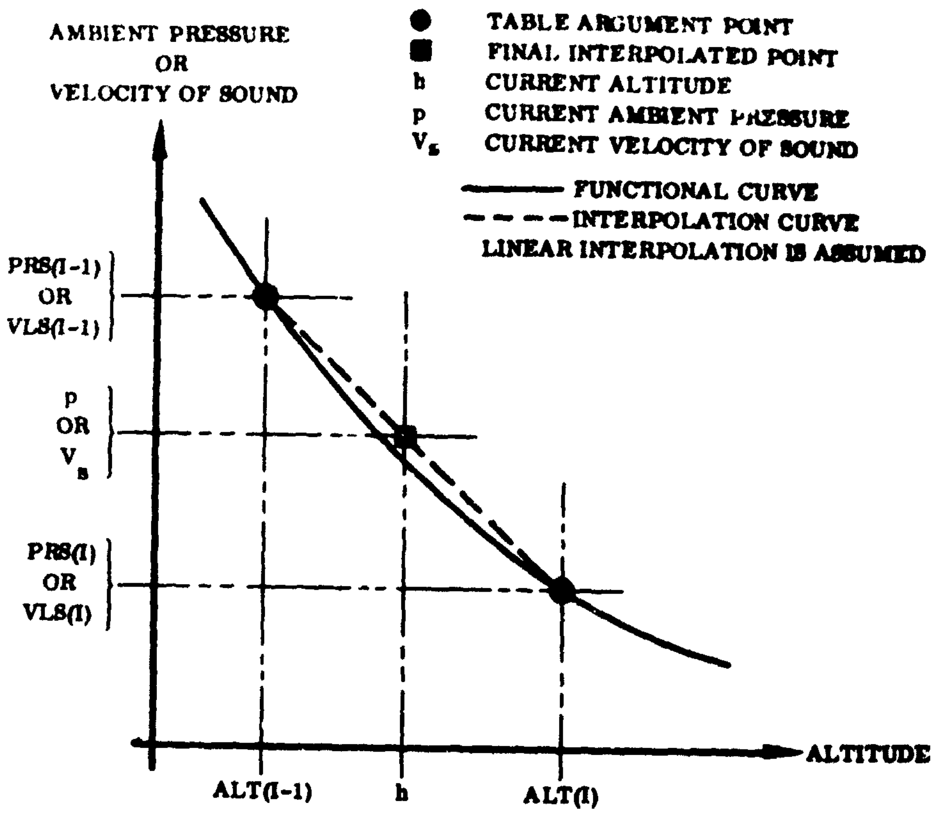

Figure 4-5. Atmosphere Table

AC1(K) **This parameter is NOT available to the user. DO NOT attempt to input.**

(28) (0.) (none) (Q(28, K))

AC2(K) The value of "AC2(K)" defines which one of five possible aerodynamic axial tables are to be used in simulation Section "K". Up to five tables are available, however the use of these tables is restricted according to simulation section number (defined by the value of the subscript K. These restrictions are explained above. The atmosphere must be defined (input "ATMC(K)" > .5 in order to obtain any aerodynamic modeling in Section K (see "ATMC(K)").

If AC2(K) = 0., no aerodynamic axial forces are computed.

If AC2(K) = L., (for L = 1., 2., 3., 4., or 5.,) the Lth aerodynamic axial table is used to define the current aerodynamic force coefficient (output parameter 22) along the standard* roll axis ($\hat{\xi}$ axis) of the vehicle. This coefficient table, the C_ξ table, is given as a function of Mach number and pitch angle of attack (output parameters 40., and 12., respectively).

(29) (0.) (none) (Q(29,K))

AC3(K) The value of "AC3(K)" defines which one of five possible aerodynamic normal tables are to be used in simulation Section "K". Up to five tables are available however the use of these tables is restricted according to simulation section number (defined by the value of the subscript K. These restrictions are explained above. The atmosphere must be defined (input "ATMC(K)" > .5 in order to obtain any aerodynamic modeling in Section K (see "ATMC(K)").

If AC3(K) = 0., no aerodynamic normal forces are computed.

If AC3(K) = L., (for L = 1., 2., 3., 4., or 5.,) the Lth aerodynamic normal table is used to define the current aerodynamic force coefficient (output parameter 23) along the standard* yaw axis ($\hat{\zeta}$ axis) of the vehicle. This coefficient table, the C_ζ table, is given as a function of Mach number and pitch angle of attack (output parameters 40., and 12., respectively).

(30) (0.) (none) (Q(30,K))

Aerodynamic Yaw Force Coefficient Table (C_η Table). This table is not available in the current version SSSP program.

A1(J, L) This parameter is NOT available to the user. DO NOT attempt to input.

(none) (none) (deg) (A1(J, L))

AREF1(K) This parameter is NOT available to the user. DO NOT attempt to input.

(4) (0.) (ft^2) (Q(4, K))

C1(I, J, L) This parameter is NOT available to the user. DO NOT attempt to input.

(none) (none) (none) (C1(I, J, L))

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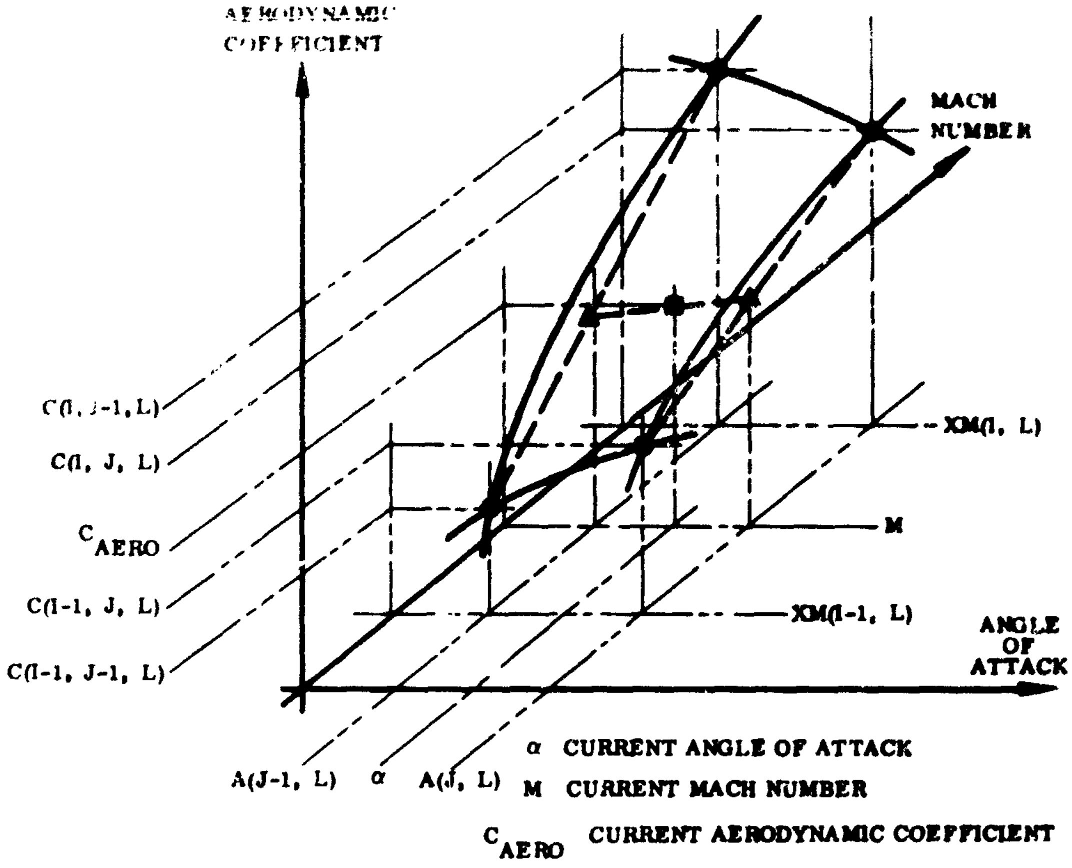

● TABLE ARGUMENT POINT
▲ INTERMEDIATE INTERPOLATED POINT
■ FINAL INTERPOLATED POINT
——— FUNCTIONAL SURFACE CURVE
– – – – INTERPOLATION LINE

A(J, L) Is either A2(J, L) or A3(J, L) according to which aerodynamic model is being defined.

C(I, J, L) Is either C2(I, J, L) or C3(I, J, L) according to which aerodynamic model is being defined.

XM(I, L) Is either XM2(I, L) or XM3(I, L) according to which aerodynamic model is being defined.

The table shown is the Lth table of either the C_ξ or C_ζ tables.

Linear interpolation is assumed.

Figure 4-6. Three-Dimensional Aerodynamic Tables

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

XXA2(I,1) Number of table arguments for the Ith Cj table. These parameters ("XXA2(I,1)" and "XXA2(I,2)") must be input for each Cj table to be used.

For N = 1, "XXA2(I,1)" is the number of Mach number arguments ("XXM2(I,L)") for the Ith Cj table. The maximum number of XXM2(I,L) arguments is 25 and the minimum number is 2, consequently 2 ≤ XXA2(I,1) ≤ 25 if the table is to be used.

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* In the algebraic sense compatible with the standard [illegible] coordinate system

* See Figure 5-10, Section 5.1.2.1, Acceleration

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For N = 2, "XKA2(2, L)" is the number of pitch angle of attack arguments ("A2(J, L)") for the Lth C_ζ table. The maximum number of "A2(J, L)" arguments is 12 and the minimum number is 2, consequently 2 ≤ XKA2(2, L) ≤ 12 if the table is to be used.

(none) (0.) (none) (XKA2(N, L))

XM2(I, L) Ith Mach number argument (first independent variable) for the Lth C_ζ table. See Figure 4-6.

(none) (none) (none) (XM2(I, L))

Aerodynamic Normal Force Coefficient Table (C_ζ Table). This table defines the aerodynamic normal force coefficient (output parameter 23) which is the aerodynamic coefficient* along the standard† $\hat{\zeta}$ axis as a function of pitch angle of attack and Mach number.

A3(J, L) Jth pitch angle of attack argument (second independent variable) for the Lth C_ζ table. See Figure 4-6.

(none) (none) (deg) (A3(J, L))

AREF3(K) Normal aerodynamic reference area used with C_ζ to define the aerodynamic force along the yaw axis ($\hat{\zeta}$ axis) during simulation Section "K".

(6) (0.) (ft^2) (Q(6, K))

C3(I, J, L) Normal aerodynamic force coefficient (C_ζ) directed along the yaw axis ($\hat{\zeta}$ axis) which corresponds to the Ith Mach number argument ("XM3(I, L)") and the Jth pitch angle of attack argument ("A3(J, L)") for the Lth C_ζ table. C_ζ is positive downward from the vehicle in accordance with the standard† $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ vehicle coordinate system, consequently in most applications it is necessary to input C_ζ with a negative value. See Figure 4-6.

(none) (none) (none) (C3(I, J, L))

XKA3(N, L) Number of table arguments for the Lth C_ζ table. These parameters ("XKA3(1, L)") and "XKA3(2, L)") must be input for each C_ζ table to be used.

For N = 1, "XKA3(1, L)" is the number of Mach number arguments ("XM3(I, L)") for the Lth C_ζ table. The maximum number of "XM3(I, L)" arguments is 25 and the minimum number is 2, consequently 2 ≤ XKA3(1, L) ≤ 25 if the table is to be used.

---

*In the algebraic sense compatible with the standard $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ coordinate system.

†See Figure 5-10, Section 5.1.2.1, Acceleration.

For N = 2, "XNA2(2, L)" is the number of pitch angle of attack arguments ("A3(2, I)") for the Lth C_ζ table. The maximum number of "A3(2, L)" arguments is 12 and the minimum number is 2, consequently 2 ≤ XKA3(2, L) ≤ 12 if the table is to be used.

