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1. **Program Order Number** *(to be filled in by PID)* . . . 43.2.001
2. **System Type** *(machine)* . . . S/360-50
3. **Search Key** . . . MIDAS/-360//ADAPTATION/ /OF/ CONVAIR MIDAS-III DIGITAL ANALOG SIMULATOR /TO/ OS-360
4. **Name of Author** *(if different than submitter's)* . . . Basic program and documentation by G. H. Burgin, General Dynamics, Convair Div. OS-360 modification by W. E. Loper [redacted]
5. **Submitter's Name** *(direct technical inquiries to)* . . . W. E. Loper
6. **Submitter's Address** . . .
   Mr. W. E. Loper
   Naval Ocean Systems Center
   Computer Architecture Branch
   Code 8315
   San Diego, CA 92152
7. **Title of Program** . . . MIDAS - An adaptation of the Convair pre-compiling MIDAS-III digital analog simulation system to OS-360 with CALCOMP plotting.
8. **Submitter's User Group Affiliation Code and Installation Code** . . . S NOL
9. **Submitter's Own Program Identification and Suffix** *(optional)* . . .
10. **Primary Subject Code** . . . 43.2
11. **Secondary Subject Codes** . . . 03.6 11.0 16.0 17.0
12. **Operating or Monitor System Required** . . . OS-360
13. **New or Revision Code** *(if revision, show prior Program Order Number in item 1)* . . . N
14. **Year Completed** . . . 66
15. **Date of Submittal** . . . 1DEC67
16. **Documentation** *(number of original pages submitted)* . . . 105
17. **Abstract** *(should contain sufficient information for a reader to determine the value of the program). Listed on the reverse side of this form are subjects which may serve as a guide for a descriptive abstract.*

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Subject Guide

- a. Purpose
- b. Programming Language used
- c. Version and modification level or release number of IBM Programming System used, or program order number for non-IBM authored program used
- d. Field of application
- e. Type of routine (main program, subroutine, etc.)
- f. Specific description of machine requirements
- g. Engineering Changes (EC) level of equipment (if pertinent)

ABSTRACT

This MIDAS program and report are adaptations of a program (MIDAS-III) and report (GDC-DDE66-022) by G. H. Burgin of General Dynamics, Convair Division, San Diego, California. The Convair version was a continuation of developments in simulation of analog computer oriented descriptions of systems of differential equations beginning with MIDAS originally produced by Wright-Patterson Air Force Base and MIDAS-II by North American Aviation. The Convair version was a contribution to the 7094 literature in that it was a pre-compiler in contrast to the previous interpreters which were an order of magnitude slower in execution.

This program and its supporting documentation modify only that which is necessary to accommodate specific differences in computers, operating systems, and peripheral equipment differences between NWCCL and Convair.

(Please attach additional pages if necessary) . . . . **Total pages attached** None

Permission to Publish

"I hereby give anyone permission to reprint, reproduce, and distribute this program to anyone else."

(18) **Signature of Submitter and Date** Warren E. Loper (signature) WARREN E. LOPER 28 Nov 1967

(19) **Signature of Installation Addressee** Warren E. Loper (signature) 23 Jan. 1968

T4SF

NAVAL ORDNANCE LABORATORY
CORONA, CALIFORNIA 91720

MIDAS

A GENERAL DIGITAL SIMULATION PROGRAM

APRIL 1967

MIDAS

The original NWCCL version of MIDAS employed single precision arithmetic. This was found to be insufficient for some types of problems, and a double precision version (DMIDAS) has therefore also been implemented. Both versions are included and supported by the catalogued procedures MIDAS and DMIDAS. Not only is the double precision version more accurate, but it is also faster for many problems, except when an attempt is made to reduce the integration interval below MININT, in which case the same number of slower instructions is being executed. When the error criterion is met earlier than in the single precision version, however, as in the case of the "Aircraft Arresting Gear" problem (sample problem 2), the speed advantage is most obvious. The single precision version ran 9 minutes while the double precision version ran only 2 minutes, both on an IBM System 360 Model 50.

The tape has 7 files in 9 track EBCDIC, 8Ø0 bpi, no labels. Files are of card image records of 80 characters, blocking factor of twenty-five. Each file ends with a single tape mark. [Thus DCB=(RECFM=FB,LRECL=8Ø,BLKSIZE=2ØØØ)]

- File 1: Catalogued procedures supporting MIDAS and DMIDAS - 152 cards
- File 2: MIDAS Precompiler Source Language - 2298 cards
- File 3: Source language of PL/1 program CONCAT used in File 4 - 65 cards
- File 4: MIDAS Execution Time Library Source Language - 1561 cards
- File 5: Linkage used in support of catalogued procedures MIDAS and DMIDAS - 27 cards
- File 6: Five sample problems - 272 cards
- File 7: DMIDAS Source Language - 2218 cards.

The job control language is that which we have used and may not be fully applicable to other installations; specifically the index level CODEØ5. The linkage editor control cards are release sensitive and run on Operating System Release 13. Release 14 will require removal of the # signs.

The CALCOMP PLOTTER Subroutines are proprietary and must be obtained from California Computer Products, Inc. or replaced with the user's own plot routines.

2/13/68

FOREWORD

This MIDAS program and report are adaptations of a program and report produced by General Dynamics, Convair Division, San Diego, California. The Convair program was a continuation of previous versions originally produced by Wright-Patterson Air Force Base and North American Aviation.

This report modifies only that information in the Convair report which necessitated modification due to specific differences in computers and computer configurations between Naval Ordnance Laboratory, Corona and Convair.

ACKNOWLEDGMENTS

Naval Ordnance Laboratory, Corona expresses thanks to G. H. Burgin, Mathematical Analysis Group, General Dynamics, Convair, San Diego, California, author of MIDAS III, and Ken Bonine of Convair who granted permission to incorporate parts of General Dynamics Report GDC-DDE66-022 into this report.

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SECTION 1
INTRODUCTION

MIDAS (Modified Integration Digital Analog Simulator) is a digital computer program that employs operational building blocks such as sign changers, summers, integrators, and multipliers. The analog programmer can learn the characteristics of these components in a few minutes, and can use them in block diagrams very similar to the schematics he uses for the analog computer. By following a few simple rules, the block diagrams can be converted into the coding that goes to the keypunch operator. The programmer turns over the resulting punched cards to the digital computer operator (not programmer) for the solution.

The ability to obtain a dynamic digital check solution for comparison with a first analog computer run is the principal virtue of MIDAS, but other advantages may be of equal value. For instance, amplitude scaling is practically automatic due to the use of floating point arithmetic which yields a dynamic range of approximately 10^{150}. Thus, a MIDAS run can yield the maximum and minimum values of all the variables in a problem and eliminate the need for "guesstimating" them when preparing an analog schematic. Even time-scaling information can be gleaned from a MIDAS solution by observing the maximum values of derivatives of the variables.

One final point before going on with the description of the system is that MIDAS programming is simpler than programming an analog computer for the aforementioned reasons of no amplitude or time scaling requirements, and further because some of the operational components (dividers and relays, for example) are single blocks rather than combinations of elements such as high-gain amplifiers or multipliers.

More and more, MIDAS is also being used without ever solving a problem on an analog computer. While it may be more efficient as far as computing time is concerned to write a digital program directly in FORTRAN, ALGOL, or PL/I, the overall efficiency of MIDAS can be quite high because no detailed knowledge of digital computer

programming and numerical analysis is required. In many cases, this eliminates the digital computer programmer and, therefore, gives the engineer direct access to the digital computer.

This program is an adaptation, for the IBM 360, of a General Dynamics Convair program. It in turn was developed from programs originally written at Wright-Patterson Air Force Base and North American Aviation, Inc. The first version of MIDAS, from Wright-Patterson Air Force Base (Reference 1) is an interpretive program. The version generated at North American Aviation (Reference 2) is also an interpretive program, but with several more operational elements such as logical elements and a new plotting package.

This MIDAS, unlike its predecessors, first generates a FORTRAN subroutine. This FORTRAN subroutine is then compiled and executed in subsequent job steps. The benefits that accrue from having a FORTRAN program generated are: 1) an efficient machine language program may be compiled from it, 20 greater flexibility is obtained for programming changes, and 3) the machine time needed for the actual calculation of a solution is considerably reduced.

The MIDAS program was originally developed at the Convair Division of General Dynamics in San Diego, California during December 1964. It was first presented at the Western Simulation Council meeting in May 1965, and was described in an article in the March 1966 issue of Simulation (Reference 3). This manual reflects the status of MIDAS as used at the Naval Ordnance Laboratory, Corona, California.

MIDAS has been used to solve a number of actual problems by the Dynamics Group at Conviar. This experience has resulted in many improvements to the program, such as additional operational elements, added outputs in the logical elements (all logical elements now have a "true" and a "false" output), multiple run capability has been added, the plotting capability modified, a "FORTRAN Black Box" element added, and others. Of all the capabilities of the previous versions of MIDAS, only the Implicit Function block has not yet been incorporated in MIDAS.

Concurrent with the development of MIDAS, many new, continuous-system simulator programs have appeared; two of the most important are MIMIC and DSL/90. Although both of these programs are more flexible, neither gives the ease of programming of the original MIDAS. This MIDAS, therefore, made only one concession to the more flexible general purpose digital computer programming languages, namely the inclusion of an element called "FORTRAN Black Box."

The author is aware that this program is only one step toward an efficient and easy to use general purpose simulation program. Improvements will doubtless be suggested by users as the program is exercised. It is this continuum of usage and modification that will eventually lead to a satisfactory and efficient simulation program for the user.

It should also be borne in mind that when used strictly as a digital simulation program, the most satisfactory use will generally be found in small problems rather than large production type programs. However, on big problems, time may be saved by having the engineer set up the basic problem using MIDAS, and then have the FORTRAN deck modified and added to by a digital programmer.

SECTION 2

GENERAL DESCRIPTION OF MIDAS

The MIDAS program provides a large number of operational elements similar to those in an analog computer. These elements include integrators, summers, multipliers, relays, sign changers and many others. Programming by means of MIDAS consists of "interconnecting" these elements to meet the requirements ı a particular problem. This is analogous to the use of patchcords on an anal computer to interconnect the electronic operational elements. Just as it ha proven useful to the analog programmer to prepare a schematic diagram to indicate the necessary interconnections, a very similar form of block diagra is the first step in preparing a MIDAS program.

Preparation of a coding form from the block diagram is the next step, specif for each element the source of its input or inputs. This is done according t a few simple rules of format. With the addition of several other items of information such as a calling sequence or numerical data the coding sheet is ready for keypunch.

A MIDAS program is run on an IBM 360 computer as a multiphase job. The firs phase, called the precompiler phase, accepts the MIDAS program input and gen a FORTRAN program that is passed to the second phase. The second phase is a FORTRAN IV-G compilation which accepts the passed source language program an generates and passes object (machine) language to the third phase. The thir phase is a Link Edit which resolves external references from the MIDAS libra produce an executable program (load module). The fourth and last phase load and executes the program with the input data. A cataloged procedure named MI is available to perform these operations in a single job of four steps. (se Section 7.) The executable load module may optionally be saved for subseque runs eliminating redundant precompilations, compilations and link editing.

SECTION 3

PREPARATION OF BLOCK DIAGRAMS

There are many different types of block diagrams. For example, the dynamic relationships existing in a system may be shown by blocks and interconnecting signal flow lines where each of the blocks may express a rather complex transfer function (relationship between the output from and the input to the box). Organization charts are another form of block diagram. For MIDAS, the blocks represent certain elemental mathematical operations such as summing, multiplying, dividing, integrating, etc.

The concept of a block diagram may be illustrated by the setup for the solution of the classical second order differential equation for the mass-spring-damper system.

$$M\ddot{x} + B\dot{x} + Kx = 0$$

$$x(0) = A$$

$$\dot{x}(0) = 0$$

where

M = mass

B = viscous damping coefficient

K = spring constant

A = initial displacement

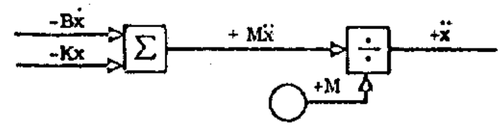
The approach used is based on the fact that integrators are available rather than differentiators. Thus, express the highest derivative of the variable of interest as a function of the lower derivatives and any forcing function. Then integrate a sufficient number of times to obtain the variable of interest and at the same time obtain the terms necessary to form the highest derivative.

In this case write:

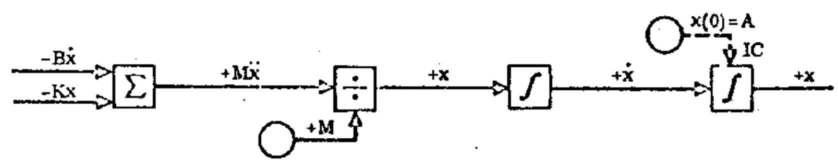
$$M\ddot{x} = -B\dot{x} - Kx$$

The equation in this form states that if the quantities $-B\dot{x}$ and $-Kx$ are added, the sum represents $M\ddot{x}$. This is shown as:

To find x(t) integrate $\ddot{x}$ twice; but first obtain $\ddot{x}$ by dividing $M\ddot{x}$ by M. The combined operations to this point are represented as:

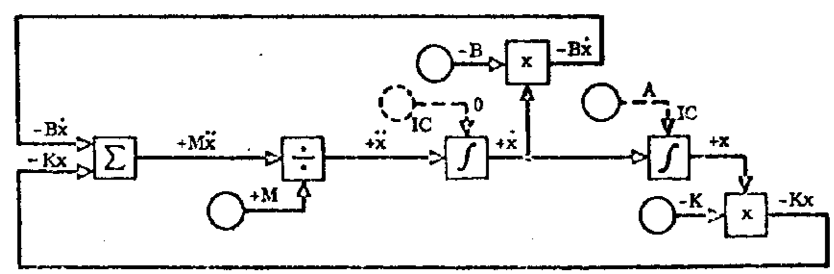


Next, the two integrations with respect to t are shown:



The initial value of x is shown as an auxiliary input to the second integrator. Analog programmers should note the absence of sign changing in the summer and integrator.

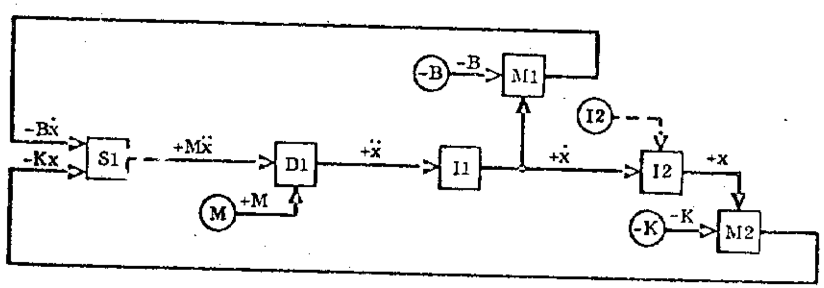
Finally, the two inputs to the summer (viz., $-B\dot{x}$ and $-Kx$) must be obtained by multiplying $\dot{x}$ and x by -B and -K respectively.



The configuration shown above uses one summer, one divider, two integrators, two multipliers, and four constants. It should be pointed out that there are several arrangements of components that would solve this equation. The only basic requirement of all these arrangements is that two integrators be used since we are dealing with a second order differential equation. In general, Nth order differential equations or sets of equations will require N integrators.

Analog programmers may find this block diagram rather strange in that multipliers and dividers are used in solving a linear equation. Also strange are the "pots" set at -B and -K whose magnitudes can have any value up to 10^{75}.

The block diagram, though, is not complete. Since the digital computer will be building a system composed of one summer, one divider, two integrators, two multipliers, and four constants, specific names must be given to the individual components. If the components are identified uniquely by type and number, and the constants are given names according to rules which will be discussed later, the result is as follows:



Note that such symbols as Σ for summation and ÷ for division have been omitted from the final diagram. The mathematical operations are evident from the first part of the name, e.g., S for summer and D for divider, and the omission of the symbol leads to a less cluttered diagram without loss of clarity.

A tabulation of the elements used above as well as all of those currently available in the MIDAS program is included in Table 5-1. This table provides a comprehensive description of each element and is divided into several categories of elements based on the type of operation performed.

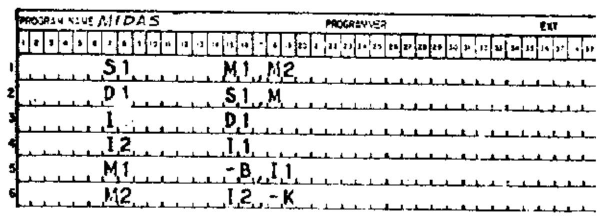
SECTION 4

PREPARATION OF CODING FORM

The cards that have to be prepared by the engineer to describe the problem to be solved by MIDAS consist of two sets. The first set is the MIDAS program, the second set consists of the data cards, the plot control cards, and the plot title cards. The data cards contain the numerical values (the constants, initial conditions and function generators) for the MIDAS run.

BLOCK DIAGRAM OF MATHEMATICAL PROBLEM

It is necessary to specify to the key punch operator not only the alphanumeric information to be punched on the cards, but also the particular location on the card where it should be placed. The rules are very simple and their observance is helped by using special MIDAS programming sheets, but Standard FORTRAN programming sheets may be used. The coding of the main part of the symbolic program for the preceding block diagram is shown below



There are six lines coded, one for each of the six boxes in the diagram. The first letter of a component is listed in column 7 while the first letter of the input(s) to this component is listed in column 15. Note the commas between multiple inputs to a component and the absence of a comma after the last input.

Of particular significance in the above coding is the line describing D1. The sequence of listing the inputs to the divider define which term is the numerator and which the denominator: the first term listed (S1) is the numerator and the second term listed

(M) is the denominator. The sequence of listing the inputs to summers or multipliers has no signifi· ance.

Just as it is true that a considerable variety of block diagram configurations will solve a given problem, the coding may be done in many different orders. Since a digital computer is a serial device that performs its operations in a very definite sequential manner, this variation in the sequence of the operations could produce very significant effects on the solutions. MIDAS takes care of this with a sorting routine that lines up the program in the proper order no matter how the programmer sets it up.

EXAMPLE USING NON-LINEAR DIFFERENTIAL EQUATIONS

Before leaving the subject of block diagram and code form preparation, two more examples are given:

$$\dot{x} = y + \frac{x}{R}(1 - R^2)$$

$$\dot{y} = -x + \frac{y}{R}(1 - R^2)$$

where

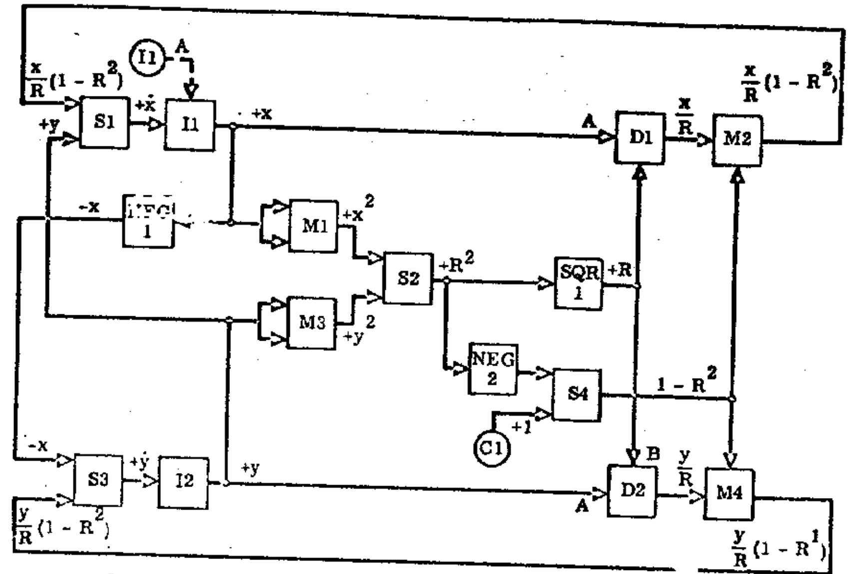
$$R = \sqrt{x^2 + y^2}$$

and

$$x(0) = A$$

$$y(0) = 0$$

A block diagram and listing for the solution of these equations is given in Figure 4-1. Note that summers S1 and S3 combine the terms comprising $\dot{x}$ and $\dot{y}$ respectively. Integrators I1 and I2 provide x and y. The remainder of the elements are used to perform the algebraic operations necessary to form the inputs to summers S1 and S3. The inputs to D1 and D2 are labeled A and B to indicate the order in which they will appear on the coding form. Not also that the input to SQR1 will always be positive (or



PROGRAM NAME

1	S1	I2, M2
2	I1	S1
3	M1	I1, I1
4	NEG1	I1
5	S2	M1, M3
6	SQR	S2
7	D1	I1, SQR1
8	D2	I2, SQR1
9	M2	D1, S4
10	S3	NEG1, M4
11	I2	S3
12	M3	I2, I2
13	NEG2	S2
14	S4	NEG2, C1
15	M4	D2, S4

$$\dot{x} = y + \frac{I}{R}(1 - R^2)$$

$$\dot{y} = -I + \frac{y}{R}(1 - R^2)$$

$$R = \sqrt{x^2 + y^2}$$

$$x(0) = A$$

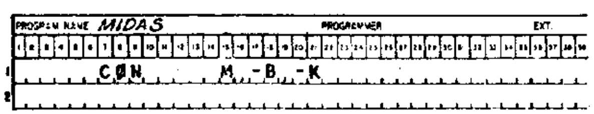
$$y(0) = 0$$

Figure 4-1. Block Diagram and Coding Form for Non-linear Differential Equation Example zero) regardless of the signs of x and y. This satisfies the requirement that the input to the square root element must not be negative. Each block on the diagram requires one line on the listing. Each block is named in column 7 just once and its inputs are given beginning in column 15. Each item appearing as an input must be defined either as one of the elements appearing in column 7 or as a constant.

CONSTANTS AND INITIAL CONDITIONS

The conversion of the mathematical problem into a block diagram and the preparation of the coding form of the main part of the program have been discussed, but as yet no numerical data has been entered. This data may be in the form of constant coefficients, initial conditions, forcing functions, or arbitrary functional relationships. The constants M, B, and K were used in the previous example without showing how they were entered into the MIDAS listing. The entering of numerical data and constants is discussed next. Note that all these data cards are needed only for the program execution phase.

<u>Constants</u>. Information about a constant will appear at least twice in a MIDAS program. It will appear in the main body of the program where the constant is given a name and again in the data part of the program where a numerical value is supplied. The naming of constants appears in the listing in the same format as the operational statements written previously. Starting in column 7 write CON; then, starting in column 15, write the names assigned to these constants. This format is illustrated below.



If the number of constants used in a problem is six or less, one constant card is used. If more than six constants are used, additional constant cards are required. Each constant card, with the exception of the last constant card, must contain six constants; the last card may contain less than six. Unlike previous versions of MIDAS, it is not allowed to have several cards with less than six constants.

Considerable latitude exists in the naming of a constant, but there are three general rules that must be followed:

1. A maximum of six alphanumeric characters may be used.
2. Blanks and commas must not be used.
3. Constants must not have the same name as a component used elsewhere in the problem. For example, if a multiplier is named M3, the problem must not contain a constant named M3.

It was stated that constants appear twice in MIDAS programs. The second place is on data dards which are submitted for the execution phase. These data cards are prepared in a different format from that previously described. First, except for plot title cards described later, they contain only numerical information. They have provisions for six numbers corresponding to the six constants named on a CON card. Second, the location of the numbers on the data card must be confined within columns 1-10, 11-20, 21-30, 31-40, 41-50, 51-60. The order in which these numbers appear on the data card must agree with the order of the names in the corresponding CON card. Finally, the numbers must be written in a form amenable to floating point operations, i.e., a number of decimal digits with a decimal point at the beginning, at the end, or between digits. A preceding + sign is optional. A decimal exponent preceded by an E may follow a floating point constant.

An example of coding the constants associated with the mass-spring-damper system follows.

Assuming M = 36.846, B = .105, and K = 1039.4, the first data card for the execution phase would appear as:

```
PROGRAM NAME MIDAS          PROGRAMMER          EXT
1 36.846     -.105      -1.0394  E3
2
```

Note that if the E format is used, the exponent field has to be right justified.

The important points to remember are:

1. The constants defined on the first CON card must be given numerical values on the first data card (vertical correspondence).
2. The order of the numbers on the data card must be the same as that given on the CON card (horizontal correspondence).
3. A decimal point must appear in each number given on the data card.

Initial Conditions. MIDAS is organized so that all integrators will start each run with zero output unless otherwise directed. The means for directing non-zero starting values is the IC (Initial Condition) card. The IC card is similar to the CON card. Assuming that integrator I2 in the mass-spring problem should have an initial condition of 20, the coding in the source program would appear as:

```
PROGRAM NAME MIDAS          PROGRAMMER          EXT
1        IC        I2
2
```

During the execution phase, a properly placed data card with a 20 in columns 1 through 10 would set that numerical value as the initial condition for integrator 2.

In MIDAS III, all the constants are defined at the beginning of the program, followed by the IC cards, followed by the body of the program.

ARBITRARY FUNCTIONS

MIDAS provides the means for handling arbitrary functions of a single variable. The x, y coordinates of the function are entered with data cards, three points to a card.

Unequal size of the increments of the independent variable is permitted; however, the data must be presented in order of algebraically increasing values of the independent variable of the function. Furthermore, a data card that states the number of points (N) in the function must immediately precede the cards containing the x, y coordinates.

```
PROGRAM NAME MIDAS     PROGRAMMER          EXT    LOC    DATE
1 N
2 X1        Y1        X2        Y2        X3        Y3
3 X4        Y4        X5        Y5        X6        Y6
4
```

As an example consider the following function data:

x	y
0	8.33
30	4.0
60	1.6
120	5.2
150	5.2
180	6.6
210	8.3
240	10.7
270	16.0
282	21.0
294	28.0
306	41.0
312	50.0
324	90.0

Since 14 points are defined, the first data card will contain only the number 14.0. Subsequent cards (5 of them) will contain the x, y coordinates as shown below.

```
PROGRAM NAME MIDAS     PROGRAMMER          EXT    LOC    DATE
1 14.0
2 0.        8.33      30.0      4.0       60.       1.6
3 120.      5.2       150.      5.2       180.      6.6
4 210.      8.3       240.      10.7      270.      16.0
5 282.      21.0      294.      28.       306.      41.
6 312.      50.0      324.      90.
7
8
9
```

MIDAS provides two interpolative schemes for computing the function, the first being linear and the second quadratic. Linear interpolation yields the same fit as an ideal diode function generator on an analog computer, while the quadratic interpolation yields a better approximation to a curve follower. The maximum number of points permitted in a function generator is 45. The name for a function generator with linear interpolation is G, for quadratic interpolation it is CG.

One remaining question in the use of function generators is the location of the associated data cards. Using the coding shown below as an example, assume that L(x), represented by 7 points, is the function on G2, and M(y), represented by 5 points, is the function of CG1. Under such conditions, the arrangement of data cards would be approximately as shown in Table 4-1, with the exception that all the entries would be numerical values in floating point form.

```
PROGRAM NAME MIDAS
1      CØN       A, B, C, D, E, F
2      CØN       G, H
3      IC        I3, I4
4      G2        S1
5      CG1       H2
```

One final point regarding the function generators is that in the undefined regions of the functions, i.e., less than the lowest tabulated value of the abscissa and greater than the highest, the function will have zero slope. Stated another way, in these undefined regions the ordinate will have a constant value equal to the first and last tabulated values.

FINISH, READOUT, AND HEADER STATEMENTS

<u>Finish Statements</u>. An analog computer operator will usually terminate a run based on graphical outputs of the problem's solution. In the case of the digital computer, since the operator cannot very easily determine where in the solution the machine is at any moment, some means must be provided to terminate a run automatically. MIDAS provides this means through the use of one or more finish (FIN) statements, any one of which when satisfied will terminate a run.

Table 4-1. Arrangement of Data Cards

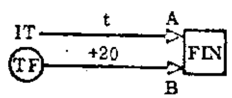
CARD NO.		CARD COLUMN 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60
1	CØN	A	B	C	D	E	F
2	CØN	G	H				
3	IC	IC I3	IC I4				
4	G2	7.0					
5	G2	x_1	$L(x_1)$	x_2	$L(x_2)$	x_3	$L(x_3)$
6	G2	x_4	$L(x_4)$	x_5	$L(x_5)$	x_6	$L(x_6)$
7	G2	x_7	$L(x_7)$				
8	CG1	5.0					
9	CG1	y_1	$M(y_1)$	y_2	$M(y_2)$	y_3	$M(y_3)$
10	CG1	y_4	$M(y_4)$	y_5	$M(y_5)$		

A FIN statement in the symbolic program appears as a component such as a multiplier, or divider. It has two inputs, A and B, and will cause a run to end when A ≥ B. However, the FIN "component" does not require a number. At least one FIN statement must be written in a program, although any number of them may be provided.

The end of a run can be based on many different considerations. One very common one is the fact that the independent variable, usually time, has reached some prescribed value. Often the fact that a dependent variable has reached some significant value will be the signal for a run to end. There is no requirement that either of the two inputs to a FIN statement be a constant. When both are variables, the run ends when the first named input is equal to or algebraically exceeds the second.

Since it has been mentioned that a much-used basis for terminating a run is the fact that the independent variable has reached some prescribed value, it should be pointed out at this time that there is available, without any explicit programming, a running measure of the independent variable. It is called for simply by specifying IT.

To illustrate this, consider that it is desired to end a run when t reaches some final time, $t_f = 20$ seconds. The block diagram notation for this would appear as shown below.



The listing for this diagram is shown below.

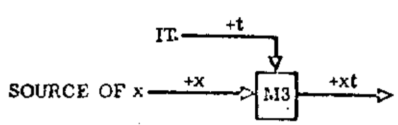
```
PROGRAM NAME MIDAS
1      FIN       IT, TF
2
```

The order of the inputs to a FIN statement is all-important. In the example above if the order of inputs were reversed, that is:

```
PROGRAM NAME MIDAS
1      FIN       TF, IT        INCORRECT FORMAT EXAMPLE
2
```

the solution would never start since TF is greater than IT (which starts at zero) from the beginning.

The quantity IT is used anytime the independent variable is required; it is not limited for use only in connection with FIN statements. For example, if the quantity xt is required the block diagram representation would be as shown below.



Readout Statements. With the readout statement, the programmer tells the MIDAS program which variables have to be printed. Not more than 100 variables in a problem can be printed at a time. The programmer may specify the elements he want printed out by writing statements in the following form:

```
PROGRAM NAME MIDAS
1      RØ        IT, S2, M3, 12, D1, RES3B
2
```

No more than six elements may be specified for each readout statement. If more t six variables are to be read out, only the last RO statement may contain less than variables. Starting a readout statement with a comma in column 15 is not allowed. is, however, all right to have the same variable read out more than once. For inst the following sequence of RO statements is permissible.

```
PROGRAM NAME MIDAS
1      RØ        IT, S2, M3, 12, D1, RES3B
2      RØ        IT, I4, S5, G7, RES2B, I7
3      RØ        IT, D6, AG1C
4
```

Unless otherwise directed, MIDAS will print out at intervals of 0.1 of the independe variable. However, the programmer may specify any readout interval by naming o of the constants TR (time between readouts) on a CON card, and by specifying a numerical value for TR on a data card. The name TR must not be used for the nam of any other constant.

Header Statements. To aid in the interpretation of the printed out data, provision exists for specifying titles in front of each variable on the printout. This method of labelling the output is preferable to the practice formerly used of printing the heade only once at the top of the page. Variables are now easily identified. These header will be the names given to the quantities called for in the RO statements. These nar may use any of the characters available on the keypunch up to a maximum of six, an they must be listed in the same order, horizontally and vertically, as the correspon ing elements in the RO statements. There must be a one-to-one correspondence between RO and HDR statements. Header statements appropriate to the readout list given in the previous section are:

```
HDR    TIME,X2DØT,XSG,XDØT,YØVERZ,SINY
HDR    TIME,Y,Y+X,F(Y),SINX,Z
HDR    TIME,Y/2X,BAND C
```

PLOTTING WITH MIDAS

An important feature of MIDAS is that results can be automatically plotted on a CALCOMP plotter. This feature was originally added by North American Aviation. The basic philosophy of the plotting capability has been carried over. Summarized, the rules for plotting are:

1. Up to 12 variables can be used for plotting.
2. Points are plotted only at printout times.
3. If 250 points of each plotting variable are accumulated, a plot is made. The plot will be scaled according to the maxima and minima found in these 250 points.
4. If a complete plot consists of more than 250 points, the scaling for the different frames will probably be different.
5. Each variable can be plotted versus each other variable, thus allowing for phase-plane-type plots.

There are two rules for programming the plotter: 1) the MIDAS program must contain statements indicating which variables are to be plotted, and 2) the data cards, which are used during the execution phase, must contain cards describing how many plots are desired, how many plots per frame, and which variables will be plotted as a function of the other variables and appropriate title cards. The following example illustrates these rules for plotter programming.

Assume the output of integrator I3 represents a displacement and the output of integrator I2 represents a velocity. In order to plot both velocity and displacement as a function of time, and also to construct a phase-plane plot, the plot statement in the MIDAS program would be as:

```
PLØT    IT,I2,I3
```

This PLOT card should appear in the MIDAS program between the FIN statements and the END card, preceding or following the RO cards. During the execution phase, plot control and title cards must be placed after the data cards containing the numerical data for a solution.

The first plot control card indicates the number of plots to be made (not counting continuations resulting from the use of more than 250 points), the number of plots per frame, and the reference number of the items to be plotted. Symbols listed on the first PLOT card are referred to as 01 through 06 in order of their listing. The second card, if used, continues with 07 through 12.

Beginning in column 1, the first two columns are used to record the number of plots, the next two for plots per frame (01, 02, or 03), the next two for the reference number of the first X variable, the next two for the first Y variable reference number, and so on for the second and subsequent plots. Four columns per plot are required plus the initial four columns. Twenty-five kinds of plots per run are allowed. If more than 19 plots are required, more than one plot control card is needed. The second card continues in column 1 with the information for the 20th plot. (The plot control card uses all 80 columns for listing plot references.)

Title cards use the first 35 columns for the X title and the second 36 for the Y title. Every plot must have a title. For two plots per frame, Y titles should be limited to 32 characters; for three per frame, 22 characters, starting at or near column 37.

The plot control card for the above examples is coded as:

```
PROGRAM NAME MIDAS          PROGRAMMER          EXT
1 030101020103030 2
2
3
```

In this example:

- 03 = three plots are required
- 01 = one plot per frame is requested
- 0102 = the first plot shall plot item 2 (I2) versus item 1 (time)
- 0103 = the second plot shall plot item 3 (I3) versus item 1 (time)
- 0302 = the third plot shall plot item 2 (I2) versus item 3 (I3)

The plot control card must be followed by as many title cards as there are plots requested. These three title cards are as follows:

```
PROGRAM NAME MIDAS     PROGRAMMER     EXT     LOC     DATE
                    TIME                              VELØCITY
                    TIME                              DISPLACEMENT
                    DISPLACEMENT                      VELØCITY
```

Examples of plotting results are included in Appendix A.

SECTION 5

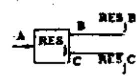
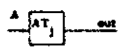
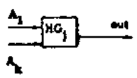
DESCRIPTION OF MIDAS OPERATIONAL ELEMENTS

Operational elements presently available in MIDAS are described in the following table. A special computational element, the FORTRAN Black Box, is discussed separately at the end of this section.

Table 5-1. Operational Elements

OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
A. MATHEMATICAL OPERATIONS			
INTEGRATE	A → [I_j] → out (IC)	$Out = \int_0^t A dt + IC$	1. Only one input can be accepted. 2. The initial condition, IC, is transmitted via an IC card and its corresponding data card.
SUM	$A_1, A_2, \ldots, A_k$ → [S_j] → out	$Out = \sum_{i=1}^{k} Ai$ $2 \le k \le 6$	A summer must have at least two inputs
NEGATIVE	A → [NEG_j] → out	$Out = -A$	
MULTIPLY	A, B → [M_j] → out	$Out = A \times B$	
DIVIDE	A, B → [D_j] → out	$Out = A/B$	The order of listing the inputs is very important. The numerator, A, must be listed first.
ABSOLUTE VALUE	A → [ABS_j] → out	$Out = \|A\|$	
SQUARE ROOT	A → [SQR_j or SQ_j] → out	$Out = +\sqrt{A}$	1. Defined only for A ≥ 0 2. Both names SQ_j or SQR_j are allowed, but refer to the same element always with the same name
EXPONENTIAL	A → [E_j] → out	$Out = e^A$	
NATURAL LOGARITHM	A → [LN_j] → out	$Out = \ln A$	Defined only for A > 0

Table 5-1. Operational Elements (Contd)

OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
RESOLVER (sin & cos)		B out = sin A C out = cos A	1. Input angle, A, must be in radians. 2. Since there are two outputs, these must be specified as $RES_j B$ or $RES_j C$ depending on whether the sine or cosine is required. 3. j can be a one or two digit number only.
ARC TANGENT		$Out = \tan^{-1} A$	1. Output is an angle in radians. 2. Defined only for the 1st and 4th quadrants, i.e., $-\pi/2 < out < \pi/2$
HIGH GAIN AMPLIFIER		$Out = \dfrac{\sum_{i=0}^{k} A_i}{A_1}$	$2 < k \le 6$

B. SWITCHING ELEMENTS

SPECIAL NOTE: Since all of these elements have more than one input, the listing of inputs must be in the normal order of A, B, C.

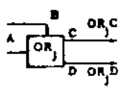
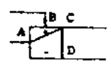
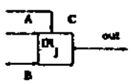
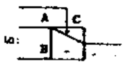
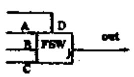
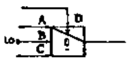
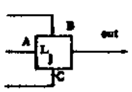
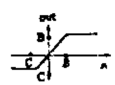
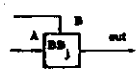
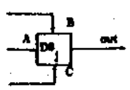
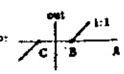
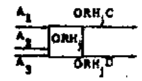
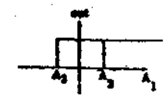
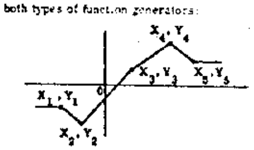
OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
OUTPUT RELAY		(B>0 / B≤0): C out = A / 0; D out = 0 / A	Equivalent to: 
INPUT RELAY (SPDT)		$out = \begin{cases} A & C > 0 \\ B & C \le 0 \end{cases}$	Equivalent to: 
FUNCTION SWITCH (SP3T)		$out = \begin{cases} A & D > 0 \\ B & D = 0 \\ C & D < 0 \end{cases}$	Equivalent to: 
LIMITER		$out = \begin{cases} B & A > B \\ A & C \le A \le B \\ C & A < C \end{cases}$	Equivalent to:  B > C
BANG-BANG		$out = \begin{cases} +B & A > 0 \\ -B & A \le 0 \end{cases}$	Equivalent to: 
DEAD SPACE		$out = \begin{cases} A-B & A > B \\ 0 & C \le A \le B \\ A-C & A < C \end{cases}$	Equivalent to:  B > C

Table 5-1. Operational Elements (Contd)

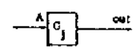
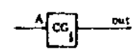
OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
OUTPUT RELAY WITH HYSTERESIS		Initial states if $A_1 \ge A_2$ $ORH_j C = 1$ $ORH_j D = 0$ Initial states if $A_1 < A_2$ $ORH_j C = 0$ $ORH_j D = 1$ Subsequent behavior if $A_1 \le A_3$ $ORH_j C = 1$ $ORH_j D = 0$ Subsequent behavior if $A_1 \ge A_2$ $ORH_j C = 0$ $ORH_j D = 1$ $ORH_j C$ and $ORH_j D$ remain unchanged from previous value if $A_2 > A_1 > A_3$	 SPECIAL NOTE: C and D = 0 if $A_3 < A_1 < A_2$ initial. This does not apply for subsequent runs on a multiple-case pass.

C. ARBITRARY FUNCTIONS

For both types of function generators:



1. Up to 45 sets of x-y coordinates can be used.
2. Spacing of breakpoints is arbitrary.
3. Slope of the function is zero above and below the set of specified points.
4. Method of introducing data is in the text.

OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
FUNCTION (LINEAR INTERPOLATION)		Out = f(A)	1. Linear interpolation. 2. Data needed for every run.
FUNCTION (QUADRATIC INTERPOLATION)		Out = f(A)	1. Quadratic interpolation. 2. Data needed for every run.

D. LOGICAL ELEMENTS

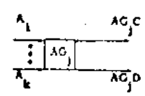
OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
AND GATE	 $3 \le k \le 6$	If all A_i (i = 1 ... k) are > 0 $out = AG_j C = 1$, $AG_j D = 0$ If any A_i (i = 1 ... k) is ≤ 0 $out = AG_j C = 0$, $AG_j D = 1$	

Table 5-1. Operational Elements (Contd)

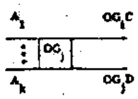
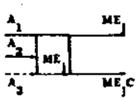
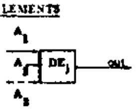
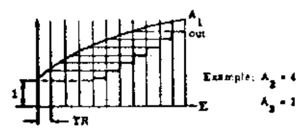
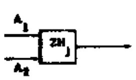
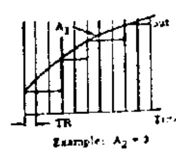
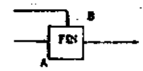
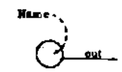
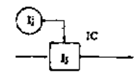
OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
OR GATE	 $1 \le k \le 8$	If any A_i ($i = 1 \ldots k$) is > 0 out = $OG_jC = 1$, $OG_jD = 0$ If all A_i ($i = 1 \ldots k$) are ≤ 0 out = $OG_jC = 0$, $OG_jD = 1$	
MEMORY ELEMENT (FLIP FLOP)		Initial state if no A_3 specified $ME_j = 1$ $ME_jC = 0$ Initial state if any A_3 specified $ME_j = 0$ $ME_jC = 1$ Subsequent state if $A_1 > 0$ and $A_2 \le 0$ out = $ME_j = 1$, $ME_jC = 0$ Subsequent state if $A_1 \le 0$ and $A_2 > 0$ out = $ME_j = 0$, $ME_jC = 1$ out = unchanged otherwise	The Memory element changes its state only at printout and is switched before the printout occurs.
E. DELAY AND HOLD ELEMENTS			
DELAY		Out = A_1	 1. Delayed by A_2 printout intervals. 2. A_3 specifies the initial condition. If no A_3 specified, initial condition assumed to be zero. 3. The delay element keeps the output constant during printout intervals.
ZERO ORDER HOLD		Out = A_1	1. Sampled and hold for A_2 printout intervals. 2. The change in the output of the hold element occurs before the printout. 

Table 5-1. Operational Elements (Contd)

OPERATION	SYMBOL & NAME	OUTPUT	REMARKS
F. RUN TERMINATION			
FINISH		None	1. When A ≥ B, computation is stopped. 2. Every program must contain at least one FIN statement. 3. Numbering of FIN statement, [illegible] required.
G. INSERTION OF NUMERICAL ITEMS			
CONSTANT or PARAMETER		Per Data Card	1. The name of a constant or parameter can be composed of at most six alphanumeric symbols excluding blanks and commas. 2. The names must not be the same as that of a functional element used in the problem. 3. The name will appear on a CON card and its numerical value on a data card. 4. Do not use these special names: IT, TR, MININT, OPTION.
INITIAL CONDITION		$I_j(0)$	1. The name must be the same as the integrator with which it is associated. 2. The name must appear on an IC card and its value on a data card 3. Only non-zero IC's need be specified.
H. SPECIAL STATEMENTS			
HEADER	HDR	None	Contents of the HDR statements are used to label the printed variables.
READOUT	RO	None	Specifies the sources of the variables to be recorded for each run.
END	END	None	Signifies the end of the MIDAS language program.
I. SPECIAL NAMES			
INDEPENDENT VARIABLE	IT	Independent Variable	1. Gives the current value of the independent variable in the appropriate units. 2. Generated internally, this variable can be obtained by specifying its source as IT.
TIME BETWEEN READOUTS	TR	None	1. When listed on a CON card, TR gives the increment of the independent variable, usually time, between successive readouts. 2. If no value of TR is given, a [illegible] value of 0.1 units will be used.
MINIMUM INTERVAL OF INTEGRATION	MININT	None	1. When listed on a CON card, MININT specifies the smallest interval [illegible] integration system is permitted [illegible] 2. If no value of MININT is given, a value of ZERO is used.
INTEGRATION OPTION	OPTIONj	None	When an integration method [illegible] criterion other than the [illegible] desired, call for OPTIONj [illegible] 1-7 somewhere within the MIDAS program (before the end card).

THE FORTRAN BLACK BOX

Since MIDAS is being used more and more as a general tool to solve the differential equations of dynamic and control problems, the problem frequently requires something done for which no MIDAS element is available or, if it can be done by interconnection of MIDAS elements, the program becomes clumsy. Examples of this type of problem are the computation of some higher functions like Bessel functions and the generation of additional operational elements.

In MIDAS III, a special computational element called FORTRAN Black Box greatly simplifies problem solving. Appearing in the block diagram as

the FORTRAN Black Box generates a call to a FORTRAN Function Subroutine. For each FORTRAN Black Box appearing in the MIDAS source program, a FORTRAN function subroutine FBBj must be written.

Rules for the use of the FORTRAN Black Box are shown in the following examples.

Example 1: Computation of Bessel Functions. In this example, it is assumed that Bessel is a library function subroutine with two arguments, the first being the argument for the Bessel function, the second one being the order.

The output of this FORTRAN Black Box is

$$out = J_0(A_1) + J_1(A_2)$$

where

J_0 and J_1 are Bessel functions

The FORTRAN subroutine will be

```
FUNCTION       FBB7 (A)
DIMENSION      A(2)
FBB7 = Bessel [A(1), 0.] + Bessel [A(2), 1.]
RETURN
END
```

Summarized, the rules for FBB routines are:

Title: FUNCTION FBBJ (ARG)

where ARG is an array with a maximum of six elements.

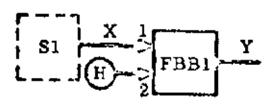
ARG(1) refers to A_1 in the MIDAS Block diagram
ARG(6) refers to A_6 in the MIDAS Block diagram.

If more than one ARG is used for a FBB, ARG has to appear in a DIMENSION statement.

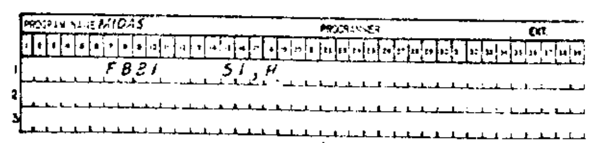
The name of the function has to appear on the left of at least one equal sign, that statement (or these statements) define the value of the output of an FBB.

Example 2: Generation of Additional Operational Elements. Another example of the use of FORTRAN Black Box is the addition of an operational element such as a hysteresis or backlash loop. An idealized hysteresis loop is shown in Figure 5-1.

The block diagram for the loop would be:



The coding for the first pass would appear as:



A FORTRAN program will be generated in the precompiler phase that has

AIN(1) = VAR9
AIN(2) = CØN4
VAR12 = FBB1(AIN)

where

VAR9 = S1
CØN4 = H

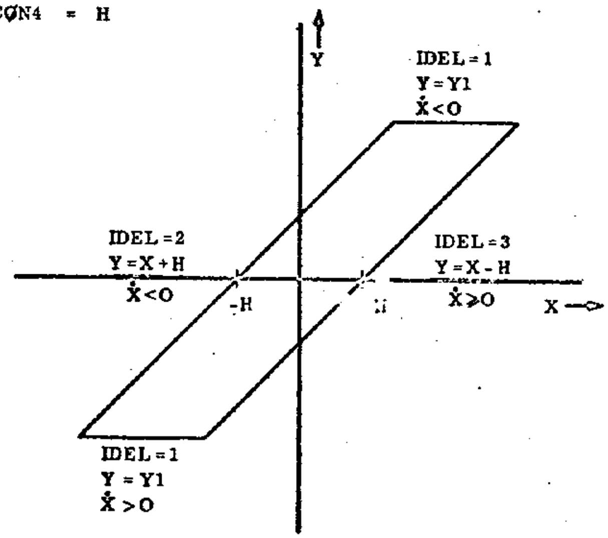


Figure 5-1. Idealized Hysteresis Loop Using FBBj

The coding for example FBBj is shown in Figure 5-2. The loop is initialized at zero and will work for stacked cases through the use of IFIN which is generated in all DERIV decks. The insertion of the coding for FORTRAN Black Boxes is illustrated in Figure 7-4.


```
//LEDPT.SYSIN DD *
//    DD
      FUNCTIØN FBB1(A)
      CØMMØN INPRD,NEQ,IØUT,ITEST,IFIN,IØPT,IR,HMIN,IPL,XPLØT
      DIMENSIØN A(2)
      IF(IFIN-1) 200,100,200
200   CØNTINUE
      IF(IDEL)5,5,10
5     X1=0.0
      Y1=0.0
      IDEL=1
10    GØ TØ (11,21,23),IDEL
11    IDEL=1
      Y=Y1
      DEL=Y-A(1)
      IF(DEL-A(2)) 22,21,21
22    IF(DEL+A(2)) 23,24,24
21    IDEL=2
      Y=A(1)+A(2)
      IF(A(1)-X1) 24,24,11
23    IDEL=3
      Y=A(1)-A(2)
      IF(A(1)-X1) 11,24,24
24    CØNTINUE
      X1=A(1)
      Y1=Y
      FBB1=Y
      RETURN
100   IDEL=0
      RETURN
      END
/*
```

Figure 5-2. FORTRAN IV-G Compiler Phase Coding for FBBj

SECTION 6

INTEGRATION SYSTEM IN MIDAS

MIDAS uses a variable step size Runge-Kutta-Merson integration routine, which is described in Reference 3. MIDAS also uses an option with a constant step size. It is a slightly modified version of the subroutine DIFE3, which is described in Reference 4.

ERROR CRITERIA

A mixture of absolute and relative error criteria is used. The step size is reduced whenever

$$\frac{|e_i|}{|y_i| + |\dot{y}_i \cdot h_i| + 1} \qquad i = 1, 2, \cdots, NEQ$$

is greater than a certain tolerance for any i.

e_i = estimated local truncation error in the i^{th} differential equation

y_i = i^{th} dependent integration variable

$\dot{y}_i$ = derivative of the i^{th} integration variable

SELECTION OF MINIMUM INTERVAL (MININT)

While it is not possible to give specific rules for the selection of MININT, there are certain guidelines that should be followed.

1. Use the built-in value MININT = 0 for the first trial run unless it is obvious that the switching elements in the problem will cause step changes in derivative terms that are to be integrated.

2. When a non-zero value of MININT is required, try MININT = 10^{-4} TR. Basing the selection on TR automatically adjusts MININT to suit the frequency content of the problem since a high frequency term will select a small TR, and the value of MININT will then be correspondingly small.

3. Check the selection of MININT by making another run at one tenth the previous value. If the results agree well enough, neither choice inhibited the integration routine to any appreciable extent. If the results differ significantly, a still lower value of MININT is required.

4. Use the largest value of MININT that gives satisfactory results, thereby minimizing the computer time requirements.

UPPER LIMIT ON STEP SIZE (MAXIMUM INTERVAL)

The upper limit on step size is determined by the programmer's selection of the read-out interval, TR. This occurs because the first trial value of step size is TR/4. If the error criterion is satisfied, the solution proceeds. It is conceivable, therefore, that a certain amount of variation of results -- all falling within the limits of the error criterion -- can occur. Normally, this is a second order effect, but it is mentioned in advance to explain any slight differences in numerical results obtained when different TR's are specified.

LOWER LIMIT ON STEP SIZE (MINIMUM INTERVAL)

Normally, the integration routine has no lower limit on step size; or, if you will, it has a minimum interval of zero. Thus, it will continue to halve its step size until the error criterion is satisfied. This is usually a fast, efficient, and accurate process but it can lead to trouble in those MIDAS problems involving switching elements such as input relays, output relays, and bang-bang elements.

As an example of such a situation, consider the third sample problem, the Pilot Ejection Study. In this problem, output relays are used at the inputs to two of the integrators, and the conditions at the instant of switching give a step change in the derivative terms feeding the integrators, quite a common type of occurrence in many problems.

This discontinuity in the derivative will cause a large truncation error. Under these conditions the program will automatically reduce the step size and eventually have such a small step size that switching occurs practically at the beginning of an integration step. In cases like this, a one-step Runge-Kutta method has a great advantage over predictor-corrector methods, because it does not make use of past values.

For a stepwise discontinuity, such as described here, an extremely small step size will be required to satisfy the error criterion required. Also, it is possible that the program would keep halving the interval until the step size was reduced below the smallest number represented in the computer and a diagnostic would be printed.

The MIDAS programmer can overcome this difficulty by specifying some minimum interval below which the integration routine is not allowed to go. This is accomplished by naming one of his constants MININT (for MINimum INTerval) on a CØN card and giving the desired value on a data card(s). Encountering a step-wise discontinuity at the input of an integrator will no longer cause the integration process to "hang up" at this point. It cuts the interval as low as you let it, then it goes on.

The fact that the integration routine tries to reduce the step size below the minimum interval means that the program can not satisfy the error criterion at that particular point. It is important that the programmer knows when and where this occurs, and a printout with the following form is provided.

```
PROGRAM TRIED TO REDUCE THE STEP SIZE BELOW MININT
ERROR IN EQUATION ··· WAS TOO LARGE, ERROR = ....
RELATIVE ERROR = ····, Y = ····, T = ····
```

<u>The Different Integration Options</u>. Three basic different integration options for variable step size are available. Although these options use the same error-criterion, namely:

$$\frac{|e_i|}{|y_i| + |h \cdot \dot{y}_i| + 1} < EPS$$

each integration option uses a different value for EPS.

Option 0, the standard option, uses EPS = 0.5×10^{-5}. This gives approximately five figures of accuracy for a single integration step, the accumulated error, of course, decreases the overall accuracy. There is no easy and reliable method to even estimate the accuracy after many integration steps.

Option 1 is used where an extremely high accuracy is desired. For instance Option 1 would be used for standard runs that would be used for comparison with other runs. Using a value of EPS = 0.5×10^{-7}, it gives about the highest accuracy obtainable and requires, therefore, the longest running times.

Option 2 should be used only in special cases. It has an EPS = 0.5×10^{-3}, which means that the result of one single step is correct only to three digits. The solution after many integration steps may be quite inaccurate.

Options 3, 4, and 5 give the same accuracy as options 0, 1, and 2; they differ from the first three options in that step size changes are printed out. In many cases, this gives a clue to which integrators in the problem require a small step size. It is also the only way to find out the actual integration step size used by the program.

If no option is specified in the MIDAS source program, the program will chose the standard option (Option 0). If a different option is desired, it is necessary to include a statement in the MIDAS source program having the word ØPTIØNJ in columns 1 through 7. Do not leave a blank between the word ØPTIØN and the number specifying the option.

<u>Summary of Integration Options</u>. The different integration options are summarized in the following table.

Table 6-1. Summary of MIDAS Integration

Integration Method:	Runge-Kutta-Merson (Fourth order, one step method)
Error Criterion:	$\frac{\lvert e_i \rvert}{\lvert y_i \rvert + \lvert h \dot{y}_i \rvert + 1} < EPS$ EPS = 0.5×10^{-5} for standard option
Step Size:	Automatically adjusted (or constant if option 6 is used, then the step size is equal to TR/4).
Maximum Step Size:	TR/4.
Minimum Step Size:	MININT = 0 unless otherwise specified.

OPTION	EPS VALUE	REMARKS
0 (Standard)	0.5×10^{-5}	Step size changes not printed.
1	0.5×10^{-7}	Step size changes not printed.
2	0.5×10^{-3}	Step size changes not printed.
3	0.5×10^{-5}	Step size changes are printed.
4	0.5×10^{-7}	Step size changes are printed.
5	0.5×10^{-3}	Step size changes are printed.
6	--	Uses a constant step size = TR/4.