(none) (0.) (none) (XNA2(N, L))

XM3(I, L) Ith Mach number argument (first independent variable) for the Lth C_ζ table. See Figure 4-6.

(none) (none) (none) (XM3(I, L))

ATTITUDE MODELS. Attitude models are available to define the roll (bank) angle (σ), the pitch angle (ζ) or the pitch angle of attack (α), and the yaw angle (λ). These rotation angles are sequenced, that is for their definitions it is assumed that the vehicle is first rolled (banked) to the required roll angle, then pitched to the required pitch angle or pitch angle of attack, and then yawed to the required yaw angle of attack. These angles, σ, ζ, α, and λ are relative angles; they are measured with respect to the current geocentric radius vector, relative velocity vector, and the standard* $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ vehicle coordinate system. This section and Section 5.1.2.1 describing output parameters 11, 12, 13, and 43 provide detailed definition.

Roll (Bank) Angle Definition.

GDOT(K) Specified time rate of change of relative flight path angle used only if either "SIGC(K) = 3.," or "ALPC(K) = 7.,". When this option is used, the roll (bank) angle or the pitch angle of attack is modulated within limits to maintain the constant specified value of "GDOT(K)". See "SIGC(K)" and "ALPC(K)" in this section.

(52) (0.) (deg/sec) (Q(52, K))

SIGC(K) Roll (bank) angle control parameter. The value of "SIGC(K)" specifies the method of defining the current value of the roll (bank) angle (σ) according to Table 4-3.

(32) (1.) (none) (Q(32, K))

---

* See Figure 5-10, Section 5.1.2.1, Acceleration.

TABLE 4-3 DEFINITION OF ROLL (BANK) ANGLE (σ)

'SIGC(K)'	Roll (Bank) Angle* (Output Parameter 11)	'SIGDT(K)'*	'SIG(K)'*
1.,	$\sigma = \dot{\sigma}\, t_R + \sigma_K$	$\dot{\sigma}$	σ_K
2.,	$\sigma = \dot{\sigma}\, t_R + \sigma_K + \sigma_0$	$\dot{\sigma}$	σ_K
3.,	$\left\{\begin{array}{ll} \sigma = C\sigma_s & \text{If } C\sigma_s > K\sigma_{LIM} \\ \sigma = \sigma_{LIM} & \text{If } C\sigma_s \le K\sigma_{LIM} \end{array}\right\}$	C	σ_{LIM}

where:

C = Roll (bank) angle coefficient used to define the required roll (bank) angle direction and magnitude when flying with reference to a specified time rate of change of relative flight path angle ($\dot{\gamma}$). For flight at a specified $\dot{\gamma}$, C (input by "SIGDT(K)") should be either +1., for a right bank angle (positive roll angle) or −1., for a left bank angle (negative roll angle).

K = $C/|C|$, a number (+1 or −1) with unit magnitude and with the same sign as C.

t_R = Time from the initiation of simulation section "K" to the current time (sec).

σ = Current roll (bank) angle (output parameter 11) about the vehicle roll axis ($\hat{\xi}$ axis) with algebraic sign in accordance with right-handed rotations of the standard $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ coordinate system (roll (bank) right is positive) (deg).

$\dot{\sigma}$ = Time rate of change of the roll (bank) angle (deg/sec).

σ_K = Constant roll (bank) angle term of the linear roll angle expression (deg).

σ_{LIM} = Minimum (maximum)† bank angle allowed for flight referenced to a specified time rate of change of relative flight path angle ($\dot{\gamma}$). If the bank angle requirement is less (greater)† than this limit, there is no reference to the specified $\dot{\gamma}$ and the flight continues with $\sigma = \sigma_{LIM}$.

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*Observe algebraic signs.

†Algebraic sense to account for right or left bank.

TABLE 4-3 DEFINITION OF ROLL (BANK) ANGLE (σ) (Continued)

where σ_s Roll (bank) angle at the current time (determined internally) which results in maintaining a constant time rate of change of relative flight path angle for a specified pitch angle of attack assuming a zero yaw angle of attack (deg).

σ_0 = Roll (bank) angle at the termination of simulation Section "K-1". If K = 1, σ_0 is the initial roll (bank) angle for the trajectory simulation (deg).

SIGDT(K) "SIGDT(K)" is the first roll (bank) angle parameter and is defined in Table 4-3. For SIGC(K) = 1., or 2., "SIGDT(K)" is the time rate of change of the vehicle roll (bank) angle. The algebraic sign is in accordance with right-handed rotations of the standard $\hat{\xi}$ - $\hat{\eta}$ - $\hat{\zeta}$ coordinate system (deg/sec).

For SIGC(K) = 3., "SIGDT(K)" is the roll (bank) angle coefficient C which is described in Table 4-3 (dimensionless).

(36)	(0.)	(deg/sec) or (none)	(Q(36,K))

SSIG(K) "SSIG(K)" is the second roll (bank) angle parameter and is defined in the table describing the use of "SIGC(K)".

For SIGC(K) = 1., or 2., "SIGC(K)" is the constant roll (bank) angle term of the linear bank angle expression. See "SIGC(K)" (deg).

For SIGC(K) = 3., "SIGC(K)" is the limiting roll (bank) angle allowed for flight referenced to a specified time rate of change of relative flight path angle. See "SIGC(K)" (deg).

(44)	(0.)	(deg)	(Q(44,K))

Pitch Angle or Pitch Angle of Attack Definition. Either the pitch angle (θ)* or the pitch angle of attack (α) can be defined by input, the other parameter is subsequently computed internally. Linear procedures similar to that described for the roll (bank) angle (σ) in the preceding paragraph are available to define α or θ and there is also a linear cotangent steering procedure available to define θ. Additionally either α or θ can be defined from tables. Up to four tables are available for α or θ definition, however Table 1 (the value of subscript I. is equal to 1) is used during simulation sections 1 and 2. Tables 2, 3, and 4 can be used in any number of simulation sections after and including Section 3 to and including the last section which is defined by "SLC", however only one of these tables can be used at a time in any single section

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*When using the pitch angle, it is assumed that the roll (bank) angle is zero

The linear cotangent steering (LCS) option defines the cotangent of θ to be a linear function of time

$$\mathrm{Cot}\,\theta = K_1 + K_2 t$$

where K_1 and K_2 are constants to be determined.

The LCS steering option* used to define the relative pitch angle θ as defined for the GTSM system (see Section 2.2.2.8, Attitude, for the definition of θ) provides a close estimate of the optimal pitch steering function if the following conditions are satisfied.

1. The earth is either flat or a sphere† with a constant radial gravitational acceleration.
2. Aerodynamic effects during LCS are negligible.
3. The LCS controlled trajectory is nearly planar.
4. The terminal altitude and velocity vector (magnitude and relative flight path angle) must be specified either directly or with equivalent other parameters while the terminal range is free.

The LCS steering option as used in the GTSM system provides a means to internally estimate the values of K_1 and K_2 in terms of physically meaningful parameters.

If the pitch angle at the initiation and at the termination of the LCS segment (θ_I and θ_f, respectively) and the duration of the LCS segment (t_{LCS}) are known then K_1 and K_2 can be determined:

$$\theta_I = \theta_{REF} + \Delta\theta$$

$$K_1 = \mathrm{Cot}\,(\theta_I)$$

$$K_2 = \frac{\mathrm{Cot}\,(\theta_f) - K_1}{t_{LCS}}$$

There are four available options which are defined by "ALPC(K)" by which either K_1 and K_2 or θ_I and θ_f can be estimated (see Table 4-4). The value of t_{LCS} is initially internally estimated by analytic integration of the time rate of change of weight ($\dot{w}$)

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* The LCS steering law is readily derived by using the calculus of variations or equivalently the Pontryagin maximum principle with the assumptions listed in this paragraph

† This latter assumption is possible because of the way in which θ is defined for the GTSM system

Table 4-4. Linear Cotangent Steering Options

ALPC(E)	OPTION
18.,	ψ_{REF}, $\Delta\psi$, and ψ_f are input
19.,	$\psi_{REF} = 90° - \gamma_o$; $\Delta\psi$ and ψ_f are input
20.,	$\psi_{REF} = \psi_o$; $\Delta\psi$ and ψ_f are input
21.,	K_1 and K_2 are input

expressions which are defined as part of the synthesis process. If the LCS input parameters are used as control variables for the second GIS block, t_{LCS} is updated by setting it equal to the value of t_{LCS} which was computed at the end of the previous iterated* trajectory. In this case, the control variables are "PSIDT(5)" and "RALP(5)" and the end conditions are altitude (output parameter 8) and inertial flight path angle (output parameter 42) at the termination of simulation section 7.

The $\dot{\psi}$ table (see Figure 4-7) defines the step pitch rates as a function of a time argument (t_A) which has a flexible definition (defined by input). This flexible time argument definition allows the $\dot{\psi}$ table to be referenced to either absolute time or simulation section relative time. The current ψ is defined by computing the area under the $\dot{\psi}$ step function to the left of the current time argument (t_A) (shaded area in Figure 4-7) and then multiplying this area by the pitch rate attenuation factor ("PITX(K)"). To this, the terms ψ_K and ψ_0 (if appropriate) are added. In the event that the current t_A is outside the lower or upper bounds of the PT(I, L) values, the $\dot{\psi}$ table is bypassed and α is assumed to define the pitch attitude and is set equal to the specified value of α_K.

The α table assumes that α is a function of Mach number (M), and is similar in form to the atmosphere table shown in Figure 4-5 except that the α table has only one dependent variable (α) and the table arguments have different definitions. The correlation between the table arguments of the atmosphere table and those of the α table is defined in Table 4-5. In the event that the current Mach number is outside the lower and upper bounds of the table Mach number argument values (the lowest and the highest values of "PT(I, L)"), an appropriate error diagnostic is printed and the synthesis case is terminated (subsequent cases are still processed) if and only if this error occurs at the successful completion of an integration step. Errors of this type occurring within an integration step do not cause termination.

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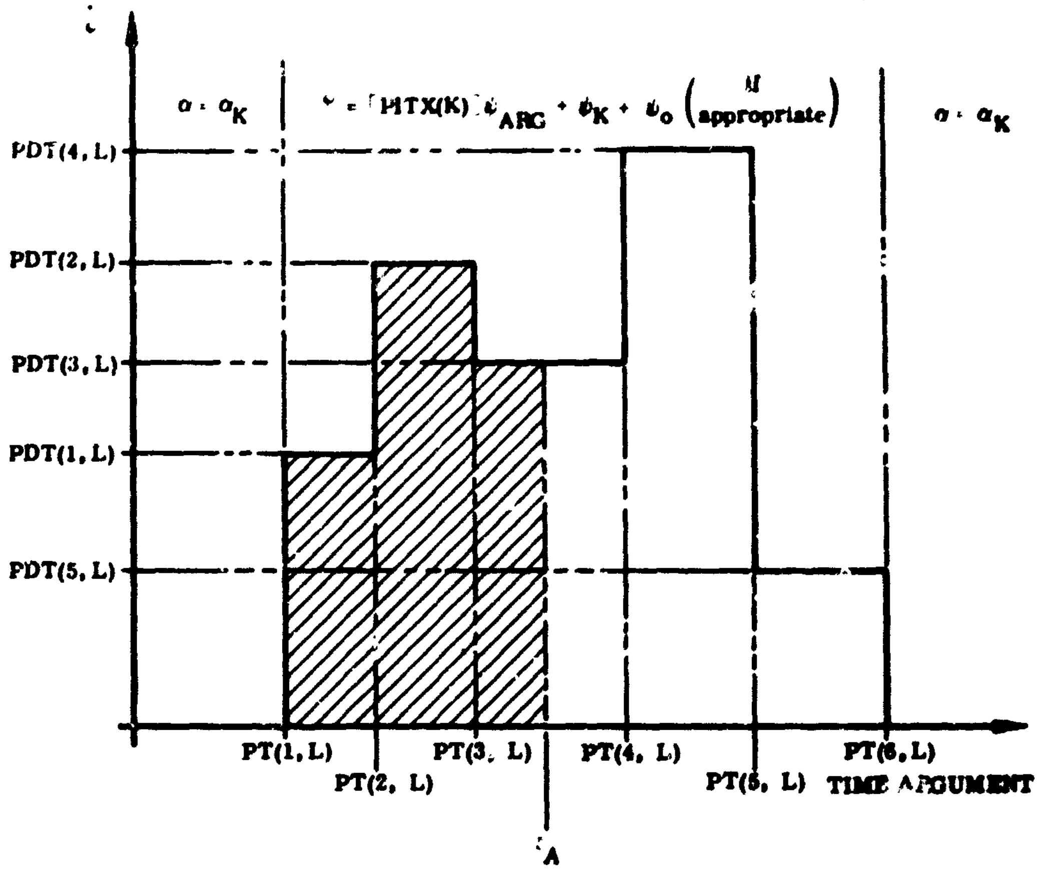
* Does not include trajectories simulated during the determination of the iteration partial derivatives.