SECTION 7

OPERATING INSTRUCTIONS

MIDAS is a four phase program; separate phases are required to get a solution for a problem. Phase 1, the precompiler phase, translates the MIDAS program into a FORTRAN source subroutine and outputs it on disk (or punched cards). Phase 2 compiles this subroutine, using the FORTRAN IV-G compiler, into machine language which is used by phase 3. Phase 3 is a Link Edit which combines the subroutine output by phase 2 with MIDAS library subroutines to produce an executable machine language program (load module). Phase 4, the final phase, then loads and executes the program using the numerical data and plot control information submitted with it.

The following operating instructions apply to running the program on the IBM 360 and the CALCOMP plotter as set up at Naval Ordnance Laboratory, Corona.

GENERAL FORMAT OF CODING SHEET

The general format is shown in Figures 7-1 and 7-2. The first part of the format (7-1) is the MIDAS program and is used for the precompiler phase, phase 1. The second part of the format (7-2) for the numerical data (in a 6E10.4 field) is used in the program execution phase, phase 4. The cards with names starting in column 1 (constants, initial conditions, etc.) are comment cards and are not essential to the running of the program; two of many methods of coding the comment cards are shown. Further program examples are shown in the sample problems in Appendix A.

Numerical data for a run with three different cases are shown for illustration. (See Figures 7-1 and 7-2.)

Case 1. M = 10., Stop = 5., -B = -2.5, -K = -S.6. The initial condition for I2 = 20.

Four different plots were requested. Acceleration, velocity and displacement versus time and a phase plane plot.

Case 2. M = 10, Stop = 5, -B = -3.6, -K = -S.3. The initial condition for I2 = 20.

Two different plots were required. Velocity and displacement versus time (2 plots per frame).

4

```
XX     TITLE
C      CØNSTANTS
       CØN       M,STØP,-B,-K,TR
INITIAL CØNDITIØNS
       IC        I2
PRØGRAM
       S1        M1,M2
       D1        S1,M
       I1        D1
       I2        I1
       M1        -B,I1
       M2        I2,-K
ØPTIØN3
FINISH STATEMENT
       FIN       IT,STØP
READØUT
       RØ        IT,D1,I1,I2
HEADER
       HDR       TIME,ACC.,VEL.,DISP.
PLØT STATEMENT
       PLØT      IT,D1,I1,I2
END STATEMENT
       END
```

Figure 7-1. MIDAS Coding for Phase 1

```
CASE 1  10.        5.        -2.5       -8.6         .1
        20.
        040101020103010404 03
                 TIME                              ACCELERATIØN
                 TIME                              VELØCITY
                 TIME                              DISPLACEMENT
                 DISPLACEMENT                      VELØCITY
CASE 2  10.        5.        -3.2       -8.6
        2.     E+1
        0202010301 04
                 TIME                              VELØCITY
                 TIME                              DISPLACEMENT
CASE 3  10.        5.        -2.5       -15.

        20.
        00
```

Figure 7-2. MIDAS Coding for Phase 4

Case 3. **M = 10, Stop = 5, -B = -2.5, -K = -15. The initial condition for I2 = 20.**

No plots were required for case 3.

RESTRICTIONS IN THIS MIDAS AND DIFFERENCES FROM OTHER VERSIONS

Restrictions in the size of the MIDAS source program are included in Table 7-1.

Table 7-1. MIDAS Source Deck Restrictions

ITEM	MAXIMUM NO.
Operational Elements	1000
Symbols (operational elements + constants + header names)	1200
Integrators	100
Function Generators	40
Points per function generator	45
Output variables	100
Delay elements	10
Delay time (increments)	100
Constants	250
Variables that can be plotted	12
Points per frame	250
Different plots per case	25

Important differences between this MIDAS and earlier versions of MIDAS are defined below.

1. COMMENTS. With the exception of the card OPTIONj, the source program considers any card with a character in column 1 a comment card. It does not allow for comments on a program card. It does allow embedded blanks in the field describing the inputs.

2. OUTPUT OF LOGICAL ELEMENTS. All logical elements have two outputs, the true and the complement.

TRUE = +1.0

FALSE = 0.0

Note the difference from the North American version, where a FALSE=-1.0.

3. IMPLICIT FUNCTIONS. The implicit function has not yet been incorporated. As a consequence, no closed loops are allowed without an integrator in the loop. If such an algebraic loop is included, the program will not compile on the first pass. See Reference 1 for a description of the implicit function.

4. MULTIPLE RUNS. Multiple runs (several runs of the same problem with different parameters) one allowed. For each run, the complete set of numerical data (constants, initial conditions, function generators, plot control and title cards) must be submitted.

5. CON, IC, RO, AND HDR CARDS. With exception of the last card of each type, all these cards must contain six items.

6. ORDER OF THE SOURCE PROGRAM STATEMENTS. The following ordering of the source program is required:

CON cards
IC cards
Actual program
RO cards
HRD cards
PLOT cards
END card

The OPTION card may be placed anywhere in the actual program. The actual program is still sorted by the MIDAS program.

7. INTEGRATION ROUTINE. The Runge-Kutta routine replaces the predictor-corrector method of the earlier versions.

8. SORTING. The sorting routine utilized in the Convair version of MIDAS sorts faster and gives more useful diagnostics about missing elements and closed loops than did earlier versions.

9. MAXIMA AND MINIMA. The list of the maximum and minimum values of each variable are not printed out in MIDAS.

MIDAS DECK SET UP

The deck set up for MIDAS is shown in Figure 7-3.

PLOTTING. When the run request indicates plotting is to be done, PLOTTAPE from unit 183 will be routed to the CALCOMP plotter and plots will be made. After the tape is run, it will be released for re-use unless it has been indicated that the tape should be saved.

PLOT CONTROL CARD. The plot control card is required whether or not plots are required. If no plots are required, use a blank card, in which case no title cards are needed. When multiple runs are being processed, each data deck must end with a plot control card and be followed by title cards (if plot control card not blank). This allows different plotting for each run of multiple runs.

MIDAS FORTRAN SOURCE. The MIDAS FORTRAN source is passed from the MIDAS precompile to the FORTRAN compiler. Ordinarily it is then deleted, but this may be overriden and the FORTRAN may be kept. If special computation element FBBj (the FORTRAN Black Box) is used in the MIDAS source program, the FORTRAN cards for the subroutin which have been coded and keypunched by the programmer must be inserted as shown in Figure 7-4.

SUBSEQUENT RUNS. When a program has been successfully developed, the appropriate machine executable load module may be substituted for subsequent runs, thus saving compilation time.

RUNNING TIME. Running time is a function of the size of the program. During the execution phase, minimum step size and truncation error criterion are the determining factors. Although no rule of thumb has been devised to predict the actual running time, all computer operating times are indicated in the sample problems shown in Appendix A.

FORTRAN Coding Form

PROGRAM MIDAS

```
//jobname JOB account.number-code,programmer.name
//        EXEC MIDAS
//MIDAS.SYSIN DD *
     {               { TITLE CARD
     { MIDAS         { CON   CARDS
     {               { IC    CARDS
     { PROGRAM       { ACTUAL PROGRAM
     {               { RO    CARDS
     { DECK          { HDR   CARDS
     {               { PLOT  CARDS
     {               { END   CARD
/*
//EXEC.SYSIN  DD *
     {               { CON  DATA CARDS
     { DATA          { IC   DATA CARDS
     {               { FUNCTION DATA CARDS
     { DECK          { PLOT CONTROL CARDS
     {               { PLOT TITLE CARDS
     { ADDITIONAL
     { DATA DECKS
     {     FOR
     { MULTIPLE RUNS
/*
```

Figure 7-3. MIDAS Deck Set up

FORTRAN Coding Form

MIDAS

```
//jobname   JOB   accountno,programmername
//          EXEC MIDAS
//MIDAS.SYSIN DD *
          { (MIDAS PROGRAM
          {      DECK)
/*                          - - - - - - -
//FORT.SYSIN  DD                         |
//            DD *                       |  INSERTION
       FUNCTION FBBj(arg)                |     OF
          { (FORTRAN                     |  FORTRAN
          {  BLACK BOX)                  |   BLACK
       FBBj = expression                 |   BOXES
       RETURN                            |
       END                               |
          { (OTHER FORTRAN               |
          {  BLACK BOXES)                |
/*                          - - - - - - -
//EXEC.SYSIN DD *
          { (DATA DECK(S))
```

Figure 7-4. Insertion of FORTRAN Black Boxes

SECTION 8

REFERENCES

1. R. T. Harnett, F. J. Sansom, L. M. Warshawsky, MIDAS Programming Guide, Wright-Patterson AFB Technical Documentary Report No. SEG-TDR-64-1, January 1964.
2. G. E. Blechman, An Enlarged Version of MIDAS, Space and Information Systems Division of North American Aviation Inc., June 1964.
3. G. H. Burgin, "MIDAS III, A Compiler Version of MIDAS," Simulation, p. 167, March 1966.
4. "Mathematical Program Abstracts," Convair Numerical Analyses Group, January 1964.
5. H. E. Petersen and F. J. Sansom, "Further Developments in the Handling of Implicit Function," Simulation, p. 15, January 1966.
6. G. H. Burgin, MIDAS III, A GENERAL DIGITAL SIMULATION PROGRAM, Report GDC-DDE66-022, General Dynamics, Convair Division, 15 May 1966.

APPENDIX A

FOUR SAMPLE PROBLEMS

SAMPLE PROBLEM 1: MASS-SPRING-DAMPER SYSTEM

The mass-spring-damper system is the example that was discussed in Section 3. Figure A-1.1 is the block diagram for this problem.

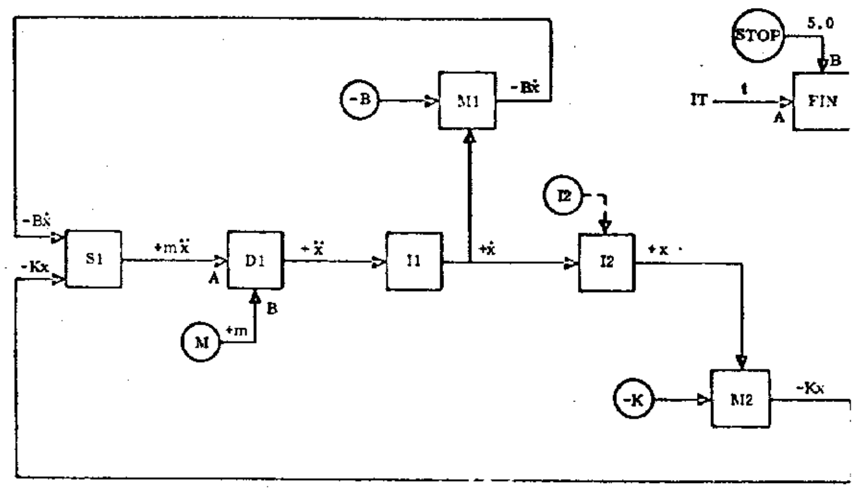


Figure A-1.1. Mass-Spring-Damper System Block Diagram

Three cases for this example have been run. (See Figure A-1.2.) Note the difference in the plot control cards. A description of the three cases is included in Section 7.

The following pages show a partial output for the precompiler phase (Figure A-1.3) an execution phase (Figure A-1.4) of this problem. (It is interesting to compare the numerical results with the results obtained by the Wright Patterson Program, which use a different integration method.) The plots for both runs (Figures A-1.5 through .9) follow the computer output.

PROGRAM NAME MIDAS

```
CASE 1
 1  10.     5.     -2.5     -8.6
 2  20.
 3  04010102010301040403
 4       TIME           ACCELERATION
 5       TIME           VELØCITY
 6       TIME           DISPLACEMENT
 7    DISPLACEMENT      VELØCITY
CASE 2
 8  10.     5.     -3.2     -8.6
 9  2.    E+1
10  020201030104
11       TIME           VELØCITY
12       TIME           DISPLACEMENT
CASE 3
13  10.     5.     -2.5     -15.
14  20.
15  0.0
```

Figure A-1.2. Mass-Spring-Damper System Input Data


```
SAMPLE PROBLEM 1 MASS-SPRING-DAMPER SYSTEM
C        CONSTANTS
         CON        M, STOP, -B, -K, T R
INITIAL CONDITIONS
         IC         I2
PROGRAM
         S1         M1,M2
         D1         S1,M
         I1         C1
         I2         I1
         M1         -B,I1
         M2         I2,-K
OPTION3
FINISH STATEMENT
         FIN        IT,STOP
READOUT
         RO         IT,C1,I1,I2
HEADER
         HDR        TIME,ACC.,VEL.,DISP.
PLOT STATEMENT
         PLOT       IT,C1,I1,I2
END STATEMENT
         END
```

Figure A-1.3. Mass-Spring-Damper System Precompiler Phase Printout

```
CONSTANTS C(I) ARE ..
      0.10000000E 02   0.5000000E 01  -0.2500000E 01  -0.8599999E 01   0.0          0.0

THE NON-ZERO INITIAL VALUES ARE..

      0.2000000E 02   0.0            0.0            0.0            0.0          0.0


NEC=NUMBER OF DIFFERENTIAL EQUATIONS=  2

INITIAL CONDITIONS FOR INTEGRATION VARIABLES
Y (  1) =  0.0             Y (  2) =  0.2000E 02

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) = -0.1720E 02      Y'(  2) =  0.0
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

MIDAS

```
TIME  0.0          ACC.  -1.7200E 01   VEL.   0.0          DISP.  2.0000E 01
TIME  1.0000E-01   ACC.  -1.6703E 01   VEL.  -1.6962E 00   DISP.  1.9915E 01
TIME  2.0000E-01   ACC.  -1.6076E 01   VEL.  -3.3362E 00   DISP.  1.9663E 01
TIME  3.0000E-01   ACC.  -1.5328E 01   VEL.  -4.9074E 00   DISP.  1.9250E 01
TIME  4.0000E-01   ACC.  -1.4469E 01   VEL.  -6.3981E 00   DISP.  1.8684E 01
TIME  5.0000E-01   ACC.  -1.3508E 01   VEL.  -7.7977E 00   DISP.  1.7973E 01
TIME  6.0000E-01   ACC.  -1.2456E 01   VEL.  -9.0965E 00   DISP.  1.7128E 01
TIME  7.0000E-01   ACC.  -1.1324E 01   VEL.  -1.0286E 01   DISP.  1.6158E 01
TIME  8.0000E-01   ACC.  -1.0124E 01   VEL.  -1.1359E 01   DISP.  1.5074E 01
TIME  9.0000E-01   ACC.  -8.8680E 00   VEL.  -1.2309E 01   DISP.  1.3890E 01
TIME  1.0000E 00   ACC.  -7.5676E 00   VEL.  -1.3131E 01   DISP.  1.2617E 01
TIME  1.1000E 00   ACC.  -6.2351E 00   VEL.  -1.3822E 01   DISP.  1.1268E 01
TIME  1.2000E 00   ACC.  -4.8826E 00   VEL.  -1.4378E 01   DISP.  9.8569E 00
TIME  1.3000E 00   ACC.  -3.5220E 00   VEL.  -1.4798E 01   DISP.  8.3970E 00
TIME  1.4000E 00   ACC.  -2.1651E 00   VEL.  -1.5082E 01   DISP.  6.9019E 00
TIME  1.5000E 00   ACC.  -8.2397E-01   VEL.  -1.5231E 01   DISP.  5.3851E 00
TIME  1.6000E 00   ACC.   4.9224E-01   VEL.  -1.5248E 01   DISP.  3.8601E 00
TIME  1.7000E 00   ACC.   1.7712E 00   VEL.  -1.5134E 01   DISP.  2.3399E 00
TIME  1.8000E 00   ACC.   3.0035E 00   VEL.  -1.4895E 01   DISP.  8.3745E-01
TIME  1.9000E 00   ACC.   4.1799E 00   VEL.  -1.4535E 01   DISP. -6.3504E-01
TIME  2.0000E 00   ACC.   5.2918E 00   VEL.  -1.4061E 01   DISP. -2.0658E 00
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

MIDAS

TIME	2.2000E 00	ACC.	7.2915E 00	VEL.	-1.2797E 01	DISP.	-4.7583E 00
TIME	2.3000E 00	ACC.	8.1660E 00	VEL.	-1.2024E 01	DISP.	-6.0001E 00
TIME	2.4000E 00	ACC.	8.9497E 00	VEL.	-1.1167E 01	DISP.	-7.1603E 00
TIME	2.5000E 00	ACC.	9.6380E 00	VEL.	-1.0237E 01	DISP.	-8.2311E 00
TIME	2.6000E 00	ACC.	1.0228E 01	VEL.	-9.2430E 00	DISP.	-9.2056E 00
TIME	2.7000E 00	ACC.	1.0716E 01	VEL.	-8.1950E 00	DISP.	-1.0078E 01
TIME	2.8000E 00	ACC.	1.1101E 01	VEL.	-7.1033E 00	DISP.	-1.0843E 01
TIME	2.9000E 00	ACC.	1.1382E 01	VEL.	-5.9782E 00	DISP.	-1.1497E 01
TIME	3.0000E 00	ACC.	1.1560E 01	VEL.	-4.8303E 00	DISP.	-1.2038E 01
TIME	3.1000E 00	ACC.	1.1636E 01	VEL.	-3.6696E 00	DISP.	-1.2463E 01
TIME	3.2000E 00	ACC.	1.1610E 01	VEL.	-2.5065E 00	DISP.	-1.2772E 01
TIME	3.3000E 00	ACC.	1.1487E 01	VEL.	-1.3508E 00	DISP.	-1.2965E 01
TIME	3.4000E 00	ACC.	1.1270E 01	VEL.	-2.1219E-01	DISP.	-1.3043E 01
TIME	3.5000E 00	ACC.	1.0962E 01	VEL.	9.0011E-01	DISP.	-1.3008E 01
TIME	3.6000E 00	ACC.	1.0568E 01	VEL.	1.9773E 00	DISP.	-1.2864E 01
TIME	3.7000E 00	ACC.	1.0095E 01	VEL.	3.0111E 00	DISP.	-1.2614E 01
TIME	3.8000E 00	ACC.	9.5479E 00	VEL.	3.9939E 00	DISP.	-1.2263E 01
TIME	3.9000E 00	ACC.	8.9330E 00	VEL.	4.9184E 00	DISP.	-1.1817E 01
TIME	4.0000E 00	ACC.	8.2576E 00	VEL.	5.7785E 00	DISP.	-1.1282E 01
TIME	4.1000E 00	ACC.	7.5287E 00	VEL.	6.5682E 00	DISP.	-1.0664E 01
TIME	4.2000E 00	ACC.	6.754[illegible]E 00	VEL.	7.2827E 00	DISP.	-9.9705E 00

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

TIME	4.3000E 00	ACC.	5.9410E 00	VEL.	7.9177E 00	DISP.	-9.2098E 00
TIME	4.4000E 00	ACC.	5.0977E 00	VEL.	8.4699E 00	DISP.	-8.3897E 00
TIME	4.5000E 00	ACC.	4.2320E 00	VEL.	8.9365E 00	DISP.	-7.5187E 00
TIME	4.6000E 00	ACC.	3.3517E 00	VEL.	9.3158E 00	DISP.	-6.6054E 00
TIME	4.7000E 00	ACC.	2.4647E 00	VEL.	9.6066E 00	DISP.	-5.6585E 00
TIME	4.8000E 00	ACC.	1.5786E 00	VEL.	9.8087E 00	DISP.	-4.6870E 00
TIME	4.9000E 00	ACC.	7.0109E-01	VEL.	9.9226E 00	DISP.	-3.6997E 00
TIME	5.0000E 00	ACC.	-1.6074E-01	VEL.	9.9495E 00	DISP.	-2.7054E 00
TIME	5.0250E 00	ACC.	-3.7292E-01	VEL.	9.9428E 00	DISP.	-2.4567E 00

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

CONSTANTS C(I) ARE ..

```
0.1000000E 02   0.3000000E 01  -0.3200000E 01  -0.8599999E 01   0.0   0.0
```

THE NON-ZERO INITIAL VALUES ARE..

```
0.2000000E 02   0.0   0.0   0.0   0.0   0.0
```

NEQ=NUMBER OF DIFFERENTIAL EQUATIONS= 2

INITIAL CONDITIONS FOR INTEGRATION VARIABLES

```
Y (  1) = 0.0          Y (  2) =  0.2000E 02
```

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES

```
Y'(  1) = -0.1720E 02     Y'(  2) =  0.0
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

TIME	0.0	ACC.	-1.7200E 01	VEL.	0.0	DISP.	2.0000E 01
TIME	1.0000E-01	ACC.	-1.6586E 01	VEL.	-1.6903E 00	DISP.	1.9915E 01
TIME	2.0000E-01	ACC.	-1.5851E 01	VEL.	-3.3132E 00	DISP.	1.9664E 01
TIME	3.0000E-01	ACC.	-1.5005E 01	VEL.	-4.8568E 00	DISP.	1.9255E 01
TIME	4.0000E-01	ACC.	-1.4059E 01	VEL.	-6.3108E 00	DISP.	1.8696E 01
TIME	5.0000E-01	ACC.	-1.3024E 01	VEL.	-7.6456E 00	DISP.	1.7996E 01
TIME	6.0000E-01	ACC.	-1.1911E 01	VEL.	-8.9130E 00	DISP.	1.7166E 01
TIME	7.0000E-01	ACC.	-1.0732E 01	VEL.	-1.0046E 01	DISP.	1.6217E 01
TIME	8.0000E-01	ACC.	-9.5001E 00	VEL.	-1.1058E 01	DISP.	1.5161E 01
TIME	9.0000E-01	ACC.	-8.2264E 00	VEL.	-1.1944E 01	DISP.	1.4010E 01
TIME	1.0000E 00	ACC.	-6.9232E 00	VEL.	-1.2702E 01	DISP.	1.2777E 01
TIME	1.1000E 00	ACC.	-5.6026E 00	VEL.	-1.3328E 01	DISP.	1.1474E 01
TIME	1.2000E 00	ACC.	-4.2761E 00	VEL.	-1.3822E 01	DISP.	1.0115E 01
TIME	1.3000E 00	ACC.	-2.9552E 00	VEL.	-1.4184E 01	DISP.	8.7139E 00
TIME	1.4000E 00	ACC.	-1.6509E 00	VEL.	-1.4414E 01	DISP.	7.2830E 00
TIME	1.5000E 00	ACC.	-3.7378E-01	VEL.	-1.4515E 01	DISP.	5.8355E 00
TIME	1.6000E 00	ACC.	8.6631E-01	VEL.	-1.4490E 01	DISP.	4.3842E 00
TIME	1.7000E 00	ACC.	2.0630E 00	VEL.	-1.4343E 01	DISP.	2.9416E 00
TIME	1.8000E 00	ACC.	3.1987E 00	VEL.	-1.4080E 01	DISP.	1.5195E 00
TIME	1.9000E 00	ACC.	4.2745E 00	VEL.	-1.3705E 01	DISP.	1.2939E-01
TIME	2.0000E 00	ACC.	5.2602E 00	VEL.	-1.3227E 01	DISP.	-1.2181E 00

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

TIME	.1000E 00	ACC.	6.2097E 00	VEL.	-1.2652E 01	.P.	-2.5120E 00
TIME	2.2000E 00	ACC.	7.0573E 00	VEL.	-1.1988E 01	DISP.	-3.7455E 00
TIME	2.3000E 00	ACC.	7.8185E 00	VEL.	-1.1243E 01	DISP.	-4.9077E 00
TIME	2.4000E 00	ACC.	8.4897E CO	VEL.	-1.0427E 01	DISP.	-5.9918E 00
TIME	2.5000E 00	ACC.	9.0678E 00	VEL.	-9.5485E 00	DISP.	-6.9911E 00
TIME	2.6000E 00	ACC.	9.5311E 00	VEL.	-8.6168E 00	DISP.	-7.8997E 00
TIME	2.7000E 00	ACC.	9.9384E CO	VEL.	-7.6415E 00	DISP.	-8.7150E 00
TIME	2.8000E 00	ACC.	1.0229E 01	VEL.	-6.6323E 00	DISP.	-9.4269E 00
TIME	2.9000E 00	ACC.	1.0425E 01	VEL.	-5.5988E 00	DISP.	-1.0039E 01
TIME	3.0000E 00	ACC.	1.0526E 01	VEL.	-4.5505E 00	DISP.	-1.0548E 01
TIME	3.1000E 00	ACC.	1.0535E 01	VEL.	-3.4967E 00	DISP.	-1.0949E 01
TIME	3.2000E 00	ACC.	1.0454E 01	VEL.	-2.4465E 00	DISP.	-1.1246E 01
TIME	3.3000E 00	ACC.	1.0288E 01	VEL.	-1.4087E 00	DISP.	-1.1438E 01
TIME	3.4000E 00	ACC.	1.0039E 01	VEL.	-3.9172E-01	DISP.	-1.1528E 01
TIME	3.5000E 00	ACC.	9.7142E 00	VEL.	5.9658E-01	DISP.	-1.1518E 01
TIME	3.6000E 00	ACC.	9.3170E CO	VEL.	1.9487E 00	DISP.	-1.1410E 01
TIME	3.7000E 00	ACC.	8.8535E 00	VEL.	2.4578E 00	DISP.	-1.1209E 01
TIME	3.8000E 00	ACC.	8.3297E 00	VEL.	3.3174E 00	DISP.	-1.0920E 01
TIME	3.9000E 00	ACC.	7.7519E CO	VEL.	4.1219E 00	DISP.	-1.0548E 01
TIME	4.0000E 00	ACC.	7.1268E CO	VEL.	4.8662E 00	DISP.	-1.0098E 01
TIME	4.1000E 00	ACC.	6.4611E 00	VEL.	5.5459E 00	DISP.	-9.5765E 00
TIME	4.2000E CO	ACC.	5.7617E CO	VEL.	6.1573E 00	DISP.	-8.9908E 00

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

MIDAS

TIME	4.3000E 00	ACC.	5.0356E 00	VEL.	6.6974E 00	DISP.	-8.3474E 00
TIME	4.4000E 00	ACC.	4.2898E CO	VEL.	7.1638E 00	DISP.	-7.6538E 00
TIME	4.5000E 00	ACC.	3.5312E 00	VEL.	7.5549E 00	DISP.	-6.9172E 00
TIME	4.6000E 00	ACC.	2.7666E 00	VEL.	7.8698E 00	DISP.	-6.1453E 00
TIME	4.7000E 00	ACC.	2.0027E 00	VEL.	8.1082E 00	DISP.	-5.3458E 00
TIME	4.8000E 00	ACC.	1.2460E CO	VEL.	8.2706E 00	DISP.	-4.5262E 00
TIME	4.9000E 00	ACC.	5.0247E-01	VEL.	8.3579E 00	DISP.	-3.6942E 00
TIME	5.0000E 00	ACC.	-2.2185E-01	VEL.	8.3717E 00	DISP.	-2.8571E 00
TIME	5.0250E 00	ACC.	-3.9928E-01	VEL.	8.3640E 00	DISP.	-2.6479E 00

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

```
NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  2

INITIAL CONDITIONS FOR INTEGRATION VARIABLES
Y (  1) =  0.0          Y (  2) =  0.2000E 02

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) = -0.3000E 02     Y'(  2) =  0.0
```

```
CONSTANTS C(I) ARE ..
   0.1000000E 02   0.5000000E 01  -0.2500000E 01  -0.1500000E 02   0.0        0.0

THE NON-ZERO INITIAL VALUES ARE..

   0.2000000E 02   0.0            0.0            0.0            0.0        0.0
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

A-12


```
TIME   0.0          ACC.  -3.0000E 01   VEL.   0.0          DISP.  2.0000E 01
TIME   1.0000E-01   ACC.  -2.9038E 01   VEL.  -2.9554E 00   DISP.  1.9651E 01
TIME   2.0000E-01   ACC.  -2.7471E 01   VEL.  -5.7941E 00   DISP.  1.9413E 01
TIME   3.0000E-01   ACC.  -2.5927E 01   VEL.  -8.4770E 00   DISP.  1.8698E 01
TIME   4.0000E-01   ACC.  -2.3844E 01   VEL.  -1.0968E 01   DISP.  1.7724E 01
TIME   5.0000E-01   ACC.  -2.1458E 01   VEL.  -1.3236E 01   DISP.  1.6512E 01
TIME   6.0000E-01   ACC.  -1.8815E 01   VEL.  -1.5251E 01   DISP.  1.5085E 01
TIME   7.0000E-01   ACC.  -1.5958E 01   VEL.  -1.6991E 01   DISP.  1.3471E 01
TIME   8.0000E-01   ACC.  -1.2936E 01   VEL.  -1.8437E 01   DISP.  1.1697E 01
TIME   9.0000E-01   ACC.  -9.7984E 00   VEL.  -1.9575E 01   DISP.  9.7934E 00
TIME   1.0000E 00   ACC.  -6.5000E 00   VEL.  -2.0394E 01   DISP.  7.7922E 00
TIME   1.1000E 00   ACC.  -3.3048E 00   VEL.  -2.0892E 01   DISP.  5.7252E 00
TIME   1.2000E 00   ACC.  -1.6976E-01   VEL.  -2.1040E 01   DISP.  3.6246E 00
TIME   1.3000E 00   ACC.   2.9489E 00   VEL.  -2.0828E 01   DISP.  1.5221E 00
TIME   1.4000E 00   ACC.   5.9470E 00   VEL.  -2.0483E 01   DISP. -5.5093E-01
TIME   1.5000E 00   ACC.   8.7831E 00   VEL.  -1.9744E 01   DISP. -2.5646E 00
TIME   1.6000E 00   ACC.   1.1419E 01   VEL.  -1.8733E 01   DISP. -4.4907E 00
TIME   1.7000E 00   ACC.   1.3821E 01   VEL.  -1.7468E 01   DISP. -6.3027E 00
TIME   1.8000E 00   ACC.   1.5959E 01   VEL.  -1.5977E 01   DISP. -7.9760E 00
TIME   1.9000E 00   ACC.   1.7809E 01   VEL.  -1.4286E 01   DISP. -9.4915E 00
TIME   2.0000E 00   ACC.   1.9349E 01   VEL.  -1.2426E 01   DISP. -1.0828E 01
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

A-13

```
TIME  2.1000E 00   ACC.  2.0565E 01   VEL. -1.0427E 01   SP. -1.1972E 01
TIME  2.2000E 00   ACC.  2.1446E 01   VEL. -8.3239E 00   DISP. -1.2910E 01
TIME  2.3000E 00   ACC.  2.1989E 01   VEL. -6.1493E 00   DISP. -1.3634E 01
TIME  2.4000E 00   ACC.  2.2193E 01   VEL. -3.9374E 00   DISP. -1.4139E 01
TIME  2.5000E 00   ACC.  2.2063E 01   VEL. -1.7218E 00   DISP. -1.4422E 01
TIME  2.6000E 00   ACC.  2.1610E 01   VEL.  4.6447E-01   DISP. -1.4484E 01
TIME  2.7000E 00   ACC.  2.0849E 01   VEL.  2.5899E 00   DISP. -1.4331E 01
TIME  2.8000E 00   ACC.  1.9798E 01   VEL.  4.6246E 00   DISP. -1.3969E 01
TIME  2.9000E 00   ACC.  1.8480E 01   VEL.  6.5406E 00   DISP. -1.3410E 01
TIME  3.0000E 00   ACC.  1.6921E 01   VEL.  8.3125E 00   DISP. -1.2666E 01
TIME  3.1000E 00   ACC.  1.5150E 01   VEL.  9.9177E 00   DISP. -1.1753E 01
TIME  3.2000E 00   ACC.  1.3199E 01   VEL.  1.1336E 01   DISP. -1.0689E 01
TIME  3.3000E 00   ACC.  1.1101E 01   VEL.  1.2553E 01   DISP. -9.4925E 00
TIME  3.4000E 00   ACC.  8.8898E 00   VEL.  1.3553E 01   DISP. -8.1854E 00
TIME  3.5000E 00   ACC.  6.6021E 00   VEL.  1.4328E 01   DISP. -6.7894E 00
TIME  3.6000E 00   ACC.  4.2733E 00   VEL.  1.4872E 01   DISP. -5.3275E 00
TIME  3.7000E 00   ACC.  1.9386E 00   VEL.  1.5182E 01   DISP. -3.8228E 00
TIME  3.8000E 00   ACC. -3.6701E-01   VEL.  1.5261E 01   DISP. -2.2988E 00
TIME  3.9000E 00   ACC. -2.6103E 00   VEL.  1.5111E 01   DISP. -7.7831E-01
TIME  4.0000E 00   ACC. -4.7596E 00   VEL.  1.4742E 01   DISP.  7.1612E-01
TIME  4.1000E 00   ACC. -6.7854E 00   VEL.  1.4163E 01   DISP.  2.1631E 00
TIME  4.2000E 00   ACC. -5.6608E 00   VEL.  1.3390E 01   DISP.  3.5423E 00
```

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)


```
TIME  4.3000E 00   ACC. -1.0362E 01   VEL.  1.2437E 01   DISP.  4.8350E 00
TIME  4.4000E 00   ACC. -1.1867E 01   VEL.  1.1324E 01   DISP.  6.0243E 00
TIME  4.5000E 00   ACC. -1.3160E 01   VEL.  1.0071E 01   DISP.  7.0951E 00
TIME  4.6000E 00   ACC. -1.4227E 01   VEL.  8.6993E 00   DISP.  8.0345E 00
TIME  4.7000E 00   ACC. -1.5056E 01   VEL.  7.2332E 00   DISP.  8.8318E 00
TIME  4.8000E 00   ACC. -1.5642E 01   VEL.  5.6962E 00   DISP.  9.4787E 00
TIME  4.9000E 00   ACC. -1.5982E 01   VEL.  4.1129E 00   DISP.  9.9695E 00
TIME  5.0000E 00   ACC. -1.6078E 01   VEL.  2.5079E 00   DISP.  1.0301E 01
TIME  5.0298E 00   ACC. -1.6064E 01   VEL.  2.1061E 00   DISP.  1.0358E 01
```

SAMPLE PROBLEM 1 - TOTAL RUNNING TIME 3.6 MINUTES

Figure A-1.4. Mass-Spring-Damper System Execution Phase Printout, (Contd)

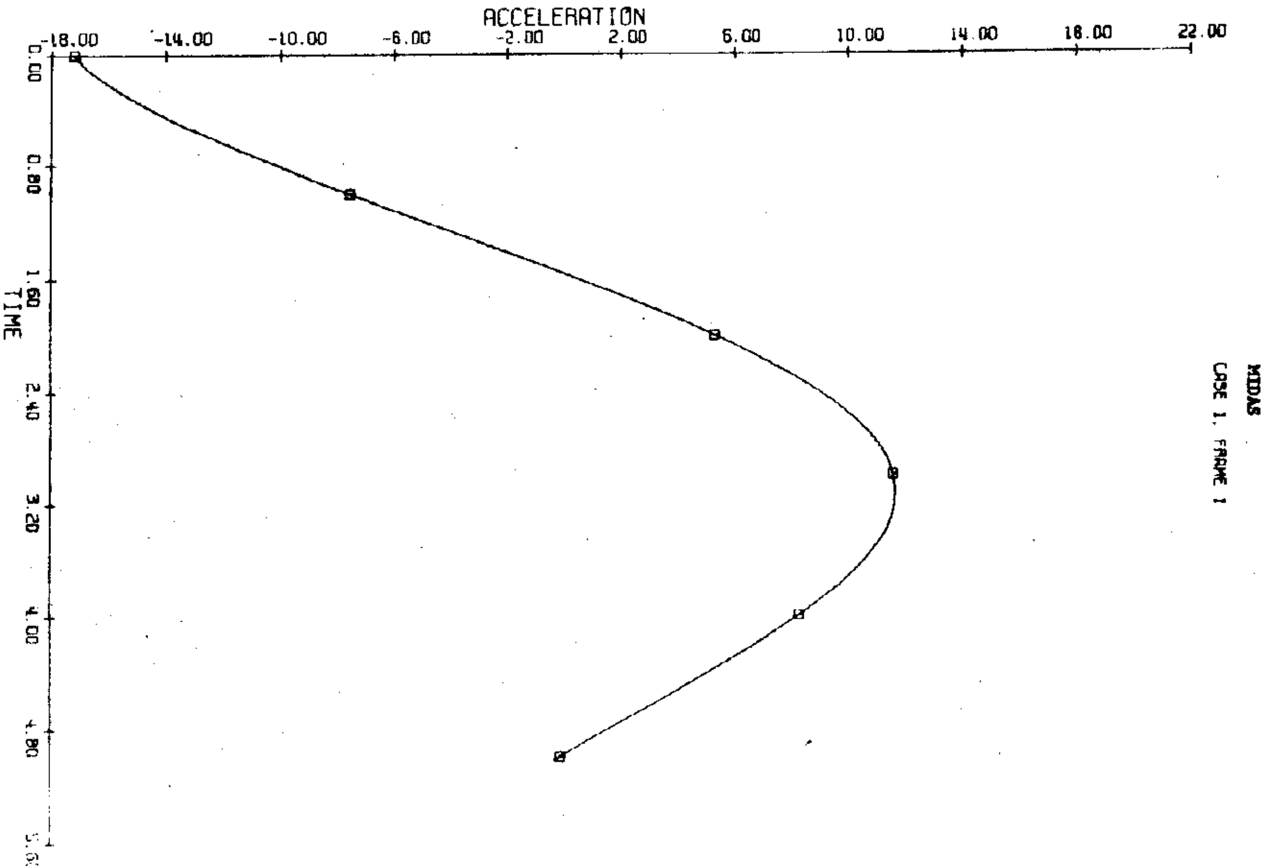


Figure A-1.5. Mass-Spring-Damper System Plot, Acceleration vs Time, Case 1

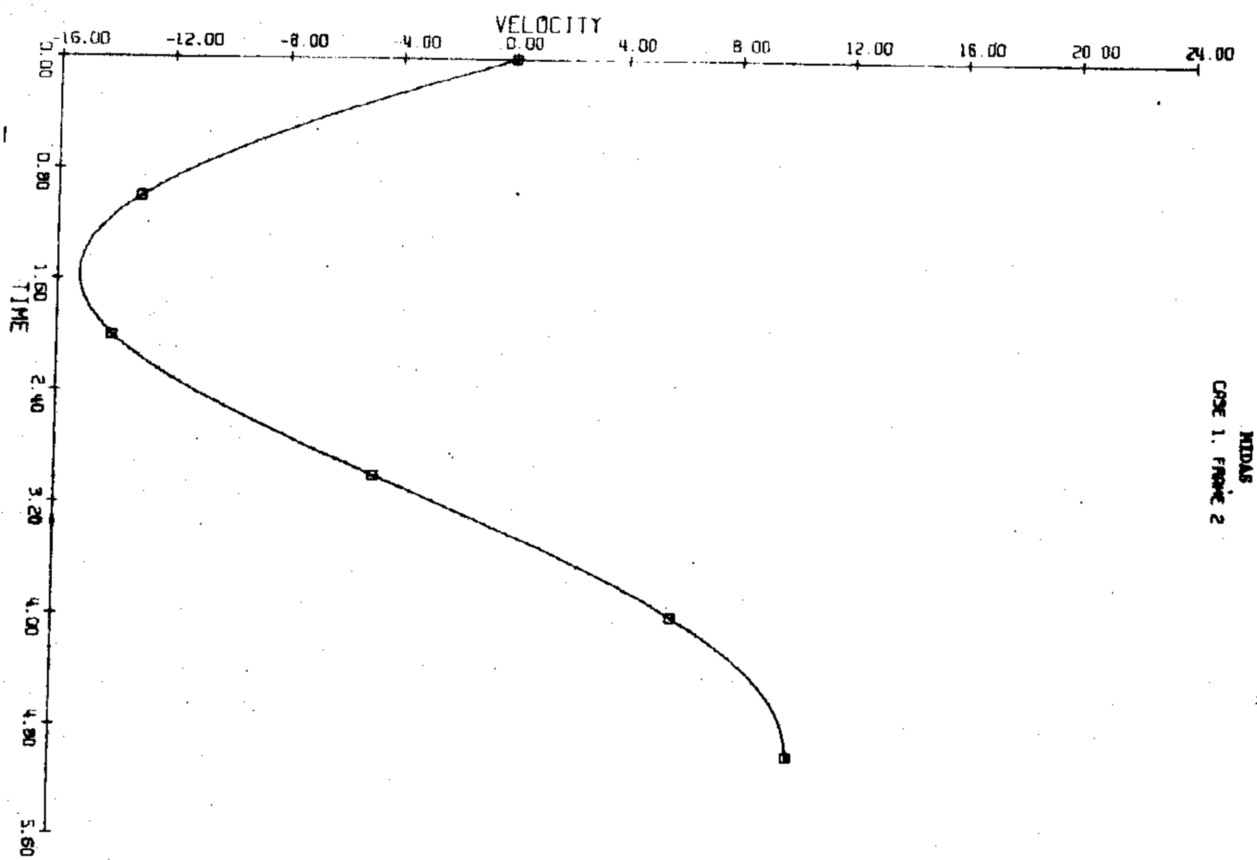


Figure A-1.6. Mass-Spring-Damper System Plot, Velocity vs Time, Case 1

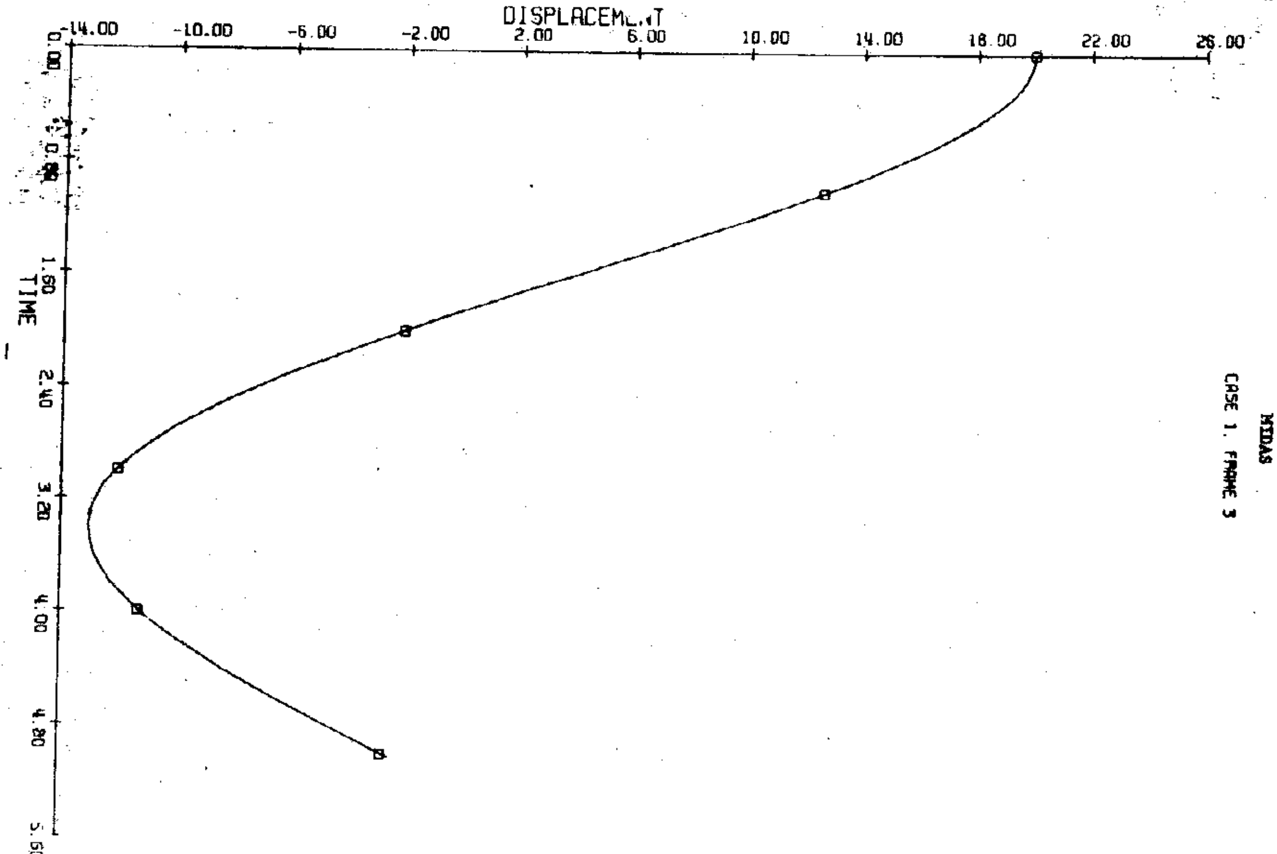


Figure A-1.7. Mass-Spring-Damper System Plot, Displacement vs Time, Case 1

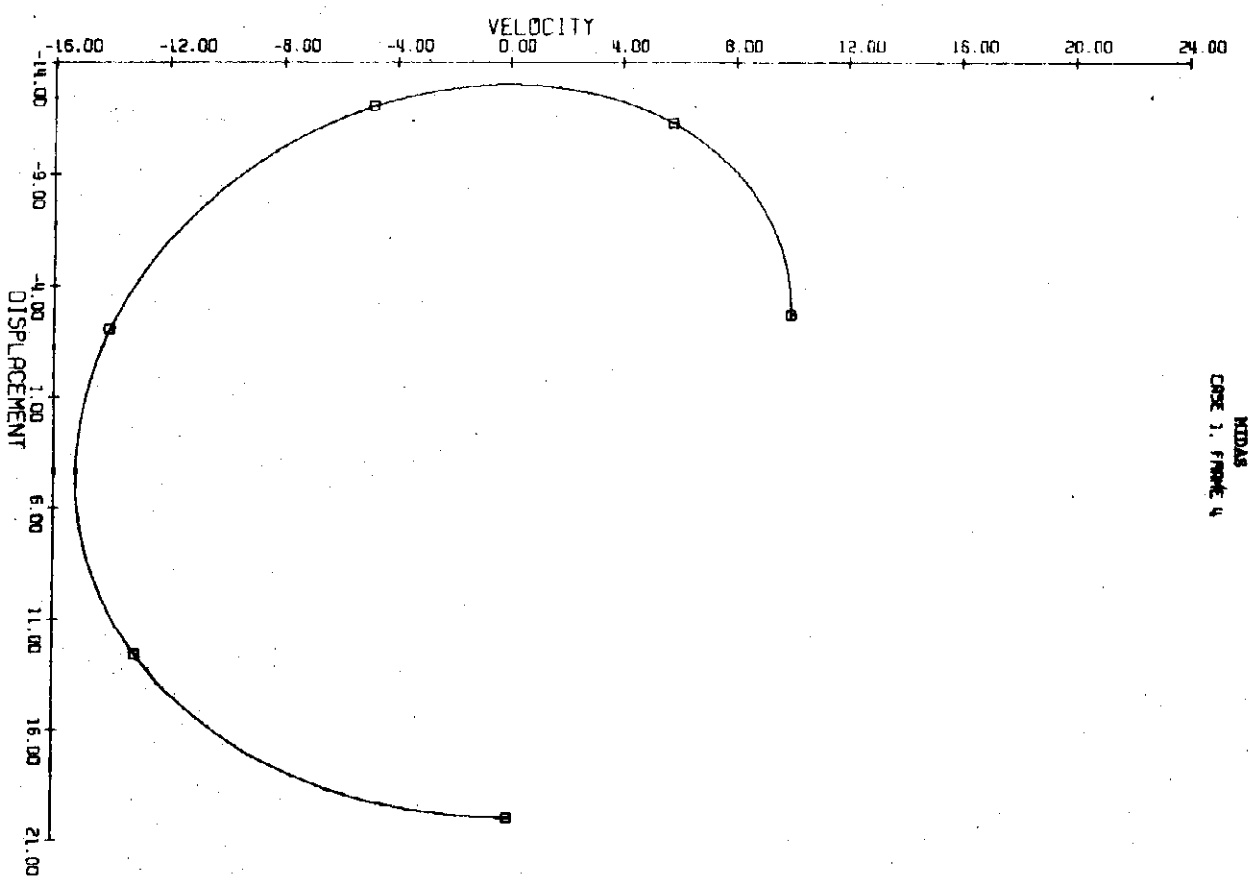


Figure A-1.8. Mass-Spring-Damper System Plot, Velocity vs Displacement, Case 1

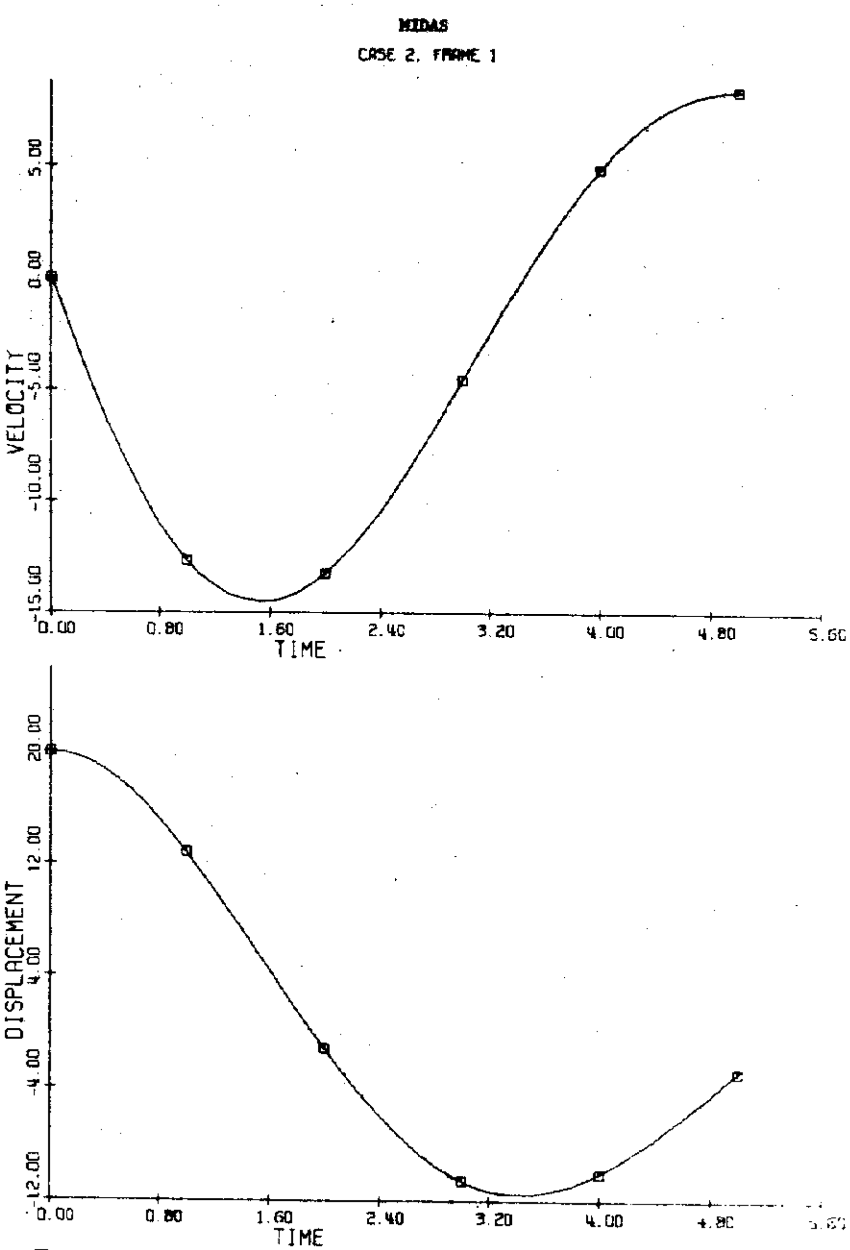


Figure A-1.9. Mass-Spring-Damper System Plot, Displacement and Velocity vs Time, Case 2

SAMPLE PROBLEM 2: AIRCRAFT ARRESTING GEAR PROBLEM

This problem was chosen to show the high degree of compatibility with the original version of MIDAS and the use of different plotting options in multiple runs.

The arresting gear system investigated here is designed to halt a moving aircraft that would otherwise overrun the end of a runway. (See Figure A-2.1.) It is similar in principle to the arresting gear used on aircraft carriers. The equations listed below describe the system, and a plot of the water squeezer damping function, $f(y_3)$, is shown in Figure A-2.1.

Basically, the aims of the investigation were to determine the range of aircraft weights and speeds that could be accommodated without exceeding the working limits of the cables or the allowable piston travel. In this example just two cases involving different aircraft velocities are investigated.

Equations:

$$m_3\ddot{y}_3 = f_{k_2} - f_D$$

$$m_2\ddot{y}_2 = 2f_{k_1} - f_{k_2}$$

$$m_1\ddot{x} = -2f_{k_1}\sin\theta$$

$$f_{k_2} = k_2(y_2 - y_3) \quad \text{for } y_2 \geq y_3$$

$$= 0 \quad y_2 < y_3$$

$$f_{k_1} = k_1(y_1 - 2y_2) \quad \text{for } y_1 \geq 2y_2$$

$$= 0 \quad y_1 < 2y_2$$

$$f_D = f(y_3) \cdot (\dot{y}_3)^2$$

$$y_1 = \sqrt{x^2 + h^2} - h$$

$$\sin\theta = \frac{x}{h + y_1} = \frac{x}{\sqrt{x^2 + h^2}}$$

Constants:

m_1 = 1400 slugs

m_2 = 45.28 slugs

m_3 = 20 slugs

k_1 = 4,550 lb/ft

k_2 = 25,300 lb/ft

h = 125 ft

Initial Conditions:

$\dot{y}_3(0) = 0$

$\dot{y}_2(0) = 0$

$\dot{x}(0)$ = 290 ft/sec (Run 1)

= 200 ft/sec (Run 2)

$y_3(0) = 0$

$y_2(0) = 0$

$x(0) = 0$

Arbitrary Function:

$f(y_3)$ = A function of y_3.

The data points for the function are shown on the block diagram, Figure A-2.2. Linear interpolation between points is desired.

BLOCK DIAGRAM (See Figure A-2.2.)

1. Input relays IR1 and IR2 are used because the cables can transmit only tensile forces. Thus, when $(y_2 - y_3) \geq 0$, there is a force in tension qual to $k_2 (y_2 - y_3)$ between the moving carriage and the piston of the water squeezer. When $(y_2 - y_3) < 0$, no compressive force exists. By feeding $(y_2 - y_3)$ to the C input of the IR, switching will occur at the proper time; in one case transmitting $(y_2 - y_3)$ through the relay and in the other providing zero.

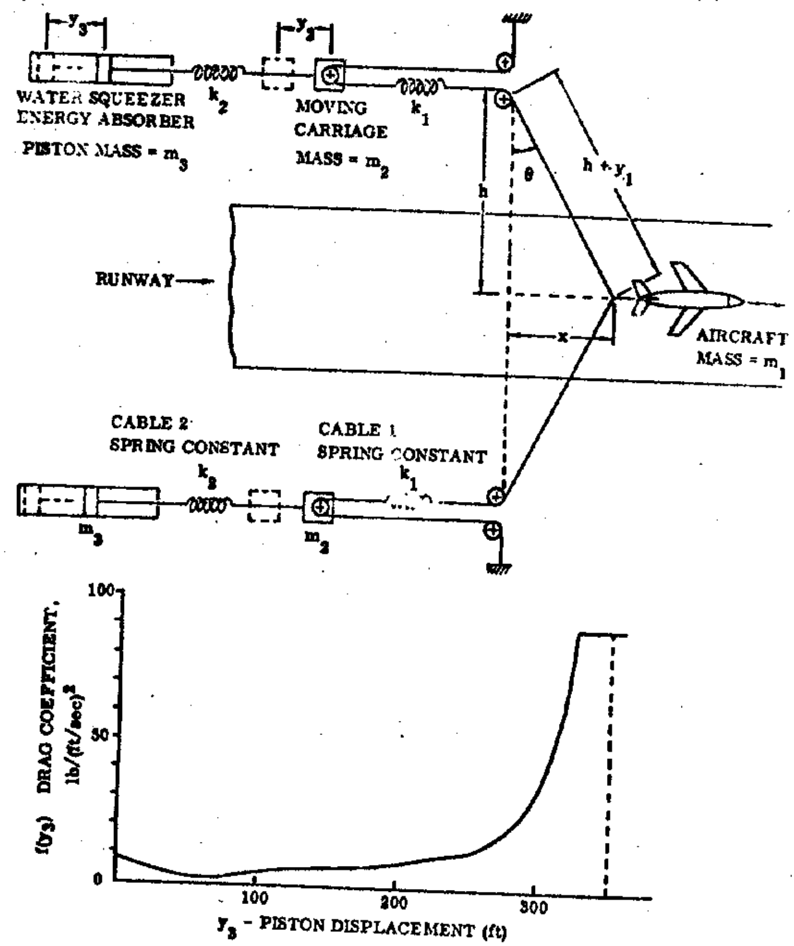


Figure A-2.1. Aircraft Arresting Gear System

2. Damping coefficient $f(y_3)$ was represented by a straight-line approximation passing through 14 breakpoints (13 segments). The tabulated values are shown on the block diagram. A better fit to the given function could have been obtained by using more breakpoints (45 are available) and a quadratic interpolation. However, it was desired to check the analog solution so the same representation was used in both setups.

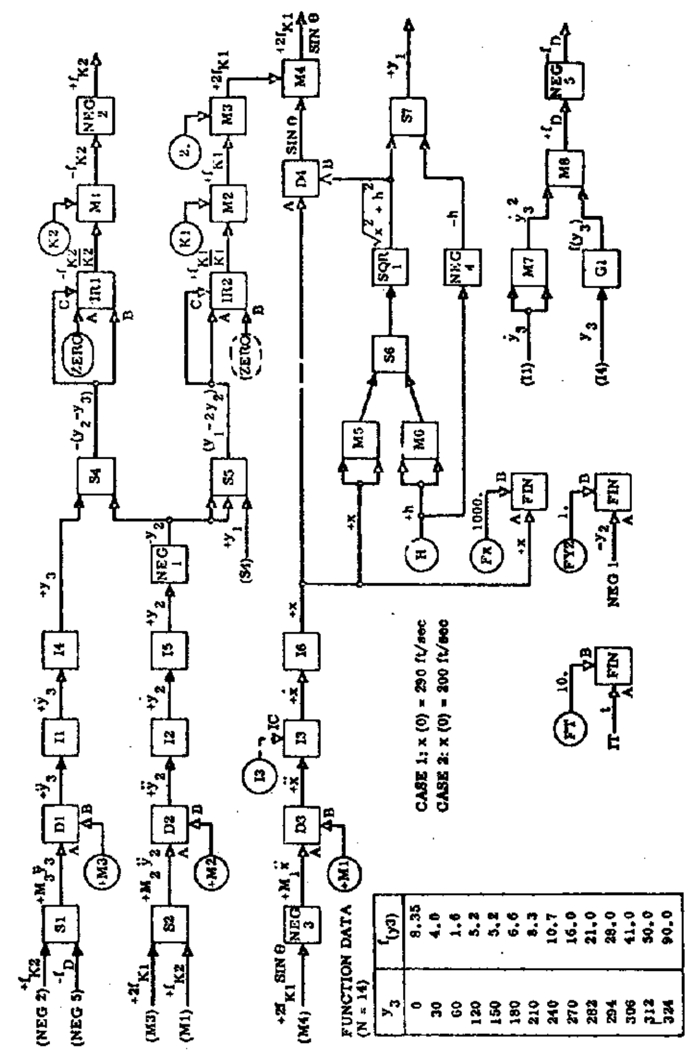
3. Note the choice of FIN conditions. One FIN statement stops the problem after 10 seconds, a second stops the problem if y_2 goes negative by one foot, and the third condition terminates the run when x reaches 1000 feet. The second condition is one of particular interest since it indicates a physically unreal situation. It was provided to end the run just in case an error existed either in the mathematical model or in the MIDAS program.

CODING

1. Note the names assigned to the constants representing the three masses. The names +M1, +M2 and +M3 are quite valid even though multipliers M1, M2, and M3 are also used in the problem. MIDAS is able to distinguish between them.

2. Since a large number of variables were of interest in this problem, the readout statements (and the corresponding headers) were arranged for ease in reading the results.

Computer printouts of the first pass are provided as Figure A-2.3. Input data and execution phase printouts are included as Figures A-2.3 and A-2.5. Only those pages of the printouts which are essential to this discussion are included. Plots of x and ẋ versus t are included in Figures A-2.6 through .8.



y_3	$f_{(y3)}$
0	8.35
30	4.8
60	1.6
120	5.2
150	5.2
180	6.6
210	8.3
240	10.7
270	16.0
282	21.0
294	28.0
306	41.0
312	50.0
324	90.0

Figure A-2.2. Aircraft Arresting Gear Block Diagram