SHOWN FOR SIX TIME ARGUMENTS (FIVE $\dot{\theta}$ ARGUMENTS)



t_A = Current time argument = $t_{ABS} - t_{s[PSEC(K)]} - PTME(K)$

t_{ABS} = Absolute time (sec) (output parameter -1)

$t_{s[K]}$ = Absolute time at the initiation of simulation section "K"

$t_{ARG} = \int_{PT(1,L)}^{t_A} \dot{\theta}\,dt$ = shaded area (area under the step function to the left of t_A)

Note: The definitions of parameters not defined here appear in appropriate places throughout this section (e.g. Table 4-6).

Figure 4-7. Relative Pitch Rate Table

Table 4-5. Corresponding Atmosphere and Pitch Angle of Attack Table Arguments

Atmosphere Table	Pitch Angle-of-Attack Table
ALT(I)	PT(I, L)
PRS(I) and VLS(I)	PDT(I, L)
XKA(I)	XKPT(L)
h	M
ρ and V_S	α

Ref. Figure 4-5, Atmosphere Table

ALPC(K) Pitch angle or pitch angle of attack control parameter. The value of "ALPC(K)" specifies the method of defining the current value of the pitch angle (ψ) or the pitch angle of attack (α) according to Table 4-6.

(33) (1.) (none) (Q(33, K))

ALPDT(K) "ALPDT(K)" is the first pitch angle of attack parameter and is defined in Table 4-6.

For ALPC(K) = 1., 2., 4., or 5., "ALPDT(K)" is the time rate of change of the vehicle pitch angle of attack. The algebraic sign is in accordance with right-handed rotations of the standard $\hat{\xi}$-$\hat{\eta}$-$\hat{\zeta}$ coordinate system (deg/sec).

For ALPC(K) = 7., "ALPDT(K)" is the pitch angle of attack increment used to initiate the Newton-Raphson iteration used to determine the pitch angle of attack which yields the specified time rate of change of relative flight path angle (deg).

For ALPC(K) = 3., 6., or values greater than 7., "ALPDT(K)" is not used and consequently can have any value.

For ALPC(K) = 18., 19., or 20., "ALPDT(K)" is the time duration of the LCS segment of flight.

For ALPC(K) = 24., 25., 26., 27., 28., or 29., "ALPDT(K)" is the time rate of change of pitch angle of attack (α).

(37) (0.) (deg/sec) (Q(37, K))
or (deg)

GDOT(K) The definition appears in the previous paragraph.

Table 4-6. Pitch Angle (φ) and Pitch Angle of Attack (α) Definition

ALPH (K)	α or φ (Output Parameter 12 or 43)	"ALPDT(K)"	"PHIDT(K)"	"ALP(K)"	"PSI(K)"
1	$\alpha = \dot{\alpha} t_R + \alpha_K$	$\dot{\alpha}$	—	α_K	—
2	$\alpha = \dot{\alpha} t_R + \alpha_K + \alpha_0$	$\dot{\alpha}$	—	α_K	—
3 **	$\phi = \dot{\phi} t_R + \phi_K + \phi_0$	—	$\dot{\phi}$	—	ϕ_K
4.	$\alpha = \dot{\alpha} t_R + \alpha_K$ (no φ or $\dot{\phi}$)*	$\dot{\alpha}$	—	α_K	—
5	$\alpha = \dot{\alpha} t_R + \alpha_K + \alpha_0$ (no φ or $\dot{\phi}$)*	$\dot{\alpha}$	—	α_K	—
6. **	$\phi = \dot{\phi} t_R + \phi_K$	—	$\dot{\phi}$	—	ϕ_K
7..	$\begin{cases} \alpha = \alpha_{MIN} \text{ if } \alpha_s < \alpha_{MIN} \\ \alpha = \alpha_s \text{ if } \alpha_{MIN} \le \alpha_s \le \alpha_{MAX} \\ \alpha = \alpha_{MAX} \text{ if } \alpha_{MAX} < \alpha_s \end{cases}$	$\Delta\alpha$	α_{MIN}	α_{00}	α_{MAX}
8.. **	$\phi = f(\dot{\phi}$ Table 1$) + \phi_K + \phi_0$	—	—	α_K	ϕ_K
9.. **	$\phi = f(\dot{\phi}$ Table 1$) + \phi_K$	—	—	α_K	ϕ_K
10.. **	$\phi = f(\dot{\phi}$ Table 2$) + \phi_K + \phi_0$	—	—	α_K	ϕ_K
11.. **	$\phi = f(\dot{\phi}$ Table 2$) + \phi_K$	—	—	α_K	ϕ_K
12.. **	$\phi = f(\dot{\phi}$ Table 3$) + \phi_K + \phi_0$	—	—	α_K	ϕ_K
13.. **	$\phi = f(\dot{\phi}$ Table 3$) + \phi_K$	—	—	α_K	ϕ_K
14.. **	$\phi = f(\dot{\phi}$ Table 4$) + \phi_K + \phi_0$	—	—	α_K	ϕ_K
15.. **	$\phi = f(\dot{\phi}$ Table 4$) + \phi_K$	—	—	α_K	ϕ_K
16..	Not available to user; Should not be input	—	—	—	—
17..		—	—	--	—
18..	$\phi = \text{Cot}^{-1}(K_1 + K_2 t)$	t_1†‡	ϕ_1†	$\Delta\phi$†	ϕ_{REF}†
19..	$\phi = \text{Cot}^{-1}(K_1 + K_2 t)$	t_1†‡	ϕ_1†	$\Delta\phi$†	—
20..	$\phi = \text{Cot}^{-1}(K_1 + K_2 t)$	t_1†‡	ϕ_1†	$\Delta\phi$†	—
21..	$\phi = \text{Cot}^{-1}(K_1 + K_2 t)$	—	—	K_2†	K_1†
22..	Not available to user; should not be input #	—	—	—	—
23..		—	—	—	—
24..	$\alpha = f(\alpha$ Table 2$) + \dot{\alpha} t_R + \alpha_K$	$\dot{\alpha}$	—	α_K	—
25..	$\alpha = f(\alpha$ Table 2$) + \dot{\alpha} t_R + \alpha_K + \alpha_0$	$\dot{\alpha}$	—	α_K	—
26..	$\alpha = f(\alpha$ Table 3$) + \dot{\alpha} t_R + \alpha_K$	$\dot{\alpha}$	—	α_K	—
27..	$\alpha = f(\alpha$ Table 3$) + \dot{\alpha} t_R + \alpha_K + \alpha_0$	$\dot{\alpha}$	—	α_K	—
28..	$\alpha = f(\alpha$ Table 4$) + \dot{\alpha} t_R + \alpha_K$	$\dot{\alpha}$	—	α_K	—
29..	$\alpha = f(\alpha$ Table 4$) + \dot{\alpha} t_R + \alpha_K + \alpha_0$	$\dot{\alpha}$	—	α_K	—
30..	Not available to user, should not be input	—	—	—	—
31..		—	—	—	—

* The pitch angle and its derivative (output parameters 43 and 78) are not computed.

** When using this mode, it is assumed that the roll (bank) angle is zero.

† This parameter is only input for the first section in which the LCS option is used (Section 5 for the ascent trajectory).

‡ The [illegible] version of GTRM internally defines this parameter and consequently need not be input.

\# These parameters represent selection of Table 1. Table 1 is reserved for the ascent $\dot{\phi}$ table which is used in Sections 1 and 2.

Table 4-6. Pitch Angle (ψ) and Pitch Angle of Attack (α) Definition, Contd

where:

K_1 = LCS constant term

K_2 = LCS coefficient of t

t_{LCS} = Time from the initiation of the LCS segment of flight

t_f = Time at the termination of the LCS segment of flight

t_R = Time from the initiation of simulation section "K" to the current time (sec)

α = Current pitch angle of attack (output parameter 12) about the vehicle pitch axis ($\hat{\eta}$ axis) with algebraic sign in accordance with right-handed rotations of the standard $\hat{\xi} - \hat{\eta} - \zeta$ coordinate system (pitch up is positive) (deg).

$\dot{\alpha}$ = Time rate of change of the pitch angle of attack (deg/sec).

α_K = Constant pitch angle of attack term of the linear pitch angle of attack expression shown in the above table or the pitch angle of attack which is assumed if the $\dot{\psi}$ table time limits are exceeded (deg).

α_{MIN} = Minimum pitch angle of attack which is allowed for flight referenced to a specified time rate of change of relative flight path angle ($\dot{\gamma}$). If the pitch angle of attack requirement is less than this limit, there is no reference to the specified $\dot{\gamma}$ and the flight continues with $\alpha = \alpha_{MIN}$ (deg).

α_{MAX} = Maximum pitch angle of attack which is allowed for flight referenced to a specified time rate of change of relative flight path angle ($\dot{\gamma}$). If the pitch angle of attack requirement is greater than this limit, there is no reference to the specified γ and the flight continues with $\alpha = \alpha_{MAX}$ (deg).

α_s = Pitch angle of attack at the current time which results in maintaining a constant time rate of change of relative flight path angle for a specified roll (bank) angle and a specified yaw angle of attack (deg).

α_{00} = The initial pitch angle of attack which is assumed to start the Newton-Raphson iteration which is needed to obtain α_s.

α_0 = Pitch angle of attack at the termination of simulation section "K-1". If K = 1, α_0 is the initial pitch angle of attack for the trajectory simulation (deg).

γ_0 = Relative flight path angle at the initiation of a simulation section

Table [illegible] Pitch Angle (ψ) and Pitch Angle of Attack (α) Definition, Contd

$\Delta\alpha$ The pitch angle of attack increment which is used to start the Newton-Raphson iteration required to obtain α_K.

$\Delta\psi$ Pitch angle increment (observe algebraic signs according to the right handed rotation of the $\hat{\xi}$ - $\hat{\eta}$ - $\hat{\zeta}$ axes - pitch up is negative) at the initiation of an LCS segment

ψ Current relative pitch angle (output parameter 43). This angle is measured from the current geocentric radius vector to the current vehicle roll axis ($\hat{\xi}$ axis) (deg).

ψ_0 Relative pitch angle at the initiation of the simulation section in which the pitch angle control procedure is initiated. For "ALPC(K) = 3., or 20.," this section is the current simulation section, "K"; for the pitch rate tables specified when "ALPC(K)" = 8., 10., 12., 14., or 16., this section is defined by "PSEC(K)" (deg).

ψ_K = Constant relative pitch angle term which appears in both the linear expression for ψ and the expression which uses a $\dot{\psi}$ table (deg).

ψ_T = Pitch angle at the termination of an LCS segment

ψ_{REF} = Pitch angle argument which is added to $\Delta\psi$ to equal ψ_T

$\dot{\psi}$ = Time rate of change of the relative pitch angle (deg/sec).

$f(\dot{\psi}$ TABLE L) = Relative pitch angle argument (ψ_{ARG}) determined by table lookup of the Lth $\dot{\psi}$ table as a function of the $\dot{\psi}$ and the current time argument. If the current time argument is between the first and the last table time argument value, then $\psi = \psi_{ARG} + \psi_K + \psi_0$ (if specified); if not, the ψ attitude definition is bypassed and α is set equal to α_K attitude definition.

$f(\alpha$ TABLE L) = Pitch angle of attack argument determined by table lookup of the Lth α-Mach number table as a function of the Mach number.

PDT(I, L) Time rate of change of relative pitch angle ($\dot{\theta}$) which is specified between the Ith and the I + 1 time argument between PT(I, L) and PT(I + 1, L). The relative pitch angle is measured from the current geocentric radius vector (up direction) to the current vehicle roll axis ($\hat{\xi}$ axis) (see Figure 4-7).

(none) (none) (sec) (PDT(I, L))

PITX(K) Pitch rate attenuation factor. Pitch rates, specified by either a $\dot{\theta}$ table ("PDT(I, L)") or simulation section input ("PSIDT(K)") are multiplied by "PITX(K)" during simulation section "K" to obtain the current effective pitch rate (output parameter 78). If "PITX(1)" is input with a negative value an estimate of the correct value of PITX(1) is made internally using the synthesis data as a basis.

(62) (0.) (none) (Q(62, K))

PSIDT(K) "PSIDT(K)" is the first relative pitch angle parameter and is defined in Table 4-8.

For ALPC(K) = 1., 2., 4., 5., or values greater than 7., "PSIDT(K)" is not used and consequently can have any value.

For ALPC(K) = 3., or 6., "PSIDT(K) is the time rate of change of the relative pitch angle during simulation section "K". The relative pitch angle is measured from the current geocentric radius vector (up direction) to the current vehicle roll axis ($\hat{\xi}$ axis) (deg/sec).

For ALPC(K) = 7., "PSIDT(K)" is the minimum pitch angle of attack allowed for flight at a specified time rate of change of relative flight path angle ($\dot{\gamma}$). If the required pitch angle of attack is less than this minimum, the flight continues with the pitch angle of attack set equal to this minimum value with no reference to the required $\dot{\gamma}$ (deg).

For ALPC(K) = 18., 19., or 20., "PSIDT(K)" is the pitch angle at the termination of an LCS segment (θ_f).

(35) (0.) (deg/sec) or (deg) (Q(35, K))

PSEC(K) Simulation section number which defines the simulation section to which the time argument ("PT(I, L)") of the $\dot{\theta}$ table is referenced during simulation section "K". (See Figure 4-7 and "PT(I, L)").

(63) (1.) (none) (Q(63, K))

PT(I, L) Ith time argument (t_A) for the Lth $\dot{\psi}$ table. This parameter is the independent variable of the $\dot{\psi}$ table (see Figure 4-7) and is defined by:

$$t_A = t_{ABS} - t_s[\text{PSEC(K)}] - \text{PTME(K)}$$

where: t_{ABS} is the current absolute time (output parameter -1)

t_s (PSEC(K)) is the absolute time at the initiation of the simulation section defined by the value of "PSEC(K)".

PTME(K) is a section input parameter which is defined subsequently.

(none) (none) (sec) (PT(I, L))

PTME(K) The reference time during the specified reference simulation section ("PSEC(K)") for the time argument ("PT(I, L)") of the $\dot{\psi}$ table. (See Figure 4-7 and "PT(I, L)").

(64) (0.) (sec) (Q(64, K))

SALP(K) "SALP(K)" is the second pitch angle of attack parameter and is defined in Table 4-6.

For ALPC(K) = 1.,, 2.,, 4.,, or 5.,, "SALP(K)" is the constant pitch angle of attack term of the linear expression which defines the current pitch angle of attack.

For ALPC(K) = 3., or 6.,, "SALP(K)" is not used and consequently can have any value.

For ALPC(K) = 7.,, "SALP(K)" is the initial pitch angle of attack which is assumed to initiate the Newton-Raphson iteration used to determine the pitch angle of attack which yields the specified time rate of change of relative flight path angle.

For ALPC(K) greater than 7.,, "SALP(K)" is the pitch angle of attack which is assumed if the current time argument is outside the time argument ("PT(I, L)") bounds for the $\dot{\psi}$ table.

For ALPC(K) = 18.., 19... or 20..., "SALP(K)" is the pitch angle increment ($\Delta\psi$) at the initiation of an LCS segment.

For ALPC(K) = 21... "SALP(K)" is the LCS coefficient of t.

For ALPC(K) = 24..., 25..., 26..., 27... 28... or 29... "SALP(K)" is the constant additive pitch angle of attack term (α_K) for the α-Mach number tables.

(45) (0.) (deg) (Q(45, K))

as follows.

SPSI(K) "SPSI(K)" is the second relative pitch angle parameter and is defined in Table 4-6.

For ALPC(K) 1., 2., 4., or 5., "SPSI(K)" is not used and consequently can have any value.

For ALPC(K) 3., or 6., "SPSI(K)" is the constant relative pitch angle term of the linear expression which defines the current relative pitch angle.

For ALPC(K) 7., "SPSI(K)" is the maximum pitch angle of attack allowed for flight at a specified time rate of change of relative flight path angle ($\dot{\gamma}$). If the required pitch angle of attack is greater than this maximum, the flight continues with the pitch angle of attack set equal to this maximum value with no reference to the required $\dot{\gamma}$.

For ALPC(K) 18., "SPSI(K)" is the pitch angle argument (θ_{REF}) which is added to $\Delta\theta$ to equal θ_1.

For ALPC(K) 21., "SPSI(K)" is the LCS constant additive term.

(43) (0.) (deg) (Q(43, K))

XKPT(L) Number of time arguments ("PT(I, L)") for the Lth $\dot{\theta}$ table. It is noted that the corresponding number of relative pitch rate arguments ("PDT(I, L)") is always one less than the value of "XKPT(L)"; this latter number is not input. The maximum number of "PT(I, L)" arguments per $\dot{\theta}$ table is 25 and the minimum number is two, consequently if the Lth $\dot{\theta}$ table is to be used, "XKPT(L)" must be input such that $2 \leq$ XKPT(L) ≤ 25.

(none) (0.) (none) (XNPT(L))

Yaw Angle of Attack Definition.

LAMC(K) Yaw angle of attack control parameter. The value of "LAMC(K)" specifies the method of defining the current value of the yaw angle of attack (λ) according to Table 4-7.

(34) (1.) (none) (Q(34, K))

LAMDT(K) "LAMDT(K)" is the time rate of change of either the vehicle yaw angle or of the azimuth of the vehicle roll axis according to Table 4-7. The algebraic sign is in accordance with right-handed rotations of the standard $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ coordinate system (deg/sec).

(38) (0.) (deg/sec) (Q(38, K))

TABLE 4-7. YAW ANGLE OF ATTACK (λ) DEFINITION

"LAMC(K)"	Yaw Angle of Attack* (Output Parameter 13)	"LAMDT(K)"	"SLAM(K)"
1.	$\lambda = \dot{\lambda} t_R + \lambda_K$	$\dot{\lambda}$	λ_K
2.	$\lambda = \dot{\lambda} t_R + \lambda_K + \lambda_0$	$\dot{\lambda}$	λ_K
3.[†]	$\delta = \dot{\delta} t_R + \delta_K$	$\dot{\delta}$	δ_K
4.[†]	$\delta = \dot{\delta} t_R + \delta_K + \delta_0$	$\dot{\delta}$	δ_K

where: t_R = time from the initiation of simulation section "K" to the current time (sec).

δ = The azimuth of the vehicle roll axis ($\hat{\xi}$). Use of this parameter for yaw angle control is particularly useful when it is necessary to maintain a specified vehicle heading regardless of the orientation of the relative velocity vector (deg).

$\dot{\delta}$ = Time rate of change of δ (deg/sec).

δ_K = Constant roll axis azimuth term of the linear roll axis expression shown above (deg).

δ_0 = Value of δ at the initiation of simulation section "K" (deg).

λ = Current yaw angle of attack (output parameter 13) about the vehicle yaw axis (ζ axis) with algebraic sign in accordance with right-handed rotations of the $\hat{\xi} - \hat{\eta} - \hat{\zeta}$ coordinate system (yaw right is positive (deg).

$\dot{\lambda}$ = Time rate of change of the yaw angle of attack (deg/sec).

λ_K = Constant yaw angle of attack term of the linear yaw angle of attack expression shown above (deg).

λ_0 = Yaw angle of attack at the termination of simulation section "K-1". If $K = 1$, λ_0 is the initial yaw angle of attack for the trajectory simulation (deg).

*Observe algebraic signs.

[†] Use of this option assumes a zero roll angle.

BLAM(K) "BLAM(K)" is either the constant yaw angle of attack term of the linear yaw angle of attack expression, or the constant roll axis azimuth term of the linear roll axis azimuth expression according to Table 4-7 (deg).

(46) (0.) (deg) (Q(46,K))

WEIGHT MODELS. There are three principal types of weight models available in OTSM; the weight statement parameters, the time rate of change of weight, and the GIMAC* control weight flow rate. The initial weight, payload, and simulation section termination weights which are the weight statement parameters are discussed in Section 4.2.3.1 under "WGH", in Section 4.2.3.1 under "PLD", and in Section 4.2.3.5 under the general simulation section termination parameters "STOC(K)", "STGD(K)", "STGT(K)", and "STOV(K)". In this last case no specific mention of weight is made, however weight is implied if the value of "STOC(K)" is equal to 7., the code number for weight. The time rate of change of weight is described in the propulsion models (later in this section) under "TWD9(I, L)" and "TWD13(K)". The GIMAC weight flow rates and jettison weights are described in this section.

GIMAC flow occurs only if the input parameter "ATMC(K)" (described in section atmosphere model) is equal to 2... The GIMAC weight flow equation is:

$$\dot{W}_{GIMAC} = 2\, C_{\zeta}\, q\, (K_1 M^3 + K_2 M^2 + K_3 M + K_4)/V$$

where: C_{ζ} = Current aerodynamic normal force coefficient (output parameter 23).

K_1 = First GIMAC coefficient.

K_2 = Second GIMAC coefficient.

K_3 = Third GIMAC coefficient.

K_4 = Fourth GIMAC coefficient.

M = Current Mach number (output parameter 40).

q = Current dynamic pressure (output parameter 9) (lb/ft^2).

V = Current relative velocity (output parameter 2) (ft/sec)

$\dot{W}_{GIMAC}$ = Current GIMAC weight flow rate. This flow rate is in addition to any defined by the parameters described under propulsion models (later in this section). The rate is considered positive if the vehicle weight is decreasing (lb/sec).

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*Gas injection maneuvering and control.

[illegible] [illegible] GIMAC coefficient (K_1 in the GIMAC weight flow equation)

[illegible] [illegible] (ft^3/sec^2) (Q([illegible], K))

GMC2(K) The second GIMAC coefficient (K_2 in the GIMAC weight flow equation)

(58) (0.) (ft^3/sec^2) (Q(58, K))

GMC3(K) The third GIMAC coefficient (K_3 in the GIMAC weight flow equation)

(59) (0.) (ft^3/sec^2) (Q(59, K))

GMC4(K) The fourth GIMAC coefficient (K_4 in the GIMAC weight flow equation)

(60) (0.) (ft^3/sec^2) (Q(60, K))

JETW(K) Jettison Weight Parameter.