```
SAMPLE PROBLEM  2   AIRCRAFT ARRESTING GEAR SYSTEM
      CON     +M1,+M2,+M3,ZERO,K1,K2
      CON     2.,+H,FT,FY2,FX,TR
      IC      I3
      S1      NEG2,NEG5
      D1      S1,+M3
      I1      D1
      I4      I1
      S2      M3,M1
      D2      S2,+M2
      I2      D2
      I5      I2
      NEG1    I5
      S4      I4,NEG1
      TR1     ZERO,S4,S4
      M1      TR1,K2
      NEG2    M1
      NEG3    M4
      D3      NEG3,+M1
      I3      D3
      I6      I3
      M5      I6,I6
      M6      H,H
      NEG4    H
      S6      M5,M6
      SOR1    S6
      S7      SOR1,NEG4
      D4      I6,SOR1
      S5      NEG1,NEG1,S7
      TR2     S5,ZERO,S5
      M2      TR2,K1
      M3      M2,2.
      M4      M3,D4
      M7      I1,I1
      G1      I4
      M8      M7,G1
      NEG5    M8
      FIN     IT,FT
      FIN     NEG1,FY2
      FIN     I6,FX
      RO      IT,D1,I1,I4,G1,M8
      RO      IT,D2,I2,I5,S4,NEG2
      RO      IT,D3,I3,I6,S5,M2
      RO      IT,S7,D4
      PLOT    IT,I5,I2
      HDR     TIME,Y3/ACC,Y3/VEL,Y3,F(Y3),FD
      HDR     TIME,Y2/ACC,Y2/VEL,Y2,Y3-Y2,FX2
      HDR     TIME,X/ACC,X/VEL,X,Y1-2Y2,FK1
      HDR     TIME,Y1,SIN
      END
```

Figure A-2.3. Aircraft Arresting Gear Precompiler Phase Printout

CASE 1

```
1400.     45.28     20.     0.      4550.     2 300.   } CONSTANTS
2.        125.      10.     1.      1000.     [illegible]
290.                                                   INITIAL CONDITION
14.
0.        8.33      30.     4.0     60.       1.6
120.      5.2       150.    5.2     180.      6.6
210.      8.3       240.    10.7    270.      16.      FUNCTION GENERATOR
282.      21.0      294.    28.     306.      41.
312.      50.0      324.    90.
020201020103                                           PLOT CONTROL CARD
          TIME                      X                  } PLOT TITLE CARDS
          TIME                      XDOT
```

CASE 2

```
1400.     45.28     20.     0.      4550.     25300.   } CONSTANTS
2.        125.      10.     1.      1000.     .2
200.                                                   INITIAL CONDITION
14.
0.        8.33      30.     4.0     60.       1.6
120.      5.2       150.    5.2     180.      6.6
210.      8.3       240.    10.7    270.      16.      FUNCTION GENERATOR
282.      21.0      294.    28.     306.      41.
312.      50.0      324.    90.
020101020103                                           PLOT CONTROL CARD
          TIME                      X                  } PLOT TITLE CARDS
          TIME                      XDOT
```

Figure A-2.4. Aircraft Aresting Gear Input Data

```
[illegible] ARE ..

     0.1400000E 04   0.4528000E 02   0.2000000E 02   0.0             0.4550000E 04   0.2530000E 05
     0.2000000E 01   0.1250000E 03   0.1000000E 02   0.1000000E 01   0.1000000E 04   0.2000000E 00


 THE NON-ZERO INITIAL VALUES ARE..


     0.2900000E 03   0.0             0.0             0.0             0.0             0.0


 VALUES FOR FUNCTION GENERATOR NUMBER   1
 NUMBER OF POINTS =    14
X =   0.0            F(X) =   0.8330000E 01

X =   0.3000000E 02  F(X) =   0.4000000E 01

X =   0.6000000E 02  F(X) =   0.1599999E 01

X =   0.1200000E 03  F(X) =   0.5200000E 01

X =   0.1500000E 03  F(X) =   0.5200000E 01

X =   0.1800000E 03  F(X) =   0.6599999E 01

X =   0.2100000E 03  F(X) =   0.8299999E 01

X =   0.2400000E 03  F(X) =   0.1070000E 02

X =   0.2700000E 03  F(X) =   0.1600000E 02

X =   0.2820000E 03  F(X) =   0.2100000E 02

X =   0.2940000E 03  F(X) =   0.2800000E 02

X =   0.3060000E 03  F(X) =   0.4100000E 02

X =   0.3120000E 03  F(X) =   0.5000000E 02

X =   0.3240000E 03  F(X) =   0.9000000E 02


NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  6


INITIAL CONDITIONS FOR INTEGRATION VARIABLES

Y (  1) =  0.0            Y (  2) =  0.0            Y (  3) =  0.0            Y (  4) =  0.0
Y (  5) =  0.2900E 03     Y (  6) =  0.0

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) =  0.0            Y'(  2) =  0.0            Y'(  3) =  0.0            Y'(  4) =  0.0
Y'(  5)    0.0            Y'(  6) =  0.2900E 03
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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```
TIME  0.0          Y3/ACC 0.0          Y3/VEL 0.0          Y3  0.0          F(Y3)  8.3300E 00   FD    0.0
TIME  0.0          Y2/ACC 0.0          Y2/VEL 0.0          Y2  0.0          Y3-Y2  0.0          FX2  -0.0
TIME  0.0          X/ACC  0.0          X/VEL  2.9000E 02   X   0.0          Y1-2Y2 0.0          FK1   0.0
TIME  0.0          Y1     0.0          SIN    0.0

TIME  2.0000E-01   Y3/ACC 3.5981E 02   Y3/VEL 4.8601E 01   Y3  3.0019E 00   F(Y3)  7.8967E 00   FD    1.8652E 04
TIME  2.0000E-01   Y2/ACC 3.8047E 02   Y2/VEL 5.7876E 01   Y2  4.0236E 00   Y3-Y2 -1.0217E 00   FX2   2.5849E 04
TIME  2.0000E-01   X/ACC -1.2942E 01   X/VEL  2.8905E 02   X   5.7953E 01   Y1-2Y2 4.7337E 00   FK1   2.1538E 04
TIME  2.0000E-01   Y1     1.2781E 01   SIN    4.2062E-01

TIME  4.0000E-01   Y3/ACC 1.7732E 02   Y3/VEL 8.8556E 01   Y3  1.7496E 01   F(Y3)  5.8047E 00   FD    4.5522E 04
TIME  4.0000E-01   Y2/ACC 1.7580E 02   Y2/VEL 9.2560E 01   Y2  1.9436E 01   Y3-Y2 -1.9395E 00   FX2   4.9068E 04
TIME  4.0000E-01   X/ACC -2.7634E 01   X/VEL  2.8513E 02   X   1.1542E 02   Y1-2Y2 6.2669E 00   FK1   2.8514E 04
TIME  4.0000E-01   Y1     4.5138E 01   SIN    6.7840E-01

TIME  6.0000E-01   Y3/ACC 1.1454E 02   Y3/VEL 1.2084E 02   Y3  3.8799E 01   F(Y3)  3.2961E 00   FD    4.8127E 04
TIME  6.0000E-01   Y2/ACC 7.2958E 01   Y2/VEL 1.1892E 02   Y2  4.0792E 01   Y3-Y2 -1.9928E 00   FX2   5.0418E 04
TIME  6.0000E-01   X/ACC -3.1030E 01   X/VEL  2.7885E 02   X   1.7103E 02   Y1-2Y2 5.9034E 00   FK1   2.6801E 04
TIME  6.0000E-01   Y1     8.7488E 01   SIN    8.0866E-01

TIME  8.0000E-01   Y3/ACC-2.2913E 02   Y3/VEL 1.2963E 02   Y3  6.4545E 01   F(Y3)  1.8727E 00   FD    3.1470E 04
TIME  8.0000E-01   Y2/ACC 3.8162E 00   Y2/VEL 1.2922E 02   Y2  6.5608E 01   Y3-Y2 -1.0628E 00   FX2   2.6808E 04
TIME  8.0000E-01   X/ACC -1.6933E 01   X/VEL  2.7386E 02   X   2.2706E 02   Y1-2Y2 2.9737E 00   FK1   1.3530E 04
TIME  8.0000E-01   Y1     1.3419E 02   SIN    8.7602E-01

TIME  1.0000E 00   Y3/ACC 1.0329E 02   Y3/VEL 1.0610E 02   Y3  8.7528E 01   F(Y3)  3.2517E 00   FD    3.7999E 04
TIME  1.0000E 00   Y2/ACC 7.8308E 01   Y2/VEL 1.1530E 02   Y2  8.9112E 01   Y3-Y2 -1.5836E 00   FX2   4.0064E 04
TIME  1.0000E 00   X/ACC -2.8470E 01   X/VEL  2.7022E 02   X   2.8151E 02   Y1-2Y2 4.7923E 00   FK1   2.1805E 04
TIME  1.0000E 00   Y1     1.8302E 02   SIN    9.1395E-01

TIME  1.2000E 00   Y3/ACC-1.4031E 01   Y3/VEL 1.1592E 02   Y3  1.1043E 02   F(Y3)  4.6259E 00   FD    6.2160E 04
TIME  1.2000E 00   Y2/ACC-1.9209E 01   Y2/VEL 1.1884E 02   Y2  1.1288E 02   Y3-Y2 -2.4452E 00   FX2   6.1863E 04
TIME  1.2000E 00   X/ACC -4.0816E 01   X/VEL  2.6315E 02   X   3.3489E 02   Y1-2Y2 6.7025E 00   FK1   3.0497E 04
TIME  1.2000E 00   Y1     2.3246E 02   SIN    9.3686E-01

TIME  1.4000E 00   Y3/ACC 2.8409E 01   Y3/VEL 1.1844E 02   Y3  1.3364E 02   F(Y3)  5.2000E 00   FD    7.2946E 04
TIME  1.4000E 00   Y2/ACC 3.1239E 01   Y2/VEL 1.1990E 02   Y2  1.3655E 02   Y3-Y2 -2.9057E 00   FX2   7.3514E 04
TIME  1.4000E 00   X/ACC -5.0925E 01   X/VEL  2.5384E 02   X   3.8662E 02   Y1-2Y2 8.2339E 00   FK1   3.7444E 04
TIME  1.4000E 00   Y1     2.8133E 02   SIN    9.5151E-01

TIME  1.6000E 00   Y3/ACC-4.4416E 01   Y3/VEL 1.1665E 02   Y3  1.5751E 02   F(Y3)  5.5503E 00   FD    7.5528E 04
TIME  1.6000E 00   Y2/ACC-3.8762E 01   Y2/VEL 1.1767E 02   Y2  1.6046E 02   Y3-Y2 -2.9502E 00   FX2   7.4639E 04
TIME  1.6000E 00   X/ACC -5.0047E 01   X/VEL  2.4371E 02   X   4.3637E 02   Y1-2Y2 8.0093E 00   FK1   3.6442E 04
TIME  1.6000E 00   Y1     3.2892E 02   SIN    9.6134E-01

TIME  1.8000E 00   Y3/ACC-1.3931E 01   Y3/VEL 1.0977E 02   Y3  1.8005E 02   F(Y3)  6.6027E 00   FD    7.9563E 04
TIME  1.8000E 00   Y2/ACC-1.9915E 01   Y2/VEL 1.1145E 02   Y2  1.8318E 02   Y3-Y2 -3.1338E 00   FX2   7.9285E 04
TIME  1.8000E 00   X/ACC -5.4210E 01   X/VEL  2.3337E 02   X   4.8410E 02   Y1-2Y2 8.6135E 00   FK1   3.9192E 04
TIME  1.8000E 00   Y1     3.7498E 02   SIN    9.6824E-01
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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```
TIME   2.0000E 00   Y3/ACC-1.9678E 01   Y3/VEL 1.0508E 02   3    2.0154E 02   F(Y3)  7.8203E 00   FD    8.6344E ..
TIME   2.0000E 00   Y2/ACC-2.0916E 01   Y2/VEL 1.0643E 02   Y2   2.0493E 02   Y3-Y2 -3.3973E 00   FX2   8.5951E 04
TIME   2.0000E 00   X/ACC -5.9094E 01   X/VEL  2.2205E 02   X    5.2966E 02   Y1-2Y2 9.3411E 00   FK1   4.2502E 04
TIME   2.0000E 00   Y1      4.1921E 02  SIN    9.7326E-01

TIME   2.2000E 00   Y3/ACC-2.8878E 01   Y3/VEL 9.9858E 01   Y3   2.2208E 02   F(Y3)  9.2661E 00   FD    9.2397E 04
TIME   2.2000E 00   Y2/ACC-3.3071E 01   Y2/VEL 1.0089E 02   Y2   2.2571E 02   Y3-Y2 -3.6292E 00   FX2   9.1820E 04
TIME   2.2000E 00   X/ACC -6.3033E 01   X/VEL  2.0983E 02   X    5.7286E 02   Y1-2Y2 9.9255E 00   FK1   4.9161E 04
TIME   2.2000E 00   Y1      4.6134E 02  SIN    9.7701E-01

TIME   2.4000E 00   Y3/ACC-5.4756E 01   Y3/VEL 9.4424E 01   Y3   2.4151E 02   F(Y3)  1.0967E 01   FD    9.7781E 04
TIME   2.4000E 00   Y2/ACC-3.0338E 01   Y2/VEL 9.5428E 01   Y2   2.4533E 02   Y3-Y2 -3.8216E 00   FX2   9.6686E 04
TIME   2.4000E 00   X/ACC -6.6710E 01   X/VEL  1.9682E 02   X    6.1354E 02   Y1-2Y2 1.0474E 01   FK1   4.7656E 04
TIME   2.4000E 00   Y1      5.0114E 02  SIN    9.7987E-01

TIME   2.6000E 00   Y3/ACC-2.8728E 01   Y3/VEL 8.5881E 01   Y3   2.5947E 02   F(Y3)  1.4139E 01   FD    1.0428E 05
TIME   2.6000E 00   Y2/ACC-2.1094E 01   Y2/VEL 8.7681E 01   Y2   2.6356E 02   Y3-Y2 -4.0991E 00   FX2   1.0371E 05
TIME   2.6000E 00   X/ACC -7.2080E 01   X/VEL  1.8303E 02   X    6.5154E 02   Y1-2Y2 1.1292E 01   FK1   5.1376E 04
TIME   2.6000E 00   Y1      5.3842E 02  SIN    9.8209E-01

TIME   2.8000E 00   Y3/ACC-4.9278E 01   Y3/VEL 7.5191E 01   Y3   2.7602E 02   F(Y3)  1.8509E 01   FD    1.1316E 05
TIME   2.8000E 00   Y2/ACC-5.7336E 01   Y2/VEL 8.0551E 01   Y2   2.8046E 02   Y3-Y2 -4.4338E 00   FX2   1.1218E 05
TIME   2.8000E 00   X/ACC -7.7006E 01   X/VEL  1.6812E 02   X    6.8667E 02   Y1-2Y2 1.2042E 01   FK1   5.4790E 04
TIME   2.8000E 00   Y1      5.7295E 02  SIN    9.8383E-01

TIME   3.0000E 00   Y3/ACC-3.5300E 01   Y3/VEL 6.9031E 01   Y3   2.9070E 02   F(Y3)  2.6076E 01   FD    1.2426E 05
TIME   3.0000E 00   Y2/ACC-5.2192E 01   Y2/VEL 7.1596E 01   Y2   2.9559E 02   Y3-Y2 -4.8835E 00   FX2   1.2355E 05
TIME   3.0000E 00   X/ACC -8.5284E 01   X/VEL  1.5190E 02   X    7.1870E 02   Y1-2Y2 1.3318E 01   FK1   6.0505E 04
TIME   3.0000E 00   Y1      6.0449E 02  SIN    9.8521E-01

TIME   3.2000E 00   Y3/ACC-3.9184E 01   Y3/VEL 5.9787E 01   Y3   3.0358E 02   F(Y3)  3.8379E 01   FD    1.3718E 05
TIME   3.2000E 00   Y2/ACC-4.7771E 01   Y2/VEL 6.1944E 01   Y2   3.0897E 02   Y3-Y2 -5.3914E 00   FX2   1.3640E 05
TIME   3.2000E 00   X/ACC -9.4571E 01   X/VEL  1.3394E 02   X    7.4731E 02   Y1-2Y2 1.4751E 01   FK1   6.7119E 04
TIME   3.2000E 00   Y1      6.3270E 02  SIN    9.8630E-01

TIME   3.4000E 00   Y3/ACC-6.1728E 01   Y3/VEL 5.0403E 01   Y3   3.1471E 02   F(Y3)  5.9040E 01   FD    1.4999E 05
TIME   3.4000E 00   Y2/ACC-6.6143E 01   Y2/VEL 5.3014E 01   Y2   3.2059E 02   Y3-Y2 -5.8796E 00   FX2   1.4875E 05
TIME   3.4000E 00   X/ACC -1.0278E 02   X/VEL  1.1415E 02   X    7.7215E 02   Y1-2Y2 1.6018E 01   FK1   7.2880E 04
TIME   3.4000E 00   Y1      6.5720E 02  SIN    9.8715E-01

TIME   3.6000E 00   Y3/ACC-2.7637E 01   Y3/VEL 4.2287E 01   Y3   3.2387E 02   F(Y3)  8.9556E 01   FD    1.6014E 05
TIME   3.6000E 00   Y2/ACC-4.7179E 01   Y2/VEL 4.4010E 01   Y2   3.3017E 02   Y3-Y2 -6.3079E 00   FX2   1.5959E 05
TIME   3.6000E 00   X/ACC -1.1109E 02   X/VEL  9.2665E 01   X    7.9286E 02   Y1-2Y2 1.7302E 01   FK1   7.8726E 04
TIME   3.6000E 00   Y1      6.7765E 02  SIN    9.8780E-01

TIME   3.8000E 00   Y3/ACC-8.1594E 00   Y3/VEL 4.1639E 01   Y3   3.3227E 02   F(Y3)  9.0000E 01   FD    1.5605E 05
TIME   3.8000E 00   Y2/ACC-4.9480E 01   Y2/VEL 3.9116E 01   Y2   3.3843E 02   Y3-Y2 -6.1614E 00   FX2   1.5588E 05
TIME   3.8000E 00   X/ACC -1.0846E 02   X/VEL  7.0385E 01   X    8.0916E 02   Y1-2Y2 1.6084E 01   FK1   7.6821E 04
TIME   3.8000E 00   Y1      6.9375E 02  SIN    9.8828E-01

TIME   4.0000E 00   Y3/ACC-1.9850E 01   Y3/VEL 3.8560E 01   Y3   3.4032E 02   F(Y3)  9.0000E 01   FD    1.3382E 05
TIME   4.0000E 00   Y2/ACC-4.8159E 01   Y2/VEL 3.3083E 01   Y2   3.4559E 02   Y3-Y2 -5.2737E 00   FX2   1.3342E 05
TIME   4.0000E 00   X/ACC -9.2678E 01   X/VEL  5.0049E 01   X    8.2115E 02   Y1-2Y2 1.4422E 01   FK1   6.5622E 04
TIME   4.0000E 00   Y1      7.0561E 02  SIN    9.8861E-01
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)


```
TIME   4.2000E 00   Y3/ACC-2.7956E 01   Y3/VEL 3.3481E 01   Y3   3.4754E 02   F(Y3)  9.0000E 01   FD    1.0089E 05
TIME   4.2000E 00   Y2/ACC-4.4459E 01   Y2/VEL 2.6706E 01   Y2   3.5150E 02   Y3-Y2 -3.9656E 00   FX2   1.0033E 05
TIME   4.2000E 00   X/ACC -6.9442E 01   X/VEL  3.3725E 01   X    8.2945E 02   Y1-2Y2 1.0804E 01   FK1   4.9158E 04
TIME   4.2000E 00   Y1      7.1381E 02  SIN    9.8883E-01

TIME   4.4000E 00   Y3/ACC-3.3718E 01   Y3/VEL 2.7006E 01   Y3   3.5360E 02   F(Y3)  9.0000E 01   FD    6.5642E 04
TIME   4.4000E 00   Y2/ACC-3.8730E 01   Y2/VEL 2.0525E 01   Y2   3.5616E 02   Y3-Y2 -2.5679E 00   FX2   6.4967E 04
TIME   4.4000E 00   X/ACC -4.4655E 01   X/VEL  2.2310E 01   X    8.3497E 02   Y1-2Y2 6.9465E 00   FK1   3.1607E 04
TIME   4.4000E 00   Y1      7.1927E 02  SIN    9.8898E-01

TIME   4.6000E 00   Y3/ACC-3.4835E 01   Y3/VEL 1.9837E 01   Y3   3.5827E 02   F(Y3)  9.0000E 01   FD    3.5416E 04
TIME   4.6000E 00   Y2/ACC-3.2119E 01   Y2/VEL 1.4898E 01   Y2   3.5965E 02   Y3-Y2 -1.3723E 00   FX2   3.4720E 04
TIME   4.6000E 00   X/ACC -2.3501E 01   X/VEL  1.5573E 01   X    8.3869E 02   Y1-2Y2 3.6555E 00   FK1   1.6633E 04
TIME   4.6000E 00   Y1      7.2295E 02  SIN    9.8907E-01

TIME   4.8000E 00   Y3/ACC-3.0262E 01   Y3/VEL 1.2938E 01   Y3   3.6153E 02   F(Y3)  9.0000E 01   FD    1.5065E 04
TIME   4.8000E 00   Y2/ACC-2.4164E 01   Y2/VEL 1.0151E 01   Y2   3.6210E 02   Y3-Y2 -5.7153E-01   FX2   1.4460E 04
TIME   4.8000E 00   X/ACC -9.4432E 00   X/VEL  1.2402E 01   X    8.4144E 02   Y1-2Y2 1.4687E 00   FK1   6.6828E 03
TIME   4.8000E 00   Y1      7.2567E 02  SIN    9.8915E-01

TIME   5.0000E 00   Y3/ACC-1.7675E 01   Y3/VEL 7.7592E 00   Y3   3.6355E 02   F(Y3)  9.0000E 01   FD    5.4184E 03
TIME   5.0000E 00   Y2/ACC-1.3286E 01   Y2/VEL 6.8243E 00   Y2   3.6375E 02   Y3-Y2 -2.0020E-01   FX2   5.0649E 03
TIME   5.0000E 00   X/ACC -3.1537E 00   X/VEL  1.1254E 01   X    8.4378E 02   Y1-2Y2 4.9048E-01   FK1   2.2317E 03
TIME   5.0000E 00   Y1      7.2799E 02  SIN    9.8920E-01

TIME   5.2000E 00   Y3/ACC-3.7133E 00   Y3/VEL 5.5944E 00   Y3   3.6483E 02   F(Y3)  9.0000E 01   FD    2.8167E 03
TIME   5.2000E 00   Y2/ACC-3.0625E 00   Y2/VEL 5.4652E 00   Y2   3.6494E 02   Y3-Y2 -1.0840E-01   FX2   2.7425E 03
TIME   5.2000E 00   X/ACC -1.8399E 00   X/VEL  1.0800E 01   X    8.4598E 02   Y1-2Y2 2.8613E-01   FK1   1.3019E 03
TIME   5.2000E 00   Y1      7.3017E 02  SIN    9.8926E-01

TIME   5.4000E 00   Y3/ACC-9.9839E-01   Y3/VEL 5.2410E 00   Y3   3.6591E 02   F(Y3)  9.0000E 01   FD    2.4721E 03
TIME   5.4000E 00   Y2/ACC-7.7264E-01   Y2/VEL 5.2086E 00   Y2   3.6600E 02   Y3-Y2 -9.6924E-02   FX2   2.4522E 03
TIME   5.4000E 00   X/ACC -1.7081E 00   X/VEL  1.0447E 01   X    8.4811E 02   Y1-2Y2 2.6563E-01   FK1   1.2086E 03
TIME   5.4000E 00   Y1      7.3227E 02  SIN    9.8931E-01

TIME   5.6000E 00   Y3/ACC-6.5614E-01   Y3/VEL 5.0740E 00   Y3   3.6694E 02   F(Y3)  9.0000E 01   FD    2.3171E 03
TIME   5.6000E 00   Y2/ACC-8.8425E-01   Y2/VEL 5.0453E 00   Y2   3.6703E 02   Y3-Y2 -9.1064E-02   FX2   2.3039E 03
TIME   5.6000E 00   X/ACC -1.5999E 00   X/VEL  1.0116E 01   X    8.5016E 02   Y1-2Y2 2.4878E-01   FK1   1.1319E 03
TIME   5.6000E 00   Y1      7.3430E 02  SIN    9.8936E-01

TIME   5.8000E 00   Y3/ACC-8.2909E-01   Y3/VEL 4.9129E 00   Y3   3.6794E 02   F(Y3)  9.0000E 01   FD    2.1723E 03
TIME   5.8000E 00   Y2/ACC-6.5241E-01   Y2/VEL 4.8873E 00   Y2   3.6802E 02   Y3-Y2 -8.5205E-02   FX2   2.1557E 03
TIME   5.8000E 00   X/ACC -1.5026E 00   X/VEL  9.8064E 00   X    8.5216E 02   Y1-2Y2 2.3364E-01   FK1   1.0631E 03
TIME   5.8000E 00   Y1      7.3627E 02  SIN    9.8941E-01

TIME   6.0000E 00   Y3/ACC-7.9252E-01   Y3/VEL 4.7631E 00   Y3   3.6890E 02   F(Y3)  9.0000E 01   FD    2.0418E 03
TIME   6.0000E 00   Y2/ACC-6.8260E-01   Y2/VEL 4.7398E 00   Y2   3.6898E 02   Y3-Y2 -8.0078E-02   FX2   2.0260E 03
TIME   6.0000E 00   X/ACC -1.4100E 00   X/VEL  9.5152E 00   X    8.5409E 02   Y1-2Y2 2.1924E-01   FK1   9.9753E 02
TIME   6.0000E 00   Y1      7.3819E 02  SIN    9.8946E-01

TIME   6.2000E 00   Y3/ACC-8.4852E-01   Y3/VEL 4.6255E 00   Y3   3.6984E 02   F(Y3)  9.0000E 01   FD    1.9256E 03
TIME   6.2000E 00   Y2/ACC-6.4216E-01   Y2/VEL 4.6025E 00   Y2   3.6992E 02   Y3-Y2 -7.5439E-02   FX2   1.9086E 03
TIME   6.2000E 00   X/ACC -1.3284E 00   X/VEL  9.2412E 00   X    8.5596E 02   Y1-2Y2 2.0654E-01   FK1   9.3977E 02
TIME   6.2000E 00   Y1      7.4004E 02  SIN    9.8950E-01
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

MIDAS