If JETW(K) < -0.00001, the vehicle weight is set equal to -JETW(K) - PLD upon termination of simulation section "K".

If -0.00001 ≤ JETW(K) < 0.00001, the vehicle weight is unchanged at termination of simulation section "K".

If JETW(K) ≥ 0.00001, the vehicle weight is decreased by the value of JETW(K) upon termination of simulation section "K".

(26) (0.) (lb) (Q(26, K))

PROPULSION MODELS. GTSM has two thrust-time tables with or without corresponding weight dot* - time tables. There are nine different SIMPO options available in each booster return simulation section. The SIMPO model option is internally specified for the ascent trajectory sections (see Appendix V). A SIMPO option is one in which the propulsion characteristics are defined in a simplified manner by three parameters which are assumed to be constant. In these options, the current thrust, weight dot, and specific impulse (Isp) are determined as a function of these three propulsion parameters and the current atmospheric ambient pressure. The thrust-time tables also employ the simple SIMPO propulsion relationships; the principal difference is that vacuum thrust and weight dot (if desired) are first determined as a function of a time argument and then assumed together with the exit area to be the three 'constant' parameters at that instant which define the necessary propulsion characteristics. In each simulation section of the booster return flight, any one of the two thrust - time tables (with or without the corresponding weight - dot - time table) and/or any one of the nine SIMPO options may be used. A given thrust - time table can be used in any number of simulation sections during the booster flyback and can be combined with any of the SIMPO options in each simulation section, that is, any given thrust - time table

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* Total time rate of change of vehicle weight, excluding any GIMAC flow rate. A positive rate is assumed if the vehicle weight is decreasing.

can be combined with any SIMPO option during any simulation section in which the table is used. The given table can be used in more than one section. In addition, a weight out may be specified in any simulation section even if there is no thrust.

TWC(K) Propulsion control parameter. The value of "TWC(K)" specifies which, if any, propulsion models are assumed during simulation section "K". The general form of the numerical value of "TWC(K)" is [10A + B]. A and B are the propulsion option designators and are defined subsequently.

a. <u>SIMPO Options:</u> The SIMPO options by themselves (not in combination with any thrust - time table) are specified by input of a "TWC(K)" value such that A = 0 and $0 \leq B \leq 9$. A in this case is not used while the value of B defines which one of nine possible SIMPO options is to be used according to Table 4-8. The "TWD11(K)", "TWD12(K)", "TWD13(K)", and "TWD14(K)" parameters are described later in this section.

<u>Examples of SIMPO Models</u>

1. If given a vacuum thrust (T_{VAC}) and the vacuum and sea level specific impulse values (I_{VAC}) and I_{SL}), then SIMPO option 2., could be used to simulate the engine if a constant $\dot{W}$ could be assumed.

2. If given a sea level thrust (T_{SL}), the propellant flow rate ($\dot{W}$), and the exit area (A_{EXIT}) then SIMPO option 5., would be used.

3. If no propulsion is desired, but a weight flow rate is required, then SIMPO option 0.,("TWC(K)" = 0.,) should be used.

b. <u>Thrust-Time Table Options:</u> A thrust-time table is specified by input of a "TWC(K)" value such that $1 \leq A \leq 10$ as shown in Table 4-9. The value of A in this case is the SIMPO option designator (corresponds to B when SIMPO is used by itself), while the value of B defines which one of two possible thrust - time tables is to be used. Note that A and B have different meanings here than for the SIMPO without thrust tables.

<u>Examples of the Value of "TWC(K)" for Models with a Thrust - Time Table</u>

1. If the 6th SIMPO option is to be combined with the 4th thrust - time table, then A = 6 and B = 4 thus requiring "TWC(K) = 64.,".

2. If the 2nd thrust - time table is to be used by itself (no accompanying SIMPO option or with SIMPO option 0., then A = 10 and B = 2 requiring "TWC(K) = 102.,".

(31) <u>(0.)</u> (none) (Q(31,K))

TABLE 4-8. SIMPO OPTION TABLE ("TWC(K)" = B.,)

"B" (SIMPO Option Number)	SIMPO Option				
	Constant Parameters				Variable Parameters
	"TWD11(K)"	"TWD12(K)"	"TWD13(K)"	"TWD14(K)"	
0.,	—	—	$\dot{W}$	—	—
1.,	T_{VAC}	T_{SL}	$\dot{W}$	—	T, Isp
2.,	T_{VAC}	I_{VAC}	I_{SL}	—	T, Isp
3.,	T_C	I_{VAC}	I_{SL}	—	$\dot{W}$, Isp
4.,	T_{VAC}	$\dot{W}$	A_{EXIT}	—	T, Isp
5.,	T_{SL}	$\dot{W}$	A_{EXIT}	—	T, Isp
6.,	$\left[T_{VAC}\right]_{MAX}$	I_{VAC}	I_{SL}	$\left[(T+F_A)/W\right]_{MAX}$	Isp, T, $\dot{W}$
7.,	$\left[T_{SL}\right]_{MAX}$	I_{VAC}	I_{SL}	$\left[(T+F_A)/W\right]_{MAX}$	Isp, T, $\dot{W}$
8.,	$\left[T_{VAC}\right]_{MAX}$	I_{VAC}	I_{SL}	$\left[T/W\right]_{MAX}$	Isp, T, $\dot{W}$
9.,	$\left[T_{SL}\right]_{MAX}$	I_{VAC}	I_{SL}	$\left[T/W\right]_{MAX}$	Isp, T, $\dot{W}$

where:

A_{EXIT} = Exit area (in^2)

F_A = Aerodynamic axial force directed along the standard $\hat{\xi}$ axis (lb).

Isp = Current specific impulse (sec).

I_{SL} = Sea level specific impulse (sec).

I_{VAC} = Vacuum specific impulse (sec).

T = Current thrust level directed along the $\hat{\xi}$ axis (lb).

T_C = Constant thrust level (lb).

T_{SL} = Sea level thrust level (lb).

TABLE 4-8. SIMPO OPTION TABLE ("TWC(K)" = 8.,) (Continued)

$\left|T_{SL}\right|_{MAX}$ = Sea level thrust level used to define T which is assumed for SIMPO options 7., and 9., if the "TWD14(K)" constraint is not exceeded (lb).

T_{VAC} = Vacuum thrust level (lb).

$\left|T_{VAC}\right|_{MAX}$ = Vacuum thrust level used to define T which is assumed for SIMPO options 7., and 9., if the "TWD14(K)" constraint is not exceeded (lb).

$\left|T/W\right|$ = Current thrust to weight ratio

$\left|T/W\right|_{MAX}$ = Maximum $\left|T/W\right|$ constraint. In SIMPO options 8., and 9., if T defined by $\left|T_{VAC}\right|_{MAX}$ or $\left|T_{SL}\right|_{MAX}$ results in exceeding $\left|T/W\right|_{MAX}$, T is redefined to yield $\left|T/W\right|_{MAX}$.

$\left|(T + F_A)/W\right|$ = Ratio of the current thrust plus the aerodynamic axial force to the current weight.

$\left|(T + F_A)/W\right|_{MAX}$ = Maximum $\left|(T + F_A)/W\right|$ constraint. In SIMPO options 6., and 7., if T defined by $\left|T_{VAC}\right|_{MAX}$ or $\left|T_{SL}\right|_{MAX}$ results in exceeding $\left|(T + F_A)/W\right|_{MAX}$. T is redefined to yield $\left|(T + F_A)/W\right|_{MAX}$.

W = Current total weight of the vehicle (lb).

$\dot{W}$ = Time rate of change of weight (excluding any GIMAC flow) (lb/sec).

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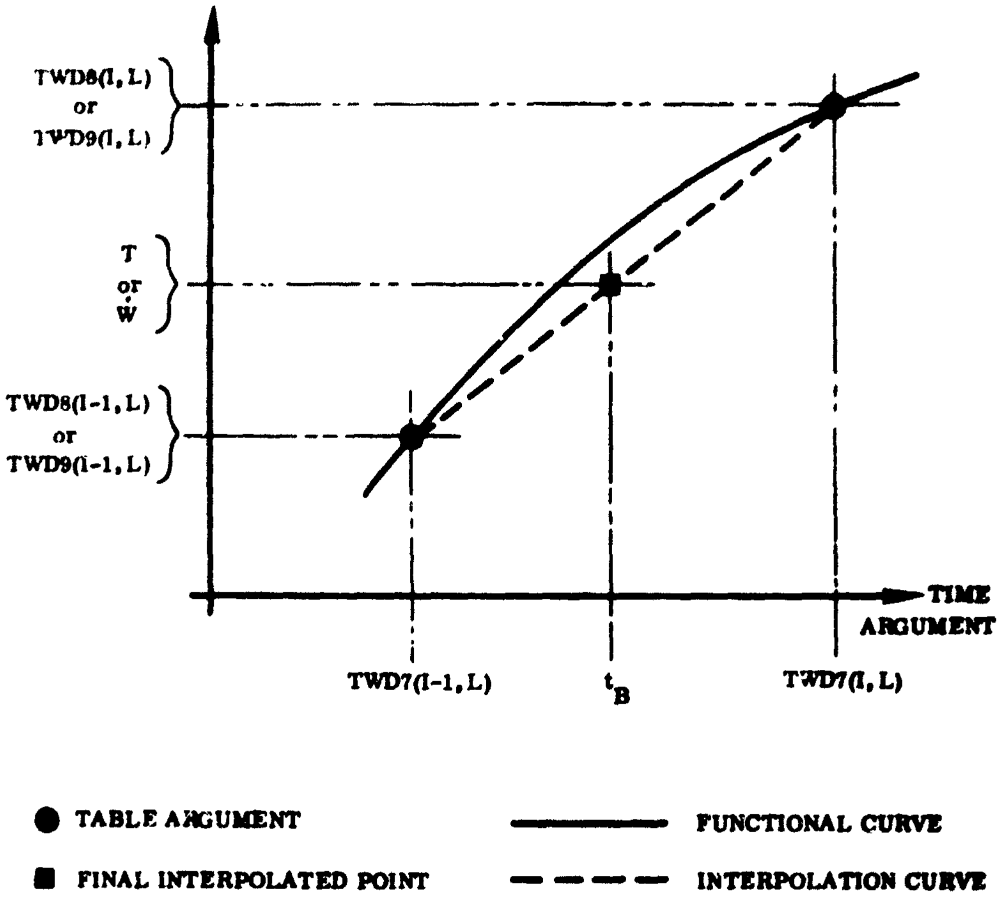
TABLE 4-9. THRUST - TIME TABLE OPTIONS ("TWC(K)" = (10A + B).,)

"A" SIMPO Designator	SIMPO Model Option which is Combined with the Thrust - Time Table Defined by "B"	"B" Thrust - Time Table Designator	Thrust - Time Table Number (Lth Table)
1.,	1.,	1.,	1.,
2.,	2.,	2.,	2.,
3.,	3.,		
4.,	4.,		
5.,	5.,		
6.,	6.,		
7.,	7.,		
8.,	8.,		
9.,	9.,		
10.,	0., that is, either no SIMPO model is assumed and the thrust - time table is used by itself, or SIMPO option 0., is assumed.		