```
TIME   .4000E 00    Y3/ACC-6.0492E-01    Y3/VEL 4.4916E 00         3.7075E 02   F(Y3)  9.0000E 01   FD    1.8157E
TIME  6.4000E 00    Y2/ACC-6.2922E-01    Y2/VEL 4.4725E 00    Y2   3.7082E 02   Y3-Y2 -7.1289E-02   FX2   1.8036E 03
TIME  6.4000E 00    X/ACC -1.2547E 00    X/VEL  8.9829E 00    X    8.5778E 02   Y1-2Y2 1.9507E-01   FK1   8.8756E 02
TIME  6.4000E 00    Y1        7.4184E 02 SIN      9.8955E-01

TIME  6.6000E 00    Y3/ACC-6.2178E-01    Y3/VEL 4.3681E 00    Y3   3.7164E 02   F(Y3)  9.0000E 01   FD    1.7172E 03
TIME  6.6000E 00    Y2/ACC-6.5456E-01    Y2/VEL 4.3504E 00    Y2   3.7171E 02   Y3-Y2 -6.7383E-02   FX2   1.7048E 03
TIME  6.6000E 00    X/ACC -1.1841E 00    X/VEL  8.7388E 00    X    8.5956E 02   Y1-2Y2 1.8408E-01   FK1   8.3757E 02
TIME  6.6000E 00    Y1        7.4360E 02 SIN      9.8959E-01

TIME  6.8000E 00    Y3/ACC-3.4567E-01    Y3/VEL 4.2495E 00    Y3   3.7250E 02   F(Y3)  9.0000E 01   FD    1.6252E 03
TIME  6.8000E 00    Y2/ACC-7.0740E-01    Y2/VEL 4.2339E 00    Y2   3.7256E 02   Y3-Y2 -6.3965E-02   FX2   1.6183E 03
TIME  6.8000E 00    X/ACC -1.1213E 00    X/VEL  8.5080E 00    X    8.6128E 02   Y1-2Y2 1.7432E-01   FK1   7.9314E 02
TIME  6.8000E 00    Y1        7.4530E 02 SIN      9.8963E-01

TIME  7.0000E 00    Y3/ACC-5.6339E-01    Y3/VEL 4.1407E 00    Y3   3.7334E 02   F(Y3)  9.0000E 01   FD    1.5431E 03
TIME  7.0000E 00    Y2/ACC-5.6398E-01    Y2/VEL 4.1227E 00    Y2   3.7340E 02   Y3-Y2 -6.0547E-02   FX2   1.5318E 03
TIME  7.0000E 00    X/ACC -1.0648E 00    X/VEL  8.2892E 00    X    8.6296E 02   Y1-2Y2 1.6553E-01   FK1   7.5315E 02
TIME  7.0000E 00    Y1        7.4697E 02 SIN      9.8967E-01

TIME  7.2000E 00    Y3/ACC-3.3552E-01    Y3/VEL 4.0338E 00    Y3   3.7416E 02   F(Y3)  9.0000E 01   FD    1.4644E 03
TIME  7.2000E 00    Y2/ACC-6.9339E-01    Y2/VEL 4.0186E 00    Y2   3.7421E 02   Y3-Y2 -5.7617E-02   FX2   1.4577E 03
TIME  7.2000E 00    X/ACC -1.0083E 00    X/VEL  8.0815E 00    X    8.6460E 02   Y1-2Y2 1.5674E-01   FK1   7.1316E 02
TIME  7.2000E 00    Y1        7.4859E 02 SIN      9.8971E-01

TIME  7.4000E 00    Y3/ACC-5.0487E-01    Y3/VEL 3.9352E 00    Y3   3.7495E 02   F(Y3)  9.0000E 01   FD    1.3937E 03
TIME  7.4000E 00    Y2/ACC-5.7746E-01    Y2/VEL 3.9192E 00    Y2   3.7501E 02   Y3-Y2 -5.4687E-02   FX2   1.3836E 03
TIME  7.4000E 00    X/ACC -9.5966E-01    X/VEL  7.8841E 00    X    8.6619E 02   Y1-2Y2 1.4917E-01   FK1   6.7072E 02
TIME  7.4000E 00    Y1        7.5017E 02 SIN      9.8975E-01

TIME  7.6000E 00    Y3/ACC-5.0360E-01    Y3/VEL 3.8380E 00    Y3   3.7573E 02   F(Y3)  9.0000E 01   FD    1.3257E 03
TIME  7.6000E 00    Y2/ACC-4.5075E-01    Y2/VEL 3.8259E 00    Y2   3.7578E 02   Y3-Y2 -5.2002E-02   FX2   1.3156E 03
TIME  7.6000E 00    X/ACC -9.1572E-01    X/VEL  7.6963E 00    X    8.6775E 02   Y1-2Y2 1.4233E-01   FK1   6.4762E 02
TIME  7.6000E 00    Y1        7.5171E 02 SIN      9.8978E-01

TIME  7.8000E 00    Y3/ACC-1.5442E-01    Y3/VEL 3.7463E 00    Y3   3.7649E 02   F(Y3)  9.0000E 01   FD    1.2631E 03
TIME  7.8000E 00    Y2/ACC-5.9687E-01    Y2/VEL 3.7401E 00    Y2   3.7654E 02   Y3-Y2 -4.9805E-02   FX2   1.2681E 03
TIME  7.8000E 00    X/ACC -8.7177E-01    X/VEL  7.5173E 00    X    8.6927E 02   Y1-2Y2 1.3550E-01   FK1   6.1652E 02
TIME  7.8000E 00    Y1        7.5321E 02 SIN      9.8982E-01

TIME  8.0000E 00    Y3/ACC-1.5780E-01    Y3/VEL 3.6631E 00    Y3   3.7723E 02   F(Y3)  9.0000E 01   FD    1.2076E 03
TIME  8.0000E 00    Y2/ACC-6.4486E-01    Y2/VEL 3.6512E 00    Y2   3.7728E 02   Y3-Y2 -4.7607E-02   FX2   1.2049E 03
TIME  8.0000E 00    X/ACC -8.3096E-01    X/VEL  7.3465E 00    X    8.7076E 02   Y1-2Y2 1.2919E-01   FK1   5.8763E 02
TIME  8.0000E 00    Y1        7.5468E 02 SIN      9.8985E-01

TIME  8.2000E 00    Y3/ACC-6.0028E-01    Y3/VEL 3.5819E 00    Y3   3.7795E 02   F(Y3)  9.0000E 01   FD    1.1547E 03
TIME  8.2000E 00    Y2/ACC-3.6017E-01    Y2/VEL 3.5690E 00    Y2   3.7800E 02   Y3-Y2 -4.5166E-02   FX2   1.1427E 03
TIME  8.2000E 00    X/ACC -7.9643E-01    X/VEL  7.1835E 00    X    8.7221E 02   Y1-2Y2 1.2378E-01   FK1   5.6320E 02
TIME  8.2000E 00    Y1        7.5612E 02 SIN      9.8989E-01

TIME  8.4000E 00    Y3/ACC-4.3575E-01    Y3/VEL 3.4992E 00    Y3   3.7866E 02   F(Y3)  9.0000E 01   FD    1.1020E 03
TIME  8.4000E 00    Y2/ACC-3.4031E-01    Y2/VEL 3.4912E 00    Y2   3.7871E 02   Y3-Y2 -4.3213E-02   FX2   1.0933E 03
TIME  8.4000E 00    X/ACC -7.6189E-01    X/VEL  7.0276E 00    X    8.7363E 02   Y1-2Y2 1.1841E-01   FK1   5.3076E 02
TIME  8.4000E 00    Y1        7.5753E 02 SIN      9.8992E-01
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Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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MIDAS

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TIME  8.6000E 00    Y3/ACC-3.3389E-01    Y3/VEL 3.4266E 00    Y3   3.7935E 02   F(Y3)  9.0000E 01   FD    1.0567E 03
TIME  8.6000E 00    Y2/ACC-4.2380E-01    Y2/VEL 3.4192E 00    Y2   3.7940E 02   Y3-Y2 -4.1904E-02   FX2   1.0500E 03
TIME  8.6000E 00    X/ACC -7.2893E-01    X/VEL  6.8704E 00    X    8.7502E 02   Y1-2Y2 1.1328E-01   FK1   5.1943E 02
TIME  8.6000E 00    Y1        7.5890E 02 SIN      9.8995E-01

TIME  8.8000E 00    Y3/ACC-6.1105E-01    Y3/VEL 3.3547E 00    Y3   3.8003E 02   F(Y3)  9.0000E 01   FD    1.0129E 03
TIME  8.8000E 00    Y2/ACC-2.6474E-01    Y2/VEL 3.3448E 00    Y2   3.8007E 02   Y3-Y2 -3.9551E-02   FX2   1.0006E 03
TIME  8.8000E 00    X/ACC -6.9910E-01    X/VEL  6.7355E 00    X    8.7638E 02   Y1-2Y2 1.0864E-01   FK1   4.9432E 02
TIME  8.8000E 00    Y1        7.6025E 02 SIN      9.8998E-01

TIME  9.0000E 00    Y3/ACC-3.6357E-01    Y3/VEL 3.2844E 00    Y3   3.8070E 02   F(Y3)  9.0000E 01   FD    9.7085E 02
TIME  9.0000E 00    Y2/ACC-2.8037E-01    Y2/VEL 3.2757E 00    Y2   3.8073E 02   Y3-Y2 -3.8086E-02   FX2   9.6357E 02
TIME  9.0000E 00    X/ACC -6.7241E-01    X/VEL  6.5985E 00    X    8.7772E 02   Y1-2Y2 1.0449E-01   FK1   4.7544E 02
TIME  9.0000E 00    Y1        7.6157E 02 SIN      9.9001E-01

TIME  9.2000E 00    Y3/ACC-5.8757E-01    Y3/VEL 3.2182E 00    Y3   3.8135E 02   F(Y3)  9.0000E 01   FD    9.3209E 02
TIME  9.2000E 00    Y2/ACC-1.5960E-01    Y2/VEL 3.2113E 00    Y2   3.8138E 02   Y3-Y2 -3.6377E-02   FX2   9.2034E 02
TIME  9.2000E 00    X/ACC -6.4573E-01    X/VEL  6.4669E 00    X    8.7902E 02   Y1-2Y2 1.0034E-01   FK1   4.5658E 02
TIME  9.2000E 00    Y1        7.6287E 02 SIN      9.9004E-01

TIME  9.4000E 00    Y3/ACC-2.8129E-01    Y3/VEL 3.1536E 00    Y3   3.8198E 02   F(Y3)  9.0000E 01   FD    8.9508E 02
TIME  9.4000E 00    Y2/ACC-3.1165E-01    Y2/VEL 3.1483E 00    Y2   3.8202E 02   Y3-Y2 -3.5156E-02   FX2   8.8945E 02
TIME  9.4000E 00    X/ACC -6.1903E-01    X/VEL  6.3405E 00    X    8.8030E 02   Y1-2Y2 9.6191E-02   FK1   4.3767E 02
TIME  9.4000E 00    Y1        7.6413E 02 SIN      9.9007E-01

TIME  9.6000E 00    Y3/ACC-4.8109E-01    Y3/VEL 3.0948E 00    Y3   3.8261E 02   F(Y3)  9.0000E 01   FD    8.6201E 02
TIME  9.6000E 00    Y2/ACC-2.2915E-01    Y2/VEL 3.0875E 00    Y2   3.8264E 02   Y3-Y2 -3.3691E-02   FX2   8.5239E 02
TIME  9.6000E 00    X/ACC -5.9548E-01    X/VEL  6.2190E 00    X    8.8156E 02   Y1-2Y2 9.2529E-02   FK1   4.2101E 02
TIME  9.6000E 00    Y1        7.6538E 02 SIN      9.9010E-01

TIME  9.8000E 00    Y3/ACC-3.5756E-01    Y3/VEL 3.0344E 00    Y3   3.8322E 02   F(Y3)  9.0000E 01   FD    8.2866E 02
TIME  9.8000E 00    Y2/ACC-2.3400E-01    Y2/VEL 3.0296E 00    Y2   3.8325E 02   Y3-Y2 -3.2471E-02   FX2   8.2191E 02
TIME  9.8000E 00    X/ACC -5.7350E-01    X/VEL  6.1021E 00    X    8.8279E 02   Y1-2Y2 8.9111E-02   FK1   4.0546E 02
TIME  9.8000E 00    Y1        7.6660E 02 SIN      9.9012E-01

TIME  1.0000E 01    Y3/ACC-8.7781E-02    Y3/VEL 2.9787E 00    Y3   3.8382E 02   F(Y3)  9.0000E 01   FD    7.9856E 02
TIME  1.0000E 01    Y2/ACC-4.2433E-01    Y2/VEL 2.9733E 00    Y2   3.8385E 02   Y3-Y2 -3.1494E-02   FX2   7.9680E 02
TIME  1.0000E 01    X/ACC -5.4995E-01    X/VEL  5.9896E 00    X    8.8400E 02   Y1-2Y2 8.5449E-02   FK1   3.8879E 02
TIME  1.0000E 01    Y1        7.6779E 02 SIN      9.9015E-01

TIME  1.0000E 01    Y3/ACC-8.6865E-02    Y3/VEL 2.9787E 00    Y3   3.8382E 02   F(Y3)  9.0000E 01   FD    7.9854E 02
TIME  1.0000E 01    Y2/ACC-3.7527E-01    Y2/VEL 2.9731E 00    Y2   3.8385E 02   Y3-Y2 -3.1494E-02   FX2   7.9680E 02
TIME  1.0000E 01    X/ACC -5.5152E-01    X/VEL  5.9893E 00    X    8.8400E 02   Y1-2Y2 8.5693E-02   FK1   3.8990E 02
TIME  1.0000E 01    Y1        7.6780E 02 SIN      9.9015E-01
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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MIDAS

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CO'  NTS C(I) ARE ..

     0.1400000E 04   0.4528000E 02   0.2000000E 02   0.0             0.4550000E 04   0.2530000E 05
     0.2000000E 01   0.1250000E 03   0.1000000E 02   0.1000000E 01   0.1000000E 04   0.2000000E 00


THE NON-ZERO INITIAL VALUES ARE..


     0.2000000E 03   0.0            0.0            0.0            0.0            0.0


VALUES FOR FUNCTION GENERATOR NUMBER    1
NUMBER OF POINTS =      14
X =   0.0              F(X) =   0.8330000E 01
X =   0.3000000E 02    F(X) =   0.4000000E 01
X =   0.6000000E 02    F(X) =   0.1599999E 01
X =   0.1200000E 03    F(X) =   0.5200000E 01
X =   0.1500000E 03    F(X) =   0.9200000E 01
X =   0.1800000E 03    F(X) =   0.6599999E 01
X =   0.2100000E 03    F(X) =   0.8299999E 01
X =   0.2400000E 03    F(X) =   0.1070000E 02
X =   0.2700000E 03    F(X) =   0.1600000E 02
X =   0.2820000E 03    F(X) =   0.2100000E 02
X =   0.2940000E 03    F(X) =   0.2800000E 02
X =   0.3060000E 03    F(X) =   0.4100000E 02
X =   0.3120000E 03    F(X) =   0.5000000E 02
X =   0.3240000E 03    F(X) =   0.9000000E 02


NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  6


INITIAL CONDITIONS FOR INTEGRATION VARIABLES
Y (  1) =  0.0             Y (  2) =  0.0          Y (  3) =  0.0          Y (  4) =  0.0
Y (  5) =  0.2000E 03      Y (  6) =  0.0

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) =  0.0             Y'(  2) =  0.0          Y'(  3) =  0.0          Y'(  4) =  0.0
Y'(  5) =  0.0             Y'(  6) =  0.2000E 03
```

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)


```
TIME   0.0            Y3/ACC 0.0            Y3/VEL 0.0            Y3   0.0           F(Y3)  8.3300E 00    FD    0.0
TIME   0.0            Y2/ACC 0.0            Y2/VEL 0.0            Y2   0.0           Y3-Y2  0.0           FX2  -0.0
TIME   0.0            X/ACC  0.0            X/VEL  2.0000E 02     X    0.0           Y1-2Y2 0.0           FK1   0.0
TIME   0.0            Y1     0.0            SIN    0.0

TIME   2.0000E-01     Y3/ACC 2.1416E 02     Y3/VEL 2.6803E 01     Y3   1.5806E 00    F(Y3)  8.1019E 00    FD    5.8203E 03
TIME   2.0000E-01     Y2/ACC 2.3493E 02     Y2/VEL 2.9731E 01     Y2   1.9800E 00    Y3-Y2 -3.9935E-01    FX2   1.0104E 04
TIME   2.0000E-01     X/ACC -4.5136E 00     X/VEL  1.9967E 02     X    3.9984E 01    Y1-2Y2 2.2792E 00    FK1   1.0371E 04
TIME   2.0000E-01     Y1     6.2392E 00     SIN    3.0467E-01

TIME   4.0000E-01     Y3/ACC 7.1912E 01     Y3/VEL 4.8611E 01     Y3   9.7597E 00    F(Y3)  6.9213E 00    FD    1.6356E 04
TIME   4.0000E-01     Y2/ACC 8.5304E 01     Y2/VEL 5.0431E 01     Y2   1.0463E 01    Y3-Y2 -7.0331E-01    FX2   1.7794E 04
TIME   4.0000E-01     X/ACC -8.3245E 00     X/VEL  1.9847E 02     X    7.9810E 01    Y1-2Y2 2.3798E 00    FK1   1.0828E 04
TIME   4.0000E-01     Y1     2.3306E 01     SIN    5.3814E-01

TIME   6.0000E-01     Y3/ACC 8.5227E 01     Y3/VEL 6.7179E 01     Y3   2.1320E 01    F(Y3)  5.2528E 00    FD    2.3703E 04
TIME   6.0000E-01     Y2/ACC 6.9656E 01     Y2/VEL 6.7630E 01     Y2   2.2324E 01    Y3-Y2 -1.0042E 00    FX2   2.5407E 04
TIME   6.0000E-01     X/ACC -1.4085E 01     X/VEL  1.9615E 02     X    1.1929E 02    Y1-2Y2 3.1386E 00    FK1   1.4281E 04
TIME   6.0000E-01     Y1     4.7787E 01     SIN    6.9040E-01

TIME   8.0000E-01     Y3/ACC 3.3433E 01     Y3/VEL 7.8975E 01     Y3   3.6137E 01    F(Y3)  3.5090E 00    FD    2.1806E 04
TIME   8.0000E-01     Y2/ACC 2.2952E 01     Y2/VEL 7.8133E 01     Y2   3.7029E 01    Y3-Y2 -8.9148E-01    FX2   2.2556E 04
TIME   8.0000E-01     X/ACC -1.3224E 01     X/VEL  1.9330E 02     X    1.5823E 02    Y1-2Y2 2.5927E 00    FK1   1.1797E 04
TIME   8.0000E-01     Y1     7.6650E 01     SIN    7.8469E-01

TIME   1.0000E 00     Y3/ACC 3.2138E 01     Y3/VEL 8.3980E 01     Y3   5.2414E 01    F(Y3)  2.2069E 00    FD    1.5964E 04
TIME   1.0000E 00     Y2/ACC 2.4719E 01     Y2/VEL 8.2503E 01     Y2   5.3055E 01    Y3-Y2 -6.4059E-01    FX2   1.6207E 04
TIME   1.0000E 00     X/ACC -1.0444E 01     X/VEL  1.9093E 02     X    1.9665E 02    Y1-2Y2 1.9040E 00    FK1   8.6632E 03
TIME   1.0000E 00     Y1     1.0801E 02     SIN    8.4393E-01

TIME   1.2000E 00     Y3/ACC-3.6620E 01     Y3/VEL 8.1489E 01     Y3   6.9336E 01    F(Y3)  2.1602E 00    FD    1.4344E 04
TIME   1.2000E 00     Y2/ACC-7.4495E 01     Y2/VEL 8.1779E 01     Y2   6.9874E 01    Y3-Y2 -5.3802E-01    FX2   1.3612E 04
TIME   1.2000E 00     X/ACC -6.4548E 00     X/VEL  1.8931E 02     X    2.3466E 02    Y1-2Y2 1.1252E 00    FK1   5.1194E 03
TIME   1.2000E 00     Y1     1.4087E 02     SIN    8.8259E-01

TIME   1.4000E 00     Y3/ACC 2.6897E 01     Y3/VEL 8.1910E 01     Y3   8.5219E 01    F(Y3)  3.1132E 00    FD    2.0887E 04
TIME   1.4000E 00     Y2/ACC 3.2522E 01     Y2/VEL 8.3437E 01     Y2   8.6066E 01    Y3-Y2 -8.4683E-01    FX2   2.1425E 04
TIME   1.4000E 00     X/ACC -1.4864E 01     X/VEL  1.8713E 02     X    2.7233E 02    Y1-2Y2 2.5162E 00    FK1   1.1449E 04
TIME   1.4000E 00     Y1     1.7465E 02     SIN    9.0884E-01

TIME   1.6000E 00     Y3/ACC-8.8525E 00     Y3/VEL 8.2072E 01     Y3   1.0178E 02    F(Y3)  4.1069E 00    FD    2.7664E 04
TIME   1.6000E 00     Y2/ACC-4.6908E 00     Y2/VEL 8.3320E 01     Y2   1.0287E 02    Y3-Y2 -1.0864E 00    FX2   2.7487E 04
TIME   1.6000E 00     X/ACC -1.8063E 01     X/VEL  1.8388E 02     X    3.0944E 02    Y1-2Y2 2.9972E 00    FK1   1.3637E 04
TIME   1.6000E 00     Y1     2.0873E 02     SIN    9.2721E-01

TIME   1.8000E 00     Y3/ACC-1.9535E 00     Y3/VEL 8.1622E 01     Y3   1.1816E 02    F(Y3)  5.0893E 00    FD    3.4072E 04
TIME   1.8000E 00     Y2/ACC-4.2499E 00     Y2/VEL 8.3008E 01     Y2   1.1950E 02    Y3-Y2 -1.3452E 00    FX2   3.4033E 04
TIME   1.8000E 00     X/ACC -2.2732E 01     X/VEL  1.7978E 02     X    3.4582E 02    Y1-2Y2 3.7187E 00    FK1   1.6920E 04
TIME   1.8000E 00     Y1     2.4272E 02     SIN    9.4045E-01

TIME   2.0000E 00     Y3/ACC 6.4031E 00     Y3/VEL 8.3731E 01     Y3   1.3469E 02    F(Y3)  5.2000E 00    FD    3.6457E 04
TIME   2.0000E 00     Y2/ACC-6.6357E 00     Y2/VEL 8.3739E 01     Y2   1.3614E 02    Y3-Y2 -1.4460E 00    FX2   3.6585E 04
TIME   2.0000E 00     X/ACC -2.4628E 01     X/VEL  1.7493E 02     X    3.8130E 02    Y1-2Y2 3.9873E 00    FK1   1.8142E 04
TIME   2.0000E 00     Y1     2.7627E 02     SIN    9.5024E-01
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Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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TIME   2.2000E 00   Y3/ACC-2.2910E 01   Y3/VEL 8.2046E 01   Y3   1.5131E 02   F(Y3)  5.2613E 00   FD    3.5417E 04
TIME   2.2000E 00   Y2/ACC-9.9284E 00   Y2/VEL 8.1864E 01   Y2   1.5270E 02   Y3-Y2 -1.3818E 00   FX2   3.4959E 04
TIME   2.2000E 00   X/ACC -2.3606E 01   X/VEL  1.7011E 02   X    4.1580E 02   Y1-2Y2 3.7922E 00   FK1   1.7259E 04
TIME   2.2000E 00   Y1        3.0918E 02   SIN    9.5766E-01

TIME   2.4000E 00   Y3/ACC-9.1568E 00   Y3/VEL 7.8049E 01   Y3   1.6728E 02   F(Y3)  6.0064E 00   FD    3.6589E 04
TIME   2.4000E 00   Y2/ACC-5.4274E 00   Y2/VEL 7.8732E 01   Y2   1.6872E 02   Y3-Y2 -1.4390E 00   FX2   3.6406E 04
TIME   2.4000E 00   X/ACC -2.4884E 01   X/VEL  1.6534E 02   X    4.4935E 02   Y1-2Y2 3.9736E 00   FK1   1.8080E 04
TIME   2.4000E 00   Y1        3.4141E 02   SIN    9.6342E-01

TIME   2.6000E 00   Y3/ACC-1.2098E 01   Y3/VEL 7.6421E 01   Y3   1.8275E 02   F(Y3)  6.7558E 00   FD    3.9955E 04
TIME   2.6000E 00   Y2/ACC-1.0658E 01   Y2/VEL 7.6939E 01   Y2   1.8430E 02   Y3-Y2 -1.5499E 00   FX2   3.9213E 04
TIME   2.6000E 00   X/ACC -2.6770E 01   X/VEL  1.6016E 02   X    4.8191E 02   Y1-2Y2 4.2561E 00   FK1   1.9369E 04
TIME   2.6000E 00   Y1        3.7289E 02   SIN    9.6797E-01

TIME   2.8000E 00   Y3/ACC-1.0395E 01   Y3/VEL 7.4085E 01   Y3   1.9780E 02   F(Y3)  7.6085E 00   FD    4.1760E 04
TIME   2.8000E 00   Y2/ACC-1.1002E 01   Y2/VEL 7.4542E 01   Y2   1.9944E 02   Y3-Y2 -1.6424E 00   FX2   4.1553E 04
TIME   2.8000E 00   X/ACC -2.8492E 01   X/VEL  1.5464E 02   X    5.1339E 02   Y1-2Y2 4.5115E 00   FK1   2.0527E 04
TIME   2.8000E 00   Y1        4.0339E 02   SIN    9.7162E-01

TIME   3.0000E 00   Y3/ACC-1.6455E 01   Y3/VEL 7.1747E 01   Y3   2.1240E 02   F(Y3)  8.4917E 00   FD    4.3713E 04
TIME   3.0000E 00   Y2/ACC-1.3218E 01   Y2/VEL 7.2138E 01   Y2   2.1411E 02   Y3-Y2 -1.7148E 00   FX2   4.3384E 04
TIME   3.0000E 00   X/ACC -2.9784E 01   X/VEL  1.4880E 02   X    5.4374E 02   Y1-2Y2 4.7017E 00   FK1   2.1393E 04
TIME   3.0000E 00   Y1        4.3292E 02   SIN    9.7458E-01

TIME   3.2000E 00   Y3/ACC-1.2192E 01   Y3/VEL 6.8802E 01   Y3   2.2644E 02   F(Y3)  9.6153E 00   FD    4.5516E 04
TIME   3.2000E 00   Y2/ACC-1.2395E 01   Y2/VEL 6.9215E 01   Y2   2.2823E 02   Y3-Y2 -1.7894E 00   FX2   4.5273E 04
TIME   3.2000E 00   X/ACC -3.1203E 01   X/VEL  1.4271E 02   X    5.7290E 02   Y1-2Y2 4.9133E 00   FK1   2.2358E 04
TIME   3.2000E 00   Y1        4.6138E 02   SIN    9.7701E-01

TIME   3.4000E 00   Y3/ACC-1.2764E 01   Y3/VEL 6.6286E 01   Y3   2.3999E 02   F(Y3)  1.0696E 01   FD    4.6998E 04
TIME   3.4000E 00   Y2/ACC-1.3615E 01   Y2/VEL 6.6493E 01   Y2   2.4180E 02   Y3-Y2 -1.8475E 00   FX2   4.6743E 04
TIME   3.4000E 00   X/ACC -3.2257E 01   X/VEL  1.3636E 02   X    6.0081E 02   Y1-2Y2 5.0688E 00   FK1   2.3063E 04
TIME   3.4000E 00   Y1        4.8867E 02   SIN    9.7904E-01

TIME   3.6000E 00   Y3/ACC-1.6679E 01   Y3/VEL 6.1068E 01   Y3   2.5275E 02   F(Y3)  1.2953E 01   FD    4.9580E 04
TIME   3.6000E 00   Y2/ACC-1.0999E 01   Y2/VEL 6.2566E 01   Y2   2.5470E 02   Y3-Y2 -1.9465E 00   FX2   4.9246E 04
TIME   3.6000E 00   X/ACC -3.4149E 01   X/VEL  1.2977E 02   X    6.2743E 02   Y1-2Y2 5.3569E 00   FK1   2.4574E 04
TIME   3.6000E 00   Y1        5.1476E 02   SIN    9.8073E-01

TIME   3.8000E 00   Y3/ACC-1.3829E 01   Y3/VEL 5.9094E 01   Y3   2.6485E 02   F(Y3)  1.5091E 01   FD    5.2699E 04
TIME   3.8000E 00   Y2/ACC-1.3479E 01   Y2/VEL 5.9577E 01   Y2   2.6692E 02   Y3-Y2 -2.0720E 00   FX2   5.2422E 04
TIME   3.8000E 00   X/ACC -3.6348E 01   X/VEL  1.2271E 02   X    6.5260E 02   Y1-2Y2 5.6936E 00   FK1   2.5906E 04
TIME   3.8000E 00   Y1        5.3954E 02   SIN    9.8215E-01

TIME   4.0000E 00   Y3/ACC-2.5701E 01   Y3/VEL 5.4803E 01   Y3   2.7631E 02   F(Y3)  1.8629E 01   FD    5.5950E 04
TIMF   4.0000E 00   Y2/ACC-3.1180E 01   Y2/VEL 5.5422E 01   Y2   2.7850E 02   Y3-Y2 -2.1912E 00   FX2   5.5436E 04
TIME   4.0000E 00   X/ACC -3.7947E 01   X/VEL  1.1530E 02   X    6.7649E 02   Y1-2Y2 5.9368E 00   FK1   2.7012E 04
TIME   4.0000E 00   Y1        5.6294E 02   SIN    9.8335E-01

TIME   4.2000E 00   Y3/ACC-2.0760E 01   Y3/VEL 5.0448E 01   Y3   2.8682E 02   F(Y3)  2.3810E 01   FD    6.0595E 04
TIME   4.2000E 00   Y2/ACC-2.9816E 01   Y2/VEL 5.1405E 01   Y2   2.8920E 02   Y3-Y2 -2.3787E 00   FX2   6.0180E 04
TIME   4.2000E 00   X/ACC -4.1369E 01   X/VEL  1.0735E 02   X    6.9876E 02   Y1-2Y2 6.4648E 00   FK1   2.9415E 04
TIME   4.2000E 00   Y1        5.8486E 02   SIN    9.8437E-01
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Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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TIME   4.4000E 00   Y3/ACC-2.6801E 01   Y3/VEL 4.6237E 01   Y3   2.9651E 02   F(Y3)  3.0715E 01   FD    6.5664E 04
TIME   4.4000E 00   Y2/ACC-3.1924E 01   Y2/VEL 4.7506E 01   Y2   2.9908E 02   Y3-Y2 -2.5742E 00   FX2   6.5128E 04
TIME   4.4000E 00   X/ACC -4.4816E 01   X/VEL  9.8694E 01   X    7.1938E 02   Y1-2Y2 6.9980E 00   FK1   3.1841E 04
TIME   4.4000E 00   Y1        6.0516E 02   SIN    9.8524E-01

TIME   4.6000E 00   Y3/ACC-1.5144E 01   Y3/VEL 4.1889E 01   Y3   3.0527E 02   F(Y3)  4.0211E 01   FD    7.0557E 04
TIME   4.6000E 00   Y2/ACC-2.2925E 01   Y2/VEL 4.3003E 01   Y2   3.0805E 02   Y3-Y2 -2.7769E 00   FX2   7.0294E 04
TIME   4.6000E 00   X/ACC -4.8746E 01   X/VEL  8.9321E 01   X    7.3019E 02   Y1-2Y2 7.6062E 00   FK1   3.4608E 04
TIME   4.6000E 00   Y1        6.2370E 02   SIN    9.8596E-01

TIME   4.8000E 00   Y3/ACC-3.6691E 01   Y3/VEL 3.7212E 01   Y3   3.1323E 02   F(Y3)  5.4085E 01   FD    7.4892E 04
TIME   4.8000E 00   Y2/ACC-2.4401E 01   Y2/VEL 3.8408E 01   Y2   3.1618E 02   Y3-Y2 -2.9312E 00   FX2   7.4198E 04
TIME   4.8000E 00   X/ACC -5.1480E 01   X/VEL  7.9285E 01   X    7.5506E 02   Y1-2Y2 8.0278E 00   FK1   3.6527E 04
TIME   4.8000E 00   Y1        6.4034E 02   SIN    9.8657E-01

TIME   5.0000E 00   Y3/ACC-1.6887E 01   Y3/VEL 3.2017E 01   Y3   3.2009E 02   F(Y3)  7.6974E 01   FD    7.8986E 04
TIME   5.0000E 00   Y2/ACC-1.5279E 01   Y2/VEL 3.3144E 01   Y2   3.2320E 02   Y3-Y2 -3.1055E 00   FX2   7.8568E 04
TIME   5.0000E 00   X/ACC -5.4907E 01   X/VEL  6.8663E 01   X    7.6987E 02   Y1-2Y2 8.5579E 00   FK1   3.8938E 04
TIME   5.0000E 00   Y1        6.5495E 02   SIN    9.8707E-01

TIME   5.2000E 00   Y3/ACC-2.1156E 00   Y3/VEL 2.9728E 01   Y3   3.2620E 02   F(Y3)  9.0000E 01   FD    7.9537E 04
TIME   5.2000E 00   Y2/ACC-1.8358E 00   Y2/VEL 2.9255E 01   Y2   3.2934E 02   Y3-Y2 -3.1421E 00   FX2   7.9495E 04
TIME   5.2000E 00   X/ACC -5.6012E 01   X/VEL  5.7526E 01   X    7.8250E 02   Y1-2Y2 8.7266E 00   FK1   3.9706E 04
TIME   5.2000E 00   Y1        6.6742E 02   SIN    9.8748E-01

TIME   5.4000E 00   Y3/ACC-1.0828E 01   Y3/VEL 2.8366E 01   Y3   3.3205E 02   F(Y3)  9.0000E 01   FD    7.2417E 04
TIME   5.4000E 00   Y2/ACC-8.2418E 00   Y2/VEL 2.4199E 01   Y2   3.3490E 02   Y3-Y2 -2.8538E 00   FX2   7.2208E 04
TIME   5.4000E 00   X/ACC -5.0679E 01   X/VEL  4.6786E 01   X    7.9291E 02   Y1-2Y2 7.8931E 00   FK1   3.5913E 04
TIME   5.4000E 00   Y1        6.7770E 02   SIN    9.8780E-01

TIME   5.6000E 00   Y3/ACC-1.6392E 01   Y3/VEL 2.5631E 01   Y3   3.3748E 02   F(Y3)  9.0000E 01   FD    5.9124E 04
TIME   5.6000E 00   Y2/ACC-1.1428E 01   Y2/VEL 2.2681E 01   Y2   3.3980E 02   Y3-Y2 -2.3240E 00   FX2   5.8797E 04
TIME   5.6000E 00   X/ACC -4.1130E 01   X/VEL  3.7581E 01   X    8.0131E 02   Y1-2Y2 6.4043E 00   FK1   2.9140E 04
TIME   5.6000E 00   Y1        6.8600E 02   SIN    9.8805E-01

TIME   5.8000E 00   Y3/ACC-1.8915E 01   Y3/VEL 2.2090E 01   Y3   3.4226E 02   F(Y3)  9.0000E 01   FD    4.3918E 04
TIME   5.8000E 00   Y2/ACC-1.2648E 01   Y2/VEL 1.9132E 01   Y2   3.4398E 02   Y3-Y2 -1.7209E 00   FX2   4.3540E 04
TIME   5.8000E 00   X/ACC -3.0330E 01   X/VEL  3.0450E 01   X    8.0808E 02   Y1-2Y2 4.7217E 00   FK1   2.1484E 04
TIME   5.8000E 00   Y1        6.9269E 02   SIN    9.8825E-01

TIME   6.0000E 00   Y3/ACC-1.8945E 01   Y3/VEL 1.8300E 01   Y3   3.4631E 02   F(Y3)  9.0000E 01   FD    3.0139E 04
TIME   6.0000E 00   Y2/ACC-1.1977E 01   Y2/VEL 1.5875E 01   Y2   3.4740E 02   Y3-Y2 -1.1763E 00   FX2   2.9760E 04
TIME   6.0000E 00   X/ACC -2.0627E 01   X/VEL  2.5397E 01   X    8.1363E 02   Y1-2Y2 3.2107E 00   FK1   1.4609E 04
TIME   6.0000E 00   Y1        6.9818E 02   SIN    9.8840E-01

TIME   6.2000E 00   Y3/ACC-1.6211E 01   Y3/VEL 1.4809E 01   Y3   3.4961E 02   F(Y3)  9.0000E 01   FD    1.9738E 04
TIME   6.2000E 00   Y2/ACC-1.0119E 01   Y2/VEL 1.3149E 01   Y2   3.5038E 02   Y3-Y2 -7.6733E-01   FX2   1.9414E 04
TIME   6.2000E 00   X/ACC -1.3384E 01   X/VEL  2.2049E 01   X    8.1835E 02   Y1-2Y2 2.0830E 00   FK1   9.4777E 03
TIME   6.2000E 00   Y1        7.0284E 02   SIN    9.8853E-01

TIME   6.4000E 00   Y3/ACC-1.1581E 01   Y3/VEL 1.2066E 01   Y3   3.5229E 02   F(Y3)  9.0000E 01   FD    1.3104E 04
TIME   6.4000E 00   Y2/ACC-7.3098E 00   Y2/VEL 1.1107E 01   Y2   3.5280E 02   Y3-Y2 -5.0879E-01   FX2   1.2872E 04
TIME   6.4000E 00   X/ACC -8.8564E 00   X/VEL  1.9870E 01   X    8.2253E 02   Y1-2Y2 1.3782E 00   FK1   6.2707E 03
TIPE   6.4000E 00   Y1        7.0697E 02   SIN    9.8865E-01
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Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

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TIME	.6000E 00	Y3/ACC-6.7139E 00	Y3/VEL 1.0240E 01		3.5451E 02	F(Y3) 9.0000E 01	FD	9.4365E 0.
TIME	6.6000E 00	Y2/ACC-5.0543E 00	Y2/VEL 9.7480E 00	Y2	3.5487E 02	Y3-Y2 -3.6768E-01	FX2	9.3022E 03
TIME	6.6000E 00	X/ACC -6.4081E 00	X/VEL 1.8372E 01	X	8.2634E 02	Y1-2Y2 9.9707E-01	FK1	4.5367E 03
TIME	6.6000E 00	Y1 7.1075E 02	SIN 9.8875E-01					
TIME	6.8000E 00	Y3/ACC-4.3719E 00	Y3/VEL 9.1435E 00	Y3	3.5444E 02	F(Y3) 9.0000E 01	FD	7.5243E 03
TIME	6.8000E 00	Y2/ACC-3.3063E 00	Y2/VEL 8.8761E 00	Y2	3.5473E 02	Y3-Y2 -2.9395E-01	FX2	7.4368E 03
TIME	6.8000E 00	X/ACC -5.1470E 00	X/VEL 1.7230E 01	X	8.2990E 02	Y1-2Y2 8.0078E-01	FK1	3.6436E 03
TIME	6.8000E 00	Y1 7.1424E 02	SIN 9.8885E-01					
TIME	7.0000E 00	Y3/ACC-2.8762E 00 *	Y3/VEL 8.4456E 00	Y3	3.5819E 02	F(Y3) 9.0000E 01	FD	6.4196E 03
TIME	7.0000E 00	Y2/ACC-2.3898E 00	Y2/VEL 8.2777E 00	Y2	3.5844E 02	Y3-Y2 -2.5144E-01	FX2	6.3621E 03
TIME	7.0000E 00	X/ACC -4.4177E 00	X/VEL 1.6280E 01	X	8.3329E 02	Y1-2Y2 6.8726E-01	FK1	3.1270E 03
TIME	7.0000E 00	Y1 7.1757E 02	SIN 9.8893E-01					
TIME	7.2000E 00	Y3/ACC-2.6145E 00	Y3/VEL 7.9399E 00	Y3	3.5983E 02	F(Y3) 9.0000E 01	FD	5.6731E 03
TIME	7.2000E 00	Y2/ACC-1.9626E 00	Y2/VEL 7.8100E 00	Y2	3.6005E 02	Y3-Y2 -2.2217E-01	FX2	5.6208E 03
TIME	7.2000E 00	X/ACC -3.9080E 00	X/VEL 1.5450E 01	X	8.3642E 02	Y1-2Y2 6.0791E-01	FK1	2.7640E 03
TIME	7.2000E 00	Y1 7.2071E 02	SIN 9.8902E-01					
TIME	7.4000E 00	Y3/ACC-1.4934E 00	Y3/VEL 7.5148E 00	Y3	3.6137E 02	F(Y3) 9.0000E 01	FD	5.0825E 03
TIME	7.4000E 00	Y2/ACC-1.9734E 00	Y2/VEL 7.4207E 00	Y2	3.6157E 02	Y3-Y2 -1.9971E-01	FX2	5.0526E 03
TIME	7.4000E 00	X/ACC -3.5045E 00	X/VEL 1.4709E 01	X	8.3943E 02	Y1-2Y2 5.4541E-01	FK1	2.4816E 03
TIME	7.4000E 00	Y1 7.2369E 02	SIN 9.8909E-01					
TIME	7.6000E 00	Y3/ACC-1.7391E 00	Y3/VEL 7.1535E 00	Y3	3.6284E 02	F(Y3) 9.0000E 01	FD	4.6056E 03
TIME	7.6000E 00	Y2/ACC-1.7351E 00	Y2/VEL 7.0665E 00	Y2	3.6302E 02	Y3-Y2 -1.8066E-01	FX2	4.5708E 03
TIME	7.6000E 00	X/ACC -3.1740E 00	X/VEL 1.4042E 01	X	8.4231E 02	Y1-2Y2 4.9365E-01	FK1	2.2461E 03
TIME	7.6000E 00	Y1 7.2653E 02	SIN 9.8917E-01					
TIME	7.8000E 00	Y3/ACC-1.7348E 00	Y3/VEL 6.8245E 00	Y3	3.6424E 02	F(Y3) 9.0000E 01	FD	4.1017E 03
TIME	7.8000E 00	Y2/ACC-1.4272E 00	Y2/VEL 6.7484E 00	Y2	3.6440E 02	Y3-Y2 -1.6431E-01	FX2	4.1570E 03
TIME	7.8000E 00	X/ACC -2.8916E 00	X/VEL 1.3436E 01	X	8.4506E 02	Y1-2Y2 4.4971E-01	FK1	2.0462E 03
TIME	7.8000E 00	Y1 7.2929E 02	SIN 9.8924E-01					
TIME	8.0000E 00	Y3/ACC-1.3756E 00	Y3/VEL 4.9295E 00	Y3	3.6557E 02	F(Y3) 9.0000E 01	FD	3.8324E 03
TIME	8.0000E 00	Y2/ACC-1.3550E 00	Y2/VEL 6.46[illegible]E 00	Y2	3.6572E 02	Y3-Y2 -1.5039E-01	FX2	3.8049E 03
TIME	8.0000E 00	X/ACC -2.6453E 00	X/VEL 1.2883E 01	X	8.4769E 02	Y1-2Y2 4.1138E-01	FK1	1.8718E 03
TIME	8.0000E 00	Y1 7.3189E 02	SIN 9.8930E-01					
TIME	8.2000E 00	Y3/ACC-9.5024E-01	Y3/VEL 6.2550E 00	Y3	3.6685E 02	F(Y3) 9.0000E 01	FD	3.5212E 03
TIME	8.2000E 00	Y2/ACC-1.3927E 00	Y2/VEL 6.2043E 00	Y2	3.6699E 02	Y3-Y2 -1.3843E-01	FX2	3.5022E 03
TIME	8.2000E 00	X/ACC -2.4304E 00	X/VEL 1.2376E 01	X	8.5021E 02	Y1-2Y2 3.7793E-01	FK1	1.7196E 03
TIME	8.2000E 00	Y1 7.3435E 02	SIN 9.8936E-01					
TIME	8.4000E 00	Y3/ACC-1.1014E 00	Y3/VEL 6.0115E 00	Y3	3.6807E 02	F(Y3) 9.0000E 01	FD	3.2525E 03
TIME	8.4000E 00	Y2/ACC-1.2784E 00	Y2/VEL 5.9603E 00	Y2	3.6820E 02	Y3-Y2 -1.2769E-01	FX2	3.2304E 03
TIME	8.4000E 00	X/ACC -2.2421E 00	X/VEL 1.1909E 01	X	8.5264E 02	Y1-2Y2 3.4863E-01	FK1	1.5863E 03
TIME	8.4000E 00	Y1 7.3675E 02	SIN 9.8942E-01					
TIME	8.6000E 00	Y3/ACC-9.6140E-01	Y3/VEL 5.7819E 00	Y3	3.6925E 02	F(Y3) 9.0000E 01	FD	3.0088E 03
TIME	8.6000E 00	Y2/ACC-1.1102E 00	Y2/VEL 5.7401E 00	Y2	3.6937E 02	Y3-Y2 -1.1816E-01	FX2	2.9896E 03
TIME	8.6000E 00	X/ACC -2.0774E 00	X/VEL 1.1477E 01	X	8.5498E 02	Y1-2Y2 3.2300E-01	FK1	1.4696E 03
TIME	8.6000E 00	Y1 7.3907E 02	SIN 9.8948E-01					

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

TIME	8.8000E 00	Y3/ACC-1.2903E 00	Y3/VEL 5.5771E 00	Y3	3.7039E 02	F(Y3) 9.0000E 01	FD	2.7993E 03
TIME	8.8000E 00	Y2/ACC-8.9881E-01	Y2/VEL 5.5309E 00	Y2	3.7050E 02	Y3-Y2 -1.0962E-01	FX2	2.7734E 03
TIME	8.8000E 00	X/ACC -1.9315E 00	X/VEL 1.1076E 01	X	8.5723E 02	Y1-2Y2 3.0029E-01	FK1	1.3663E 03
TIME	8.8000E 00	Y1 7.4130E 02	SIN 9.8954E-01					
TIME	9.0000E 00	Y3/ACC-7.8766E-01	Y3/VEL 5.3788E 00	Y3	3.7140E 02	F(Y3) 9.0000E 01	FD	2.6038E 03
TIME	9.0000E 00	Y2/ACC-1.0261E 00	Y2/VEL 5.3429E 00	Y2	3.7150E 02	Y3-Y2 -1.0229E-01	FX2	2.5881E 03
TIME	9.0000E 00	X/ACC -1.7965E 00	X/VEL 1.0703E 01	X	8.5941E 02	Y1-2Y2 2.7930E-01	FK1	1.2708E 03
TIME	9.0000E 00	Y1 7.4345E 02	SIN 9.8959E-01					
TIME	9.2000E 00	Y3/ACC-9.3025E-01	Y3/VEL 5.2001E 00	Y3	3.7254E 02	F(Y3) 9.0000E 01	FD	2.4337E 03
TIME	9.2000E 00	Y2/ACC-8.3735E-01	Y2/VEL 5.1684E 00	Y2	3.7264E 02	Y3-Y2 -9.5459E-02	FX2	2.4151E 03
TIME	9.2000E 00	X/ACC -1.6804E 00	X/VEL 1.0355E 01	X	8.6151E 02	Y1-2Y2 2.6123E-01	FK1	1.1886E 03
TIME	9.2000E 00	Y1 7.4554E 02	SIN 9.8964E-01					
TIME	9.4000E 00	Y3/ACC-9.0873E-01	Y3/VEL 5.0320E 00	Y3	3.7356E 02	F(Y3) 9.0000E 01	FD	2.2789E 03
TIME	9.4000E 00	Y2/ACC-7.6348E-01	Y2/VEL 5.0018E 00	Y2	3.7365E 02	Y3-Y2 -8.9355E-02	FX2	2.2607E 03
TIME	9.4000E 00	X/ACC -1.5737E 00	X/VEL 1.0030E 01	X	8.6355E 02	Y1-2Y2 2.4463E-01	FK1	1.1131E 03
TIME	9.4000E 00	Y1 7.4755E 02	SIN 9.8969E-01					
TIME	9.6000E 00	Y3/ACC-6.3929E-01	Y3/VEL 4.8735E 00	Y3	3.7455E 02	F(Y3) 9.0000E 01	FD	2.1376E 03
TIME	9.6000E 00	Y2/ACC-8.0446E-01	Y2/VEL 4.8500E 00	Y2	3.7464E 02	Y3-Y2 -8.3984E-02	FX2	2.1240E 03
TIME	9.6000E 00	X/ACC -1.4764E 00	X/VEL 9.7252E 00	X	8.6553E 02	Y1-2Y2 2.2949E-01	FK1	1.0442E 03
TIME	9.6000E 00	Y1 7.4951E 02	SIN 9.8973E-01					
TIME	9.8000E 00	Y3/ACC-4.7645E-01	Y3/VEL 4.7260E 00	Y3	3.7551E 02	F(Y3) 9.0000E 01	FD	2.0100E 03
TIME	9.8000E 00	Y2/ACC-8.2587E-01	Y2/VEL 4.7030E 00	Y2	3.7559E 02	Y3-Y2 -7.9182E-02	FX2	2.0013E 03
TIME	9.8000E 00	X/ACC -1.3885E 00	X/VEL 9.4386E 00	X	8.6744E 02	Y1-2Y2 2.1582E-01	FK1	9.8198E 02
TIME	9.8000E 00	Y1 7.5140E 02	SIN 9.8978E-01					
TIME	1.0000E 01	Y3/ACC-6.4040E-01	Y3/VEL 4.5907E 00	Y3	3.7645E 02	F(Y3) 9.0000E 01	FD	1.8967E 03
TIME	1.0000E 01	Y2/ACC-7.8343E-01	Y2/VEL 4.5672E 00	Y2	3.7652E 02	Y3-Y2 -7.4463E-02	FX2	1.8839E 03
TIME	1.0000E 01	X/ACC -1.3069E 00	X/VEL 9.1687E 00	X	8.6930E 02	Y1-2Y2 2.0313E-01	FK1	9.2422E 02
TIME	1.0000E 01	Y1 7.5325E 02	SIN 9.8982E-01					
TIME	1.0000E 01	Y3/ACC-6.3019E-01	Y3/VEL 4.5905E 00	Y3	3.7645E 02	F(Y3) 9.0000E 01	FD	1.8969E 03
TIME	1.0000E 01	Y2/ACC-7.8343E-01	Y2/VEL 4.5669E 00	Y2	3.7652E 02	Y3-Y2 -7.4463E-02	FX2	1.8839E 03
TIME	1.0000E 01	X/ACC -1.3069E 00	X/VEL 9.1682E 00	X	8.6931E 02	Y1-2Y2 2.0313E-01	FK1	9.2422E 02
TIME	1.0000E 01	Y1 7.5325E 02	SIN 9.8982E-01					

SAMPLE PROBLEM 2 - TOTAL RUNNING TIME 9.0 MINUTES

Figure A-2.5. Aircraft Arresting Gear Execution Phase Printout, (Contd)