Propulsion Table. The following ten input parameters ("TWD1(K)") to "TWD10(K)" define the five possible thrust - time tables. Each table (see Figure 4-8) defines the vacuum thrust (T) directed along the $\hat{\xi}$ axis as a function of a time argument (t_B) which has a flexible definition (defined by input). This flexible time argument definition allows the thrust - time table to be referenced to either absolute time or simulation section relative time in a manner similar to that discussed earlier in this section for the $\dot{\phi}$ tables. In the event that the current t_B value is greater than the upper bound of the table time argument values (the highest value of "TWD7(I, L)"), an appropriate error diagnostic is printed and the trajectory case is terminated (subsequent cases are still processed) if and only if this error occurs at the successful completion of an integration step. Errors of this type occurring within an integration step do not cause termination. If the current t_B value is below the first table time argument value ("TWD7(I, L)" then the thrust, flow rate and specific impulse resulting from the table model are assumed to be zero; in other words the table is not "cut in"

VACUUM THRUST DIRECTED ALONG THE $\acute{\xi}$ AXIS FOR A SINGLE MOTOR (T)
TIME RATE OF CHANGE IN WEIGHT FOR A SINGLE MOTOR ($\dot{W}$)



LINEAR INTERPOLATION IS ASSUMED

t_B = Current time argument = $t_{ABS} - t_{s\,[TWD1(K)]}$ - TWD2(K)

t_{ABS} = Current absolute time (sec) (output parameter -1)

$t_{s\,(K)}$ = Absolute time at the initiation of simulation section "K"

Figure 4-8. Propulsion Tables

until the current t_B value reaches the first table time argument value ("TWD7(1, L)"). There are two modes to define the corresponding current time rate of change of weight ($\dot{W}$). The first mode assumes a constant effective vacuum specific impulse ("TWD10(K)") which is divided into the current value of the vacuum thrust (obtained by table lookup) to define the current $\dot{W}$. The other mode utilizes a conjugate table to define $\dot{W}$ as a function of the same time argument used for the thrust - time table. Both tables are identical in form and there is one available $\dot{W}$ table for each thrust - time table.

TWD1(K) Simulation section number which defines the simulation section to which the time argument ("TWD7(1, L)") of the thrust - time table (and $\dot{W}$ table if specified) is referenced during simulation section "K". (See Figure 4-8 and "TWD7(1, L)").

(47) (1.) (none) (Q(47, K))

TWD2(K) The reference time during the specified reference simulation section ("TWD1(K)") for the time argument ("TWD7(1, L)") of the thrust - time table (and $\dot{W}$ table if specified). (See Figure 4-8 and "TWD7(1, L)").

(48) (0.) (sec) (Q(48, K))

TWD3(K) The number of motor groups where each group is modeled by the thrust - time table (and $\dot{W}$ table if specified). For example, for a configuration using two strap-on solids, table data could be prepared for one solid with "TWD3(K) = 2".,. The pressure-adjusted thrust (and the $\dot{W}$ if defined by table), obtained by table lookup and subsequent adjustment for atmospheric ambient pressure (by exit area) is multiplied by "TWD3(K)" to obtain the total pressure-adjusted thrust magnitude (and total $\dot{W}$ if appropriate).

(49) (1.) (none) (Q(49, K))

TWD4(K) The nozzle cant angle. This is the angle between the vehicle roll axis and the thrust application vector. The total pressure-adjusted thrust magnitude (see "TWD3(K)") is multiplied by the cosine of "TWD4(K)" to obtain the total effective thrust along the $\hat{\xi}$ axis which is derived from a thrust - time table. It is the net thrust due to symmetric mounting of such canted engines that acts along the $\hat{\xi}$ axis; the other components are assumed to cancel out.

(50) (0.) (deg) (Q(50, K))

TWD5(L) The number of time arguments ("TWD7(I, L)") for the Lth thrust - time table (and the Lth $\dot{W}$ table if specified). The maximum number of "TWD7(I, L)" arguments per thrust - time table (per $\dot{W}$ table if specified) is 25 and the minimum number is two, consequently if the Lth thrust - time table (and $\dot{W}$ table if required) is to be used, "TWD5(L)" must be input such that $2 \leq \text{TWD5(L)} \leq 25$.

(none) (0.) (none) (XNP(L))

TWD6(K) Motor group exit area for the corresponding thrust - time table.

(61) (0.) (in^2) (Q(61, K))

TWD7(I, L) Ith time argument (t_B) for the Lth thrust - time table (and the Lth $\dot{W}$ table if specified). This parameter is the independent variable of these tables (see Figure 4-9) and is defined by:

$$t_B = t_{ABS} - t_{s[\text{TWD1(K)}]} - \text{TWD2(K)}$$

where: T_{ABS} is the current absolute time (output parameter -1).

$T_{s[\text{TWD1(K)}]}$ is the absolute time at the initiation of the simulation section defined by the value of "TWD1(K)".

TWD2(K) is a section input parameter which is defined above.

(none) (none) (sec) (TWD7(I, L))

TWD8(I, L) Ith vacuum thrust argument which corresponds to the Ith time argument ("TWD7(I, L)") for thrust - time table "L". This thrust is the total vacuum thrust magnitude directed along the $\hat{\xi}$ axis at time "TWD7(I, L)" for the motor group modeled by the Lth thrust - time table.

(none) (none) (lb) (TWD8(I, L))

TWD9(I, L) Ith time rate of change of weight ($\dot{W}$) argument which corresponds to the Ith time argument ("TWD7(I, L)") for the thrust - time table "L". This $\dot{W}$ is the total $\dot{W}$ at time "TWD7(I, L)" for the motor group modeled by the Lth thrust - time table. This table is used only if thrust - time table "L" is specified and if $|\text{TWD10(K)}| < 0.000001$.

(none) (none) (lb/sec) (TWD9(I, L))

TWD10(K) The time rate of change of weight ($\dot{W}$) - specific impulse parameter.

If $|TWD10(K)| < 0.000001$, the $\dot{W}$ table which corresponds to the specified thrust - time table is used during simulation section "K".

If $|TWD10(K)| > 0.000001$, "TWD10(K)" is the constant effective vacuum specific impulse assumed during simulation section "K" for the specified thrust - time table. The current $\dot{W}$ is obtained by dividing the vacuum thrust obtained by table lookup by "TWD10(K)" and then multiplying the result by the number of motor groups ("TWD3(K)").

(51) (0.) (sec) (Q(51,K))

SIMPO. The following four input parameters are the propulsion system parameters required by the various SIMPO options. They are defined in the SIMPO option table listed under "TWC(K)", consequently only their code numbers, internally stored values, units, and corresponding internal parameters are presented here.

TWD11(K) See "TWC(K)" for definition.

(1) (0.) (lb) (Q(1,K))

TWD12(K) See "TWC(K)" for definition.

(2) (0.) (lb) or (sec) or (lb/sec) (Q(2,K))

TWD13(K) See "TWC(K)" for definition.

(3) (0.) (lb/sec) or (sec) or (in^2) (Q(3,K))

TWD14(K) See "TWC(K)" for definition.

(66) (0.) (g) (Q(66,K))

[illegible] Input Parameter Index

This Input Parameter Index section lists all the possible input parameters with their code numbers, internally compiled-in values, units and corresponding internal parameters. For the input parameters with subscripts these subscripts are defined:

I	First independent variable table position number
J	Second independent variable table position number
K	Simulation section number
L	Table number
M	General iteration block number
N	Denotes first or second independent variable table argument.

The $DATA1 input parameters which are internally defined (see Appendix V) are denoted by placing an arrow ➪ in the left margin adjacent to the parameter in the list.

A detailed listing of input parameters begins on the next page.

INPUT PARAMETER	CODE NUMBER	INTERNALLY COMPILED VALUE	UNITS	CORRESPONDING INTERNAL PARAMETER
	1.	**INITIAL CONDITIONS**		
		VEHICLE STATE		
ALP	62	0.	DEG	V(62)
ALT0	8	0.	FT	V(8)
AZM	4	270.	DEG	V(4)
GAM	3	90.	DEG	V(3)
LAM	63	0.	DEG	V(63)
LAT	5	34.5615	DEG	V(5)
LNG	6	-120.6233	DEG	V(6)
◇ PLD	10	0.	LB	V(10)
PSI	60	0.	DEG	V(60)
RAD	1	0.	FT	V(1)
SIG	61	0.	DEG	V(61)
T0	51	0.	SEC	V(51)
VEL	2	0.	FT/SEC	V(2)
◇ WGH	7	0.	LB	V(7)
		PROGRAM CONTROL		
AGQ	41	85.	DEG	V(41)
ALTF	71	0.	NONE	V(71)
ALTQ	47	300000.	FT	V(47)
ATQ	42	0.	SEC	V(42)
AZMF	72	0.	NONE	V(72)
AZMI	75	1000.	DEG	V(75)
GTIP	76	1000.	DEG	V(76)
MULT	64	0.	NONE	V(64)
PRNT	66	0.	NONE	V(66)
PSIF	67	1.	NONE	V(67)
◇ RFCN	74	0.	NONE	V(74)
◇ SEC	9	7.	NONE	V(9)
STPF	48	0.	NONE	V(48)
TWE	73	1000.	SEC	V(73)
VELQ	65	10.	FT/SEC	V(65)
VGAI	77	0.	NONE	V(77)
YOUT	78	0.	NONE	V(78)
ZOUT	84	0.	NONE	V(84)

INPUT PARAMETER	CODE NUMBER	INTERNALLY COMPILED VALUE	UNITS	CORRESPONDING INTERNAL PARAMETER
		CONSTANTS		
A	49	20925741.	FT	V(49)
B	50	20855591.	FT	V(50)
CK	36	1.407654×10^{16}	FT^3/SEC^2	V(36)
CNV1	44	3.14159265	RAD/180 DEG	V(44)
CNV2	45	57.295780	DEG/RAD	V(45)
CNV3	46	6076.1033	FT/N. MI.	V(46)
CNV4	79	$0.30480061 \times 10^{-3}$	KM/FT	V(79)
D2	38	1082.30×10^{-6}	NONE	V(38)
D3	39	-2.30×10^{-6}	NONE	V(39)
D4	40	-1.80×10^{-6}	NONE	V(40)
G0	35	32.174049	FT/SEC^2	V(35)
P0	43	14.7510	LB/IN^2	V(43)
WE	37	$0.41780746 \times 10^{-2}$	DEG/SEC	V(37)
	2.	GENERAL ITERATION		
◇ CVC1(M)	11	0.	NONE	V(11), VQ(1, M)
CVC2(M)	12	0.	NONE	V(12), VQ(2, M)
CVC3(M)	13	0.	NONE	V(13), VQ(3, M)
CVL1(M)	29	0.	C. V. UNITS*	V(29), VQ(19, M)
CVL2(M)	30	0.	C. V. UNITS*	V(30), VQ(20, M)
CVL3(M)	31	0.	C. V. UNITS*	V(31), VQ(21, M)
CVM1(M)	26	0.	C. V. UNITS*	V(26), VQ(16, M)
CVM2(M)	27	0.	C. V. UNITS*	V(27), VQ(17, M)
CVM3(M)	28	0.	C. V. UNITS*	V(28), VQ(18, M)
◇ CVN1(M)	14	0.	NONE	V(14), VQ(4, M)
CVN2(M)	15	0.	NONE	V(15), VQ(5, M)
CVN3(M)	16	0.	NONE	V(16), VQ(6, M)
◇ DCV1(M)	23	0.	C. V. UNITS*	V(23), VQ(13, M)
DCV2(M)	24	0.	C. V. UNITS*	V(24), VQ(14, M)
DCV3(M)	25	0.	C. V. UNITS*	V(25), VQ(15, M)
◇ EC1(M)	52	0.	E. C. UNITS**	V(52), VQ(25, M)
◇ EC2(M)	53	0.	E. C. UNITS**	V(53), VQ(26, M)
EC3(M)	54	0.	E. C. UNITS**	V(54), VQ(27, M)
◇ ECC1(M)	17	0.	NONE	V(17), VQ(7, M)
◇ ECC2(M)	18	0.	NONE	V(18), VQ(8, M)
ECC3(M)	19	0.	NONE	V(19), VQ(9, M)
◇ ECN1(M)	20	0	NONE	V(20), VQ(10, M)

*Control Variable Units

** End Condition Parameter Units

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[illegible] LABEL	[illegible] NUMBER	[illegible] COMPUTED VALUE	UNITS	[illegible] PARAMETER
	2. GENERAL ITERATION (Continued)			
ECON2(M)	21	0	NONE	V(21), VQ(11,M)
ECON3(M)	22	0	NONE	V(22), VQ(12,M)
ECT1(M)	32	0.	E.C. UNITS*	V(32), VQ(22,M)
ECT2(M)	23	0.	E.C. UNITS*	V(33), VQ(23,M)
ECT3(M)	34	0.	E.C. UNITS*	V(34), VQ(24,M)
GIN(M)	55	0.	NONE	V(56), VQ(28,M)
HANM	NONE	0.	N.MI.	SQ(3,1), HANM
HPNM	NONE	0.	N.MI.	SQ(3,2), HPNM
ITT1(M)	57	10.	NONE	V(57), VQ(29,M)
ITT2(M)	58	10.	NONE	V(58), VQ(30,M)
ITT3(M)	59	10.	NONE	V(59), VQ(31,M)
TRANON	NONE	0.	DEG	SQ(3,3), TRANON
	3. TARGETING			
CHGF(M)	68	0.	NONE	V(68), VQ(32,M)
RDALT(M)	80	0.	FT	V(80), VQ(35,M)
TLAT(M)	69	0.	DEG	V(69), VQ(33,M)
TLNG(M)	70	0.	DEG	V(70), VQ(34,M)
	4. INTEGRATION CONTROL			
HCOEF(K)	40	2.0	NONE	Q(40,K)
HMIN(K)	39	0.05	SEC	Q(39,K)
HTL1(K)	15	0.10	FT	Q(15,K)
HTL2(K)	16	0.05	FT/SEC	Q(16,K)
HTL3(K)	17	0.01	DEG	Q(17,K)
HTL4(K)	18	0.01	DEG	Q(18,K)
HTL5(K)	19	0.01	DEG	Q(19,K)
HTL6(K)	20	0.01	DEG	Q(20,K)
HTL7(K)	21	0.10	LB	Q(21,K)
HTL8(K)	55	1000000.	LB/(FT-SEC)	Q(55,K)
STEP(K)	7	2.0, 1000.	SEC	Q(7,K)
TOL1(K)	8	1.0	FT	Q(8,K)
TOL2(K)	9	0.5	FT/SEC	Q(9,K)
TOL3(K)	10	0.1	DEG	Q(10,K)
TOL4(K)	11	0.1	DEG	Q(11,K)
TOL5(K)	12	0.1	DEG	Q(12,K)
TOL6(K)	13	0.1	DEG	Q(13,K)
TOL7(K)	14	1.0	LB	Q(14,K)
TOL8(K)	54	1000000.	LB/(FT-SEC)	Q(54,K)

*End Condition Parameter Units

	INPUT PARAMETER	CODE NUMBER	INTERNALLY COMPILED VALUE	UNITS	CORRESPONDING INTERNAL PARAMETER
		5. **PROGRAM CONTROL**			
	BCKT(K)	41	500.	SEC	Q(41,K)
	BCKTT(K)	42	0.001	SEC	Q(42,K)
◇	ORB(K)	56	0.	NONE	Q(56,K)
	PRIF(K)	65	0.	NONE	Q(65,K)
◇	STGC(K)	22	0.	NONE	Q(22,K)
◇	STGD(K)	25	1.	NONE	Q(25,K)
◇	STGT(K)	24	0.001	S.T.P. UNITS*	Q(24,K)
◇	STGV(K)	23	0.	S.T.P. UNITS*	Q(23,K)
	VINC(K)	68	0.	FT/SEC	Q(68,K)
	VSET(K)	67	0.	NONE	Q(67,K)
	WOUT(K)	69	0.	NONE	Q(69,K)
	XOUT(K)	53	1.	NONE	Q(53,K)
		6. **MODELING CONTROL**			
		ATMOSPHERE MODEL			
	ATMC(K)	27	0.	NONE	Q(27,K)
	ALT(I)	NONE	See Appendix III	FT	ALT(I)
	PRS(I)	NONE	See Appendix III	LB/IN^2	PRS(I)
	XKAO	NONE	193.	NONE	XNAO
	VLS(I)	NONE	See Appendix III	FT/SEC	VLS(I)
		AERODYNAMIC MODELS			
	AC1(K)	28	0.	NONE	Q(28,K)
◇	AC2(K)	29	0.	NONE	Q(29,K)
◇	AC3(K)	30	0.	NONE	Q(30,K)
		AERODYNAMIC YAW FORCE COEFFICIENT TABLE (C_η TABLE)			
	A1(J,L)	NONE	NONE	DEG	A1(J,L)
	AREF1(K)	4	0.	FT^2	Q(4,K)
	C1(I,J,L)	NONE	NONE	NONE	C1(I,J,K)
	XKA1(N,L)	NONE	0.	NONE	XNA1(N,L)
	XM1(I,L)	NONE	NONE	NONE	XM1(I,L)

*Section Termination Parameter Units

INPUT PARAMETER	CODE NUMBER	INTERNALLY COMPILED VALUE	UNITS	CORRESPONDING INTERNAL PARAMETER
		AERODYNAMIC AXIAL FORCE COEFFICIENT TABLE (C_ξ TABLE)		
A2(J, L)	NONE	NONE	DEG	A2(J, L)
◇ AREF2(K)	5	0.	FT^2	Q(5, K)
C2(I, J, L)	NONE	NONE	NONE	C2(I, J, K)
XKA2(N, L)	NONE	0.	NONE	XNA2(N, L)
XM2(I, L)	NONE	NONE	NONE	XM2(I, L)
		AERODYNAMIC NORMAL FORCE COEFFICIENT TABLE (C_ξ TABLE)		
A3(J, L)	NONE	NONE	DEG	A3(J, L)
◆ AREF3(K)	6	0.	FT^2	Q(6, K)
C3(I, J, L)	NONE	NONE	NONE	C3(I, J, K)
XKA3(N, L)	NONE	0.	NONE	XNA3(N, L)
XM3(I, L)	NONE	NONE	NONE	XM3(I, L)
		ATTITUDE MODELS		
		ROLL (BANK) ANGLE DEFINITION		
GDOT(K)	52	0.	DEG/SEC	Q(52, K)
SIGC(K)	32	1.	NONE	Q(32, K)
SIGDT(K)	36	0.	DEG/SEC or NONE	Q(36, K)
SSIG(K)	44	0.	DEG	Q(44, K)
		PITCH ANGLE OR PITCH ANGLE OF ATTACK DEFINITION		
◆ ALPC(K)	33	1.	NONE	Q(33, K)
◆ ALPDT(K)	37	0.	DEG/SEC or DEG	Q(37, K)
GDOT(K)	52	0.	DEG/SEC	Q(52, K)
PDT(I, L)	NONE	NONE	DEG/SEC	PDT(I, L)
◆ PITX(K)	62	1.	NONE	Q(62, K)
PSIDT(K)	38	0.	DEG/SEC or DEG	Q(38, K)
PSEC(K)	63	1.	NONE	Q(63, K)
PT(I, L)	NONE	NONE	SEC	PT(I, L)
PTME(K)	64	0.	SEC	Q(64, K)

*Section Termination Parameter Units

INPUT PARAMETER	CODE NUMBER	INTERNALLY COMPILED VALUE	UNITS	CORRESPONDING INTERNAL PARAMETER
PITCH ANGLE OR PITCH ANGLE OF ATTACK DEFINITION (Continued)				
◇ SALP(K)	45	0.	DEG	Q(45,K)
SPSI(K)	43	0.	DEG	Q(43,K)
XKPT(L)	NONE	0.	NONE	XNPT(L)
YAW ANGLE OF ATTACK DEFINITION				
LAMC(K)	34	1.	NONE	Q(34,K)
LAMDT(K)	38	0.	DEG/SEC	Q(38,K)
SLAM(K)	46	0.	DEG	Q(46,K)
WEIGHT MODELS				
GMC1(K)	57	0.	FT^3/SEC^2	Q(57,K)
GMC2(K)	58	0.	FT^3/SEC^2	Q(58,K)
GMC3(K)	59	0.	FT^3/SEC^2	Q(59,K)
GMC4(K)	60	0.	FT^3/SEC^2	Q(60,K)
◇ JETW(K)	26	0.	LB	Q(26,K)
PROPULSION MODELS				
◇ TWC(K)	31	0.	NONE	Q(31,K)
PROPULSION TABLE				
TWD1(K)	47.	1.	NONE	Q(47,K)
TWD2(K)	48.	0.	SEC	Q(48,K)
TWD3(K)	49.	1.	NONE	Q(49,K)
TWD4(K)	50.	0.	DEG	Q(50,K)
TWD5(L)	NONE	0.	NONE	XNP(L)
TWD6(K)	61.	0.	IN^2	Q(61,K)
TWD7(I,L)	NONE	NONE	SEC	TWD7(I,L)
TWD8(I,L)	NONE	NONE	LB	TWD8(I,L)
TWD9(I,L)	NONE	NONE	LB/SEC	TWD9(I,L)
TWD10(K)	51.	0.	SEC	Q(51,K)
SIMPO				
◇ TWD11(K)	1.	0.	LB	Q(1,K)
◇ TWD12(K)	2.	0.	LB,SEC,LB/SEC	Q(2,K)
◇ TWD13(K)	3.	0.	LB/SEC,SEC, IN^2	Q(3,K)
TW[illegible](K)	66.	0.	[illegible]	Q(66,K)

4.3 BASIC SYNTHESIS OPERATION

This section contains the basic operation instructions for using the synthesis driver for the SSSP and for control of its various synthesis options as discussed under Section 2.3, Synthesis Techniques. The input data block $DATA2 contains the basic input data requirements necessary to drive the SSSP however, the various synthesis procedures rely on the values of certain parameters that must be input to the $DATA3 (orbiter and booster) and $DATA1 input blocks in order to be successfully used. The basic input parameters for the $DATA3 and $DATA1 blocks are described in Section 4.2 and will be referenced in this section where necessary.

The succeeding paragraphs are broken down into the following basic categories:

1. Propulsion Option
2. Stage Burn Sequence
3. Booster Cruise Range Calculation
4. Booster Cruise Fuel Calculation
5. Stage Weight Constraints and Solid Rocket Thrust Augmentation

Included in each of the first 4 categories are optional procedures or methods necessary to drive the SSSP. One procedure from each category must be selected for a given computer run. The last category contains those options which may be utilized in conjunction with the selected procedure but are not required for a given computer run. If options from the last category are not selected, the run obtained will yield the stage gross weights, performance, and design data for the following fixed inputs:

$DATA3 - ORBITER: selected value of C(103) = system payload weight
$DATA3 - BOOSTER: selected value of MR(3) = main impulse mass ratio (booster)

In addition this section will assume that the basic parameters necessary to drive the sizing process ($DATA3, orbiter and booster), and the simulation of the baseline ascent trajectory ($DATA1) have been input.

4.3.1 PROPULSION OPTION

4.3.1.1 Fixed Booster Thrust (Common Stage Engines). This option specifies that the thrust level for the booster is obtained from the total vacuum thrust of the orbiter. This option is described in Section 2.3.2.1. The following are the input data requirements:

$DATA2	set flags BOOTW=0., TWLOI= -1., set desired value of TRATIO = ratio of booster vacuum thrust to orbiter vacuum thrust
$DATA3-ORBITER	set desired value of C(129) = vacuum thrust/engine and CTHRST=0.,
or	set desired value of CTHRST = ignition thrust/weight at vacuum conditions and C(129)=0.,

4.3.1.2 Fixed Liftoff Thrust-to-Weight. This option specifies that the vehicle thrust/weight at liftoff be held constant independent of the gross liftoff weight resulting from the sizing process. This option is described in Section 2.3.2.2. One of two procedures is available and the following are the input data requirements:

a. Non-common Stage Engines

$DATA2:	set flag BOOTW=1.,
$DATA3-ORBITER:	set flag desired value of C(129) = vacuum thrust/engine and CTHRST = 0.,
or	set desired value of CTHRST=ignition thrust/weight at vacuum conditions and C(129) = 0.,
$DATA3-BOOSTER:	set desired value of <u>liftoff</u> thrust/weight (sea level conditions)=CTHRST
	NOTE: The booster sizing process is still performed on the basis of total stage vacuum thrust/stage gross weight. The adjustment to CTHRST to accommodate this basis is performed internally prior to synthesis of the booster stage.

b. Common Stage Engines

$DATA2:	set flag BOOTW=0., set desired value of TRATIO=ratio of booster vacuum thrust to orbiter vacuum thrust, TWLO= liftoff thrust/weight for vehicle, TOLTW= iteration tolerance on TWLO (~.001.), and TWLOI= number of max. allowable iterations to obtain TWLO (~6.,)

$DATA3-ORBITER estimate CTHRST ignition thrust/weight at vacuum conditions (≈1.3, typical) and C(129) = 0.,

4.3.2 STAGE BURN SEQUENCE

4.3.2.1 Sequential Stage Burns. This is the normal operating procedure utilized for the shuttle concept and involves only solo-burns of the stages as if the stages were in the normal "stacked" arrangement of expendable launch vehicles. This option is described in Section 2.3.3.1. The following are the input data requirements:

$DATA2: set flag FIRE =2.,

set desired values of booster sea level and vacuum specific impulses and thrust factors for ascent flight sections 1 -4: ISLB(I), IVACB(I), TFCTRB(I); I=1,...,4

set desired values of orbiter sea level and vacuum specific impulses and thrust factors for ascent flight sections 3 -7: ISLO(I), IVACO(I), TFCTRO(I); I=3,...,7

NOTE: the booster and orbiter specific impulses and thrust factors for flight sections 3 and 4 are used only for printed output purposes since these sections are coast simulated (see Section 4.2.2 above for use).

4.3.2.2 Simultaneous Stage Burns. This option allows for utilizing the orbiter main rocket engines along with the booster engines during the initial boost phase of flight for thrust augmentation. It assumes that the stages are in a parallel arrangement (or "piggy-back" arrangement) on the launch pad. This option is described in Section 2.3.3.2. One of two procedures is available and the following are the input data requirements:

a. No Crossfeed

$DATA2: set flags FIRE =1.,
NXFOB =1., (or ≠ 0.,)

set desired values of booster sea level and vacuum specific impulses and thrust factors for ascent flight sections 1 -4: ISLB(I), IVACB(I), TFCTRB(I); I=1,...,4 set desired values of orbiter sea level and vacuum specific impulses and thrust factors for ascent flight sections 1 - 7 ISLO(I), IVACO(I), TFCTRO(I); I=1, . . . , 7

NOTE the booster and orbiter specific impulses and thrust factors for flight sections 3 and 4 are used only for printed output purposes since these sections are coast simulated (see Section 4.2.2 above for use).

$DATA1 ascent flight simulation section 1 must be terminated on time from liftoff, therefore:

set flags STGC(1) =1.,
STGD(1) =1.,
STGT(1) =.001, (typical)

set desired value of STGW(1)=absolute time (sec) from liftoff to terminate flight section

b. With Crossfeed

$DATA2: set flags FIRE= 1.,
NXFOB =0.,

set desired values of specific impulses and thrust factors for each stage per procedure outlined in "a. No Crossfeed" above.

4.3.3 BOOSTER CRUISE RANGE CALCULATION

This paragraph describes the operation instructions for providing the SSSP with a method for calculating the booster reference range requirement discussed in Section 2.3.4.1. This reference range is used for determining the cruise performance parameter (Section 2.3.4.2) used in synthesis of the booster. Five options are available.

4.3.3.1 Parametric Flyback Range Data. The following are the input data requirements:

$DATA2: set flag FLYBCK = 1.,
set desired value of DRNG = additive range factor used to bias results of obtained reference range requirement (≈ .25 n. mi)

set desired value of CLVG = adjustment factor on range requirement due to variations in the booster entry hypersonic characteristics

4.3.2.2 Staging-Q Function Range. The following are the input data requirements:

$DATA2: set flag FLYBCK = 2.,
set desired value of DRNG = additive range factor used to bias results of obtained reference range requirements

$DATA1: the initial pitchover maneuver during ascent flight simulation section must be used to target to an specified value of the staging dynamic pressure, Q_s, at the termination of ascent flight simulation section 3, therefore:

set the flags: ECC1(1) = 92.,
ECN1(1) = 3.,
ECT1(1) = .001, (typical)
EC(1) = $\log_{10}(Q_s)$

where Q_s is the desired value of the staging dynamic pressure (psf).

4.3.3.3 Constant Range. The following are the input data requirements:

$DATA2: set flag FLYBCK = 3.,
set desired value of DRNG = range increment used to define reference range requirement

4.3.3.4 Ballistic Impact Range. The following are the input data requirements:

$DATA2: set flag FLYBCK = 4.,
set desired value of DRNG = additive range factor used to bias results of obtained reference range requirement

[illegible]

[illegible] Entry Trajectory Simulation Range. The following are the input data requirements

$DATA2	set flag FLYBCK = 5., set desired value of DRNG - additive range factor used to bias results of obtained reference range requirement
$DATA1	the booster entry/return trajectory is computed by numerical integration of the flight differential equations of motion therefore the trajectory profile, vehicle control, and vehicle modeling must be input by the user. Set flag SEC > 7 as required (7 < SEC ≤ 15) to specify the total number of simulation sections for the entry trajectory. All input must be satisfied as specified by Section 4.2.3, $DATA1 where section subscripts must be greater than 7 (also see Section 2.3.4.1e for restrictions placed on this option).

4.3.4 BOOSTER CRUISE PERFORMANCE CALCULATION

This paragraph describes the operation instructions for providing the SSSP with a method for calculating the booster cruise performance parameter discussed in Section 2.3.4.2. This parameter is used in the sizing of the booster in the form of the cruise performance mass ratio minus one. Three options are available.

4.3.4.1 Simplified Single Segment Cruise. The following are the input data requirements

$DATA2	set flag FBFUEL = 1., set desired values of Breguet constants for cruise condition: SFC, VCRUSE, ALD set desired value of WFLYX - optional additive weight term
$DATA3-BOOSTER	estimate C(214) - cruise performance mass ratio minus 1

4.3.4.2 Four Segment Reference Range Option 1. The following are the input data requirements

$DATA3	set flag FBFUEL = 2., set desired values of Breguet constants for cruise condition: SFC2, VFLY2, ALD2 set desired value of WFLYX = optional additive weight term set desired values of CA and CB constants used for the idle and final descent portions of flight, respectively set desired values of the cruise range decrements RT, R1, R2 used for the transition, idle descent and final descent portions of flight, respectively
$DATA3-BOOSTER:	estimate C(214) = cruise performance mass ratio minus 1

4.3.4.3 Four Segment Reference Range Option 2. The following are the input data requirements:

$DATA2	set flag FBFUEL = 3., set desired values of Breguet constants for idle descent: SFC1, VFLY1, ALD1; cruise: SFC2, VFLY2, ALD2; and final descent; SFC3, VFLY3, ALD3 set desired value of WFLYX = optional additive weight term set desired values of the cruise range decrements RT, R1, R2 used for the transition, idle descent and final descent portions of flight, respectively
$DATA-BOOSTER:	estimate C(214) = cruise performance mass ratio minus 1.

4.3.5 STAGE WEIGHT CONSTRAINTS AND SOLID ROCKET THRUST AUGMENTATION

(Note the options outlined in the following paragraphs are not input requirements necessary for driving the SSSP, but may be combined with the majority of the possible selected combinations derived from the preceding paragraphs).

4.3.5.1 Fixed Booster Gross Weight (Liftoff Weight). This option provides for the capability of fixing the gross weight of the booster (or gross liftoff weight of the system. This option is described in Section 2.3.2.3.

NOTE: this option should only be used when the selected procedure above includes the Propulsion Option described in Section 4.3.1.1 with C(129) specified ($DATA3-ORBITER). The following are the input data requirements:

$DATA2	set desired value of GWREQ - booster gross weight (liftoff weight)
	set BOOTW = 0., TWLOX = -1., and desired value of TRATIO (see Section 4.3.1.1)
$DATA3-ORBITER:	estimate C(103) - system payload set desired value of C(129) (see Section 4.3.1.1)
	NOTE: if this option is not desired, set GWREQ ≤ 0.

4.3.5.2 Fixed Orbiter Gross Weight. This option provides the capability of fixing the gross weight of the orbiter. This option is described in Section 2.3.2.4. The following are the input data requirements:

$DATA2:	set desired value of WOREQ - orbiter gross weight
$DATA3-BOOSTER:	estimate MR(3) - main impulse mass ratio (booster)
	NOTE: if this option not desired, set WOREQ < 0.

4.3.5.3 Fixed Orbiter Propellant Weight. This option provides the capability of fixing the total impulse propellants expended during the orbiter burns (ascent and on-orbit). This option is described in Section 2.3.2.5. The following are the input data requirements:

$DATA2	set desired value of WPOREQ - total expended orbiter impulse propellants
$DATA3-BOOSTER:	estimate MR(3) - main impulse mass ratio (booster)
$DATA3-ORBITER:	set MR(8) - total on-orbit velocity budget (fps) or mass ratio for total on-orbit maneuvering required.
	NOTE: if this option is not desired, set WPOREQ ≤ 0.

NOTE: this option should only be used when the selected procedure above includes the Propulsion Option described in Section 4.3.1.1 with C(129) specified ($DATA3-ORBITER). The following are the input data requirements:

$DATA2:	set desired value of GWREQ = booster gross weight (liftoff weight) set BOOTW = 0 , TWLOI = -1., and desired value of TRATIO (see Section 4.3.1.1)
$DATA3-ORBITER:	estimate C(103) = system payload set desired value of C(129) (see Section 4.3.1.1) NOTE: if this option is not desired, set GWREQ ≤0.

4.3.5.2 Fixed Orbiter Gross Weight. This option provides the capability of fixing the gross weight of the orbiter. This option is described in Section 2.3.2.4. The following are the input data requirements:

$DATA2:	set desired value of WOREQ = orbiter gross weight
$DATA3-BOOSTER:	estimate MR(3) = main impulse mass ratio (booster) NOTE: if this option not desired, set WOREQ ≤ 0.

4.3.5.3 Fixed Orbiter Propellant Weight. This option provides the capability of fixing the total impulse propellants expended during the orbiter burns (ascent and on-orbit). This option is described in Section 2.3.2.5. The following are the input data requirements:

$DATA2:	set desired value of WPOREQ = total expended orbiter impulse propellants
$DATA3-BOOSTER:	estimate MR(3) = main impulse mass ratio (booster)
$DATA3-ORBITER:	set MR(8) = total on-orbit velocity budget (fps) or mass ratio for total on-orbit maneuvering required. NOTE: if this option is not desired, set WPOREQ <0.

4.3.5.4 Fixed Solid Rocket Motor Augmentation. This option provides for thrust augmentation during initial boost phase of flight (flight section 1) by utilizing fixed solid rocket strap-ons. This option is described in Section 2.3.3.3. The following are the input data requirements:

$DATA2: set desired value of SOLID = number of solid rockets and TSBO = burn time duration of rockets (total propellant depletion)
set desired values of AS, ES, SISP, SINERT, and S[illegible] as defined in Section 2.3.3.3.

NOTE: flight section 1 is automatically terminated on the input value of TSBO at which time the spent solid rockets (=SOLID * SINERT) are jettisoned. If this option is not desired, set SOLID ≤0.