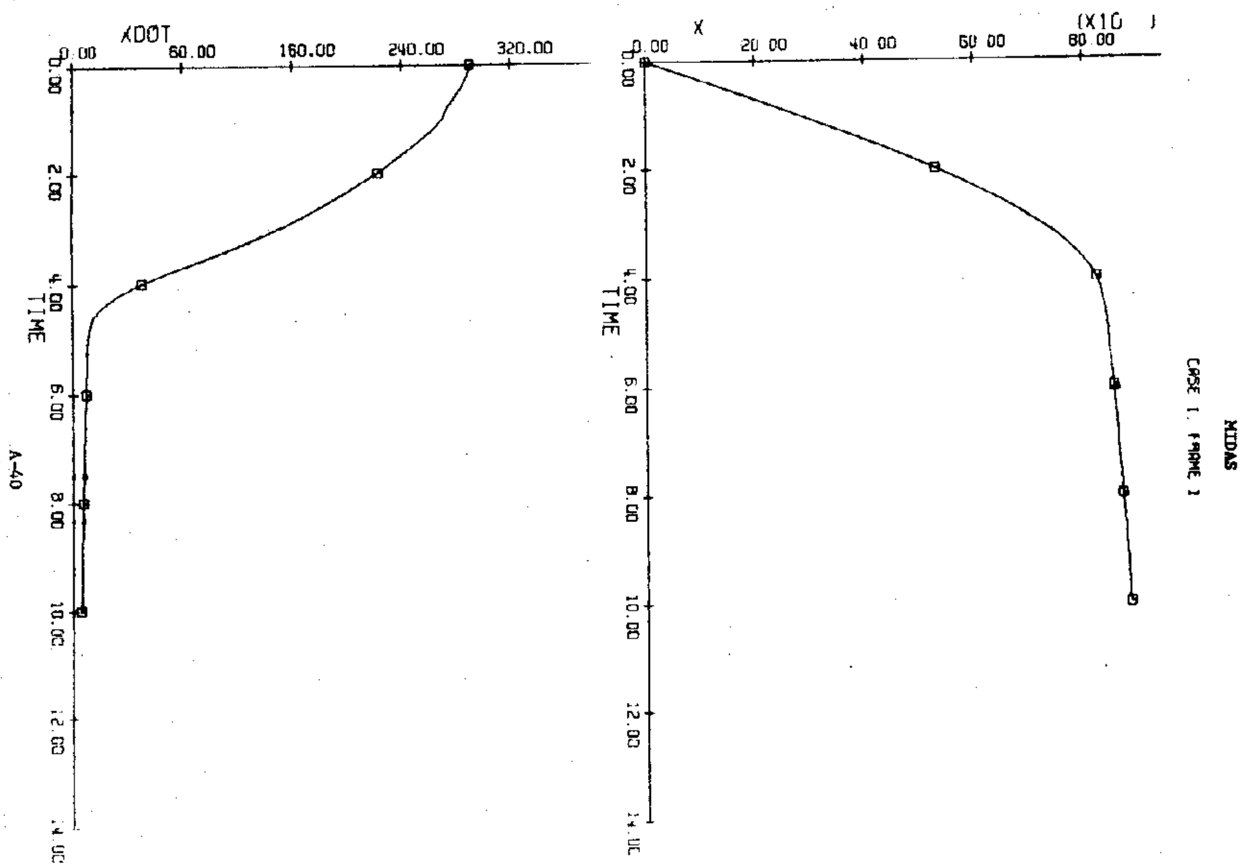

Figure A-2.6. Aircraft Arresting Gear Plots, X and X vs Time, Case 1

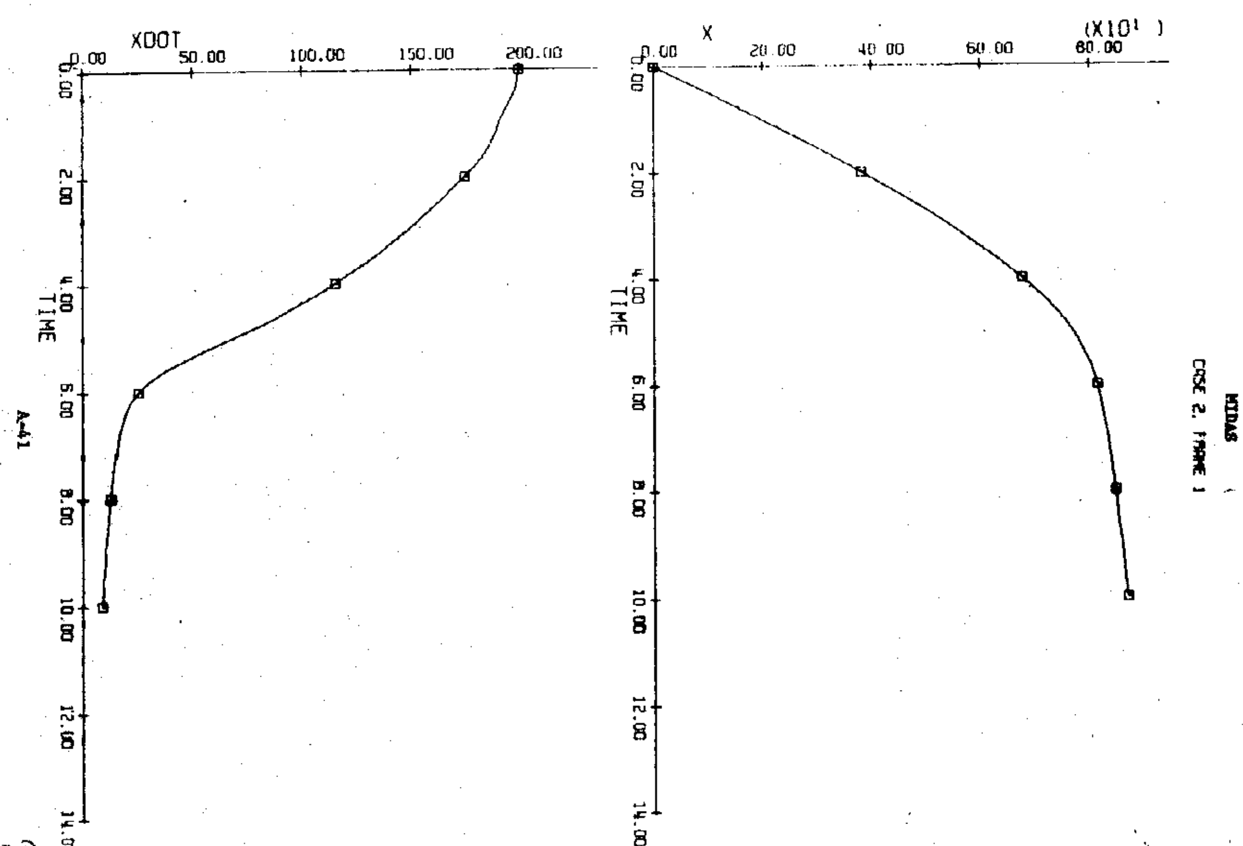

Figure A-2.8. Aircraft Arresting Gear Plot, X and X vs Time, Case 2

SAMPLE PROBLEM 3: PILOT EJECTION STUDY

This problem determines the trajectory of a pilot ejected from a fighter aircraft to ascertain whether he will strike the vertical stabilizer of the aircraft. Several combinations of aircraft speed and altitude are investigated since the drag on the pilot, causing his relative horizontal motion with respect to the aircraft, is a function of air density and velocity (squared). The ejection system is so devised that it causes the pilot and his seat to travel along rails at a specified exit velocity, V_E, at an angle, θ_E, backward from vertical. The seat becomes disengaged from the rails at $Y = Y_1$. This first phase of the ejection is illustrated in the Figure A-3.1.

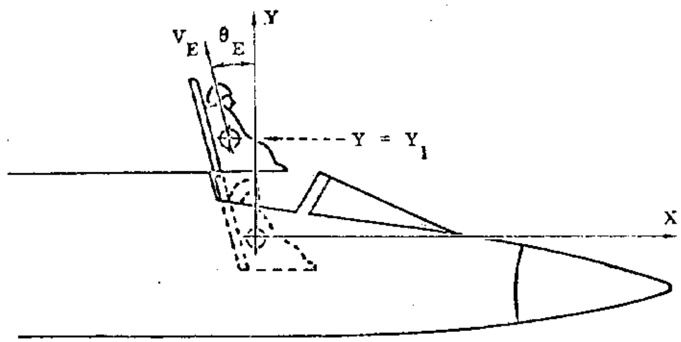

Figure A-3.1. Pilot Ejection, Phase I

Once the pilot and seat combination leaves the rails, it follows a ballistic trajectory that can be determined; but since it is the relative motion of the pilot with respect to the aircraft (which is assumed to fly level at constant speed) that is important, we can formulate our equations to obtain this directly. This phase of the ejection is shown in Figure A-3.2.

The governing equations are:

$$\dot{X} = V\cos\theta - V_A$$

$$\dot{Y} = V\sin\theta$$

$$\dot{V} = 0 \qquad 0 \le Y < Y_1$$

$$\quad = -g\sin\theta \qquad Y \ge Y_1$$

$$\dot{\theta} = 0 \qquad 0 \le Y < Y_1$$

$$\quad = -(g\cos\theta)/V \qquad Y \ge Y_1$$

$$D = \frac{1}{2}\rho C_d S V^2$$

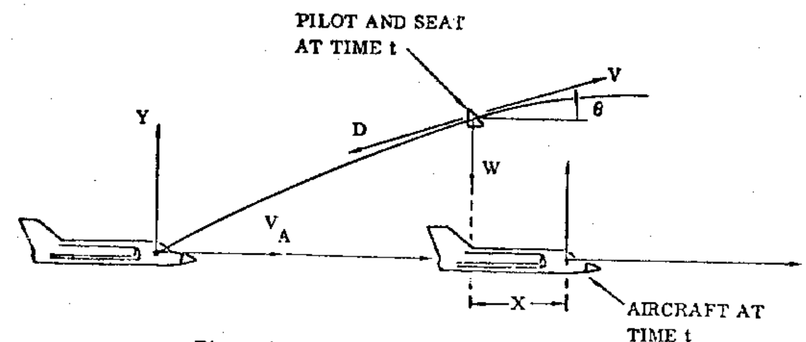

Figure A-3.2. Pilot Ejection, Phase II

Four cases will be run:

Case 1:	V_A = 900 ft/sec	
	ρ = 2.3769 x 10^{-3} slugs/ft^3	(sea level)
Case 2:	V_A = 900 ft/sec	
	ρ = 0.2238 x 10^{-3} slugs/ft^3	(60,000 ft)
Case 3:	V_A = 500 ft/sec	
	ρ = 2.3769 x 10^{-3} slugs/ft^3	(sea level)
Case 4:	V_A = 500 ft/sec	
	ρ = 0.2238 x 10^{-3} slugs/ft^3	(60,000 ft)

Constants (for all cases)

$$m = 7 \text{ slugs}$$
$$g = 32.2 \text{ ft/sec}^2$$
$$C_d = 1$$
$$S = 10 \text{ ft}^2$$
$$Y_1 = 4 \text{ ft}$$
$$V_E = 40 \text{ ft/sec}$$
$$\theta_E = 15^\circ \quad (= 15/57.3 \text{ radians})$$

The initial values of V and θ (pilot's initial velocity vector at moment of leaving cockpit rails) are given by:

$$V(0) = \sqrt{(V_A - V_E \sin\theta_E)^2 - (V_E \cos\theta_E)^2}$$

$$\theta(0) = \tan^{-1} \frac{V_E \cos\theta_E}{V_A - V_E \sin\theta_E}$$

$$X(0) = Y(0) = 0$$

A run is to be terminated when any one of these conditions occurs:

	$X \leq -60$ feet	(pilot beyond vertical stabilizer)
	$Y \geq 30$ feet	(pilot well above 12 ft high tail)
	$t \geq 4.0$ sec	
Time between printouts:	0.02 sec.	
Quantities to be printed out:	$t, \dot{V}, V, \theta, X, Y$	

BLOCK DIAGRAM (See Figure A-3.3.)

1. Observe use of output relays OR1 and OR2 which cause $\dot{V}$ and $\dot{\theta}$ to be zero until Y reaches Y_1.

2. Note that I1 and I2 are used to compute ΔV and $\Delta\theta$ respectively, i.e., the change in these variables from their initial values. V and θ are obtained by adding in V (0) and θ (0) in S5 and S6 rather than setting the IC's with Data Cards. The reason

behind this is the rather complex expression involved in computing V (0) and θ (0). These expressions are evaluated by the computer rather than by hand calculations.

3. Note the circuitry involving BB1 and BB2 which extends the range of the arc tangent from its present range of $-\frac{\pi}{2}$ to $+\frac{\pi}{2}$ to $-\pi$ to $+\pi$. The equation involved is:

$$\theta(0) = \tan^{-1}\left(\frac{N}{D}\right) + \frac{N}{|N|}\left(1 - \frac{D}{|D|}\right)\frac{\pi}{2}$$

where

$$N = V_E \cos\theta_E$$
$$D = V_A - V_E \sin\theta_E$$

Although, by the nature of this physical problem, θ (0) will always remain in the first quadrant (unless the airplane were sitting stationary on the ground), this circuit is included to demonstrate the use of additional MIDAS elements as well as some of the tricks that can be perpetrated with them.

This example demonstrates the integration option which prints out step size changes.

Two cases are run, both use the same set of parameters. The first case uses a minimum integration step size of 10^{-3} second, the second case uses 2×10^{-9} second.

Figure A-3.5 shows the coding of the input data for the two cases. Note the blank card between the two cases. There is also a blank card after the second case.

The execution time for both cases together was 5 seconds. This shows clearly the improved efficiency in execution time, since the original MIDAS used 1 minute for one case alone, and could not solve the problem in 8 minutes using a minimum step size of 2×10^{-9}.

Computer printouts for the first and second pass are provided as Figure A-3.6. Only those pages of the printout which are essential to this discussion are included.

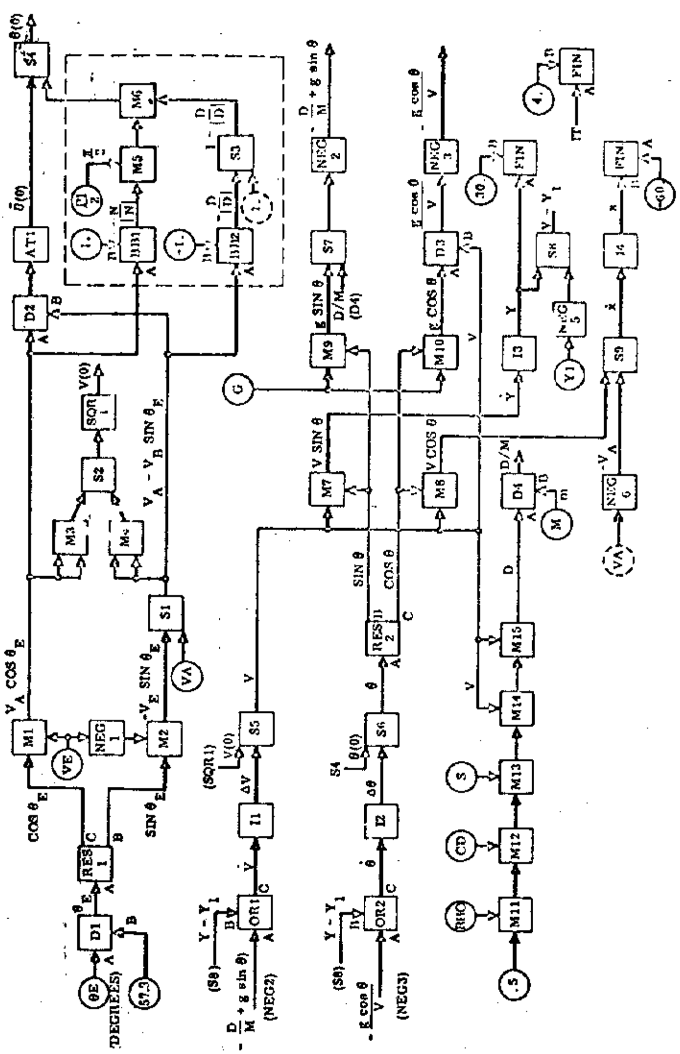

Figure A-3.3. Pilot Ejection Block Diagram


```
SAMPLE PROBLEM 3  PILOT EJECTION STUDY
        CON     THETAE,57.3,VE,1.,-1.,PI/2
        CON     G,.5,CD,S,M,Y1
        CON     30.,4.,-60.,TR,MININT,VA
        CON     RHO
OPTION4
        D1      THETAE,57.3
        RES1    D1
        M1      RES1C,VE
        NEG1    VE
        M2      RES1B,NEG1
        S1      M2,VA
        M3      M1,M1
        M4      S1,S1
        S2      M3,M4
        SQ1     S2
        D2      M1,S1
        AT1     D2
        BB1     M1,1.
        BB2     S1,-1.
        S3      BB2,1.
        M5      BB1,PI/2
        M6      M5,S3
        S4      AT1,M6
        OR1     NEG2,S8
        OR2     NEG3,S8
        I1      OR1C
        I2      OR2C
        S5      I1,SQ1
        S6      I2,S4
        RES2    S6
        M7      RES2B,S5
        M8      RES2C,S5
        M9      RES2B,G
        M10     RES2C,G
        S7      M9,D4
        NEG2    S7
        D3      M10,S5
        NEG3    D3
        M11     .5,RHO
        M12     M11,CD
        M13     M12,S
        M14     M13,S5
        M15     M14,S5
        D4      M15,M
        I3      M7
        NEG5    Y1
        S8      I3,NEG5
        NEG6    VA
        S9      48,NEG6
        I4      S9
        FIN     I3,30.
        FIN     -60.,I4
        FIN     IT,4.
        HDR     TIME,YDOT,V,THETA,X,Y
        RO      IT,OR1C,S5,S6,I4,I3
        END
```

Figure A-3.4. Pilot Ejection Precompiler Phase Printout

15.	57.3	40.	1.	-1.	1.5709
32.2	.5	1.	10.	7.	4.
30.	4.	-60.	.02	1.	E-3 900.
0.0023769					
BLANK CARD HERE					
15.	57.3	40.	1.	-1.	1.5706
32.2	.5	1.	10.	7.	4.
30.	4.	-60.	.02	2.	E- 900.
0.0023769					
BLANK CARD HERE					

Figure A-3.5. Pilot Ejection Input Data


```
CONSTANTS C(I) ARE ..

   0.1500000E 02   0.5729999E 02   0.4000000E 02   0.1000000E 01  -0.1000[illegible]   0.15[illegible]
   0.3220000E 02   0.5000000E 00   0.1000000E 01   0.1000000E 02   0.7000000[illegible]   0.[illegible]
   0.3000000E 02   0.4000000E 01  -0.6000000E 02   0.2000000E-01   0.999999[illegible]-0[illegible]   0.[illegible]
   0.2376900E-02   0.0             0.0             0.0             0.0             0.0

NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  4

INITIAL CONDITIONS FOR INTEGRATION VARIABLES
Y (  1) =  0.0          Y (  2) =  0.0          Y (  3) =  0.0          Y (  4) =  0.0

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) =  0.0          Y'(  2) =  0.0          Y'(  3) =  0.3[illegible]          Y'(  4) = -0.[illegible]
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)

```
TIME  0.0          YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X   0.0          Y   0.0

TIME  2.0000E-02   YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X  -2.0705E-01   Y   7.7274E-01

TIME  4.0000E-02   YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X  -4.1409E-01   Y   1.5459E 00

TIME  6.0000E-02   YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X  -6.2114E-01   Y   2.3182E 00

TIME  8.0000E-02   YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X  -8.2818E-01   Y   3.0910E 00

TIME  1.0000E-01   YDOT  0.0           V   8.9049E 02   THETA  4.3403E-02   X  -1.0352E 00   Y   3.8637E 00

  STEPSIZE DECREASED AT X =  0.99999964E-01  NEW STEP =      0.24999995E-02
 ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.2246135E 00      REL.ERROR =   0.6919408E-01

  STEPSIZE DECREASED AT X =  0.10250002E 00  NEW STEP =      0.12499997E-02
 ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR = -0.7678389E 00      REL.ERROR =   0.1193982E 00

 PROGRAM TRIED TO REDUCE THE STEPSIZE BELOW MININT
ERROR IN EQUATION  1 WAS TOO LARGE, ERROR =   0.5615340E-01
RELATIVE ERROR =   0.3596041E-01, Y =  -0.2807670E 00, T =   0.1037500E 00

 PROGRAM TRIED TO REDUCE THE STEPSIZE BELOW MININT
ERROR IN EQUATION  1 WAS TOO LARGE, ERROR =  -0.3662108E-06
RELATIVE ERROR =   0.7809935E-07, Y =  -0.1961130E 01, T =   0.1050000E 00

TIME  1.2000E-01   YDOT  -1.2830E 03   V   8.6884E 02   THETA  4.2801E-02   X  -1.4214E 00   Y   4.6244E 00

TIME  1.4000E-01   YDOT  -1.2105E 03   V   8.4392E 02   THETA  4.2049E-02   X  -2.3110E 00   Y   5.3507E 00

 STEPSIZE INCREASED AT X =  0.14999992E 00   NEW STEP SIZE =  0.24999995E-02

  LARGEST ERROR IN EQUATION  2  ERROR =-0.14590704E-10     REL. ERROR =  0.14564697E-10
TIME  1.6000E-01   YDOT  -1.1440E 03   V   8.2038E 02   THETA  4.1276E-02   X  -3.6853E 00   Y   6.0439E 00

TIME  1.8000E-01   YDOT  -1.0828E 03   V   7.9812E 02   THETA  4.0480E-02   X  -5.5157E 00   Y   6.7053E 00

TIME  2.0000E-01   YDOT  -1.0264E 03   V   7.7704E 02   THETA  3.9663E-02   X  -7.7786E 00   Y   7.3363E 00

TIME  2.2000E-01   YDOT  -9.7427E 02   V   7.5704E 02   THETA  3.8824E-02   X  -1.0451E 01   Y   7.9382E 00

TIME  2.4000E-01   YDOT  -9.2602E 02   V   7.3804E 02   THETA  3.7963E-02   X  -1.3513E 01   Y   8.5120E 00
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)


```
TIME  2.6000E-01   YDOT  -8.8127E 02   V   7.1998E 02   THETA  3.7080E-02   X  -1.6945E 01   Y   9.0590E 00

TIME  2.8000E-01   YDOT  -8.3968E 02   V   7.0277E 02   THETA  3.6175E-02   X  -2.0728E 01   Y   9.5800E 00

TIME  3.0000E-01   YDOT  -8.0097E 02   V   6.8637E 02   THETA  3.5249E-02   X  -2.4847E 01   Y   1.0074E 01

TIME  3.2000E-01   YDOT  -7.6487E 02   V   6.7072E 02   THETA  3.4300E-02   X  -2.9285E 01   Y   1.0548E 01

TIME  3.4000E-01   YDOT  -7.3116E 02   V   6.5576E 02   THETA  3.3329E-02   X  -3.4029E 01   Y   1.0996E 01

TIME  3.6000E-01   YDOT  -6.9962E 02   V   6.4146E 02   THETA  3.2337E-02   X  -3.9065E 01   Y   1.1422E 01

TIME  3. .000E-01  YDOT  -6.7008E 02   V   6.2776E 02   THETA  3.1323E-02   X  -4.4380E 01   Y   1.1826E 01

TIME  4.0000E-01   YDOT  -6.4237E 02   V   6.1464E 02   THETA  3.0288E-02   X  -4.9963E 01   Y   1.2209E 01

TIME  4.2000E-01   YDOT  -6.1634E 02   V   6.0206E 02   THETA  2.9228E-02   X  -5.5803E 01   Y   1.2571E 01

TIME  4.3500E-01   YDOT  -5.9784E 02   V   5.9295E 02   THETA  2.8420E-02   X  -6.0344E 01   Y   1.2829E 01
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)

```
CO.  .ANTS C(I) ARE ..

     0.1500000E 02   0.5729999E 02   0.4000000E 02   0.1000000E 01  -0.1000000E 01   0.1570800E 01
     0.3220000E 02   0.5000000E 00   0.1000000E 01   0.1000000E 02   0.7000000E 01   0.4000000E 01
     0.3000000E 02   0.4000000E 01  -0.6000000E 02   0.2000000E-01   0.2000000E-08   0.9000800E 03
     0.2376900E-02   0.0             0.0             0.0             0.0             0.0
```

```
NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  4

INITIAL CONDITIONS FOR INTEGRATION VARIABLES
Y (  1) =  0.0           Y (  2) =  0.0           Y (  3) =  0.0           Y (  4) =  0.0

COMPUTED INITIAL CONDITIONS FOR FIRST DERIVATIVES
Y'(  1) =  0.0           Y'(  2) =  0.0           Y'(  3) =  0.3864E 02    Y'(  4) = -0.1035E 02
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)


```
TIME   0.0          YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X    0.0         Y   0.0

TIME   2.0000E-02   YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X   -2.0705E-01  Y   7.7274E-01

TIME   4.0000E-02   YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X   -4.1409E-01  Y   1.5455E 00

TIME   6.0000E-02   YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X   -6.2114E-01  Y   2.3182E 00

TIME   8.0000E-02   YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X   -8.2818E-01  Y   3.0910E 00

TIME   1.0000E-01   YDOT   0.0       V   8.9049E 02   THETA  4.3403E-02   X   -1.0352E 00  Y   3.8637E 00

   STEPSIZE DECREASED AT X =  0.99999964E-01  NEW STEP =      0.24999995E-02
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.2246135E 00      REL.ERROR =   0.6919408E-01

   STEPSIZE DECREASED AT X =  0.10250002E 00  NEW STEP =      0.12499997E-02
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR = -0.7078389E 00      REL.ERROR =   0.1193982E 00

   STEPSIZE DECREASED AT X =  0.10249996E 00  NEW STEP =      0.62499987E-03
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.5615340E-01      REL.ERROR =   0.3996041E-01

   STEPSIZE DECREASED AT X =  0.10312498E 00  NEW STEP =      0.31249993E-03
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.2007669E-01      REL.ERROR =   0.2192179E-01

   STEPSIZE DECREASED AT X =  0.10343748E 00  NEW STEP =      0.15624997E-03
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.2808989E-01      REL.ERROR =   0.1650743E-01

   STEPSIZE DECREASED AT X =  0.10343748E 00  NEW STEP =      0.78124984E-04
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.7019173E-02      REL.ERROR =   0.6558798E-02

   STEPSIZE DECREASED AT X =  0.10351963E 00  NEW STEP =      0.39062492E-04
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.7019993E-02      REL.ERROR =   0.5972113E-02

   STEPSIZE DECREASED AT X =  0.10351557E 00  NEW STEP =      0.19531246E-04
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.3509796E-02      REL.ERROR =   0.3224700E-02

   STEPSIZE DECREASED AT X =  0.10351963E 00  NEW STEP =      0.97656230E-05
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.8773967E-03      REL.ERROR =   0.8497654E-03

   STEPSIZE DECREASED AT X =  0.10352540E 00  NEW STEP =      0.48828115E-05
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.8774099E-03      REL.ERROR =   0.8585774E-03

   STEPSIZE DECREASED AT X =  0.10352540E 00  NEW STEP =      0.24414057E-05
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR = -0.1535449E-02      REL.ERROR =   0.1518792E-02
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)

```
   STEPSIZE DECREASED AT X =  0.10352540E 00  NEW STEP =      0.12[illegible]7029E-05
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.1096746E-03     REL.ERROR =   0.1095544E-03

   STEPSIZE DECREASED AT X =  0.10352659E 00  NEW STEP =      0.61035144E-06
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.5483729E-04     REL.ERROR =   0.5480723E-04

   STEPSIZE DECREASED AT X =  0.10352719E 00  NEW STEP =      0.30517572E-06
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.5483722E-04     REL.ERROR =   0.5476216E-04

   STEPSIZE DECREASED AT X =  0.10352719E 00  NEW STEP =      0.15258786E-06
ERROR IN EQUATION   1 WAS TOO LARGE,,ABS.ERROR =  0.2741862E-04     REL.ERROR =   0.2739984E-04

   STEPSIZE DECREASED AT X =  0.10352719E 00  NEW STEP =      0.76293929E-07
ERROR IN EQUATION   1 WAS TOO LARGE,,ABS.ERROR =  0.1370931E-04     REL.ERROR =   0.1370461E-04

   STEPSIZE DECREASED AT X =  0.10352719E 00  NEW STEP =      0.38146965E-07
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.6854653E-05     REL.ERROR =   0.6853483E-05

   STEPSIZE DECREASED AT X =  0.10352719E 00  NEW STEP =      0.19073482E-07
ERROR IN EQUATION   1 WAS TOO LARGE..ABS.ERROR =  0.1713665E-05     REL.ERROR =   0.1713637E-05

STEPSIZE INCREASED AT X =  0.10352725E 00   NEW STEP SIZE =  0.38146965E-07
 LARGEST ERROR IN EQUATION  1  ERROR =-0.40357292E-11     REL. ERROR =  0.40355245E-11

STEPSIZE INCREASED AT X =  0.10352731E 00   NEW STEP SIZE =  0.76293929E-07
 LARGEST ERROR IN EQUATION  1  ERROR =-0.80714593E-11     REL. ERROR =  0.80704271E-11

STEPSIZE INCREASED AT X =  0.10352737E 00   NEW STEP SIZE =  0.15258786E-06
 LARGEST ERROR IN EQUATION  1  ERROR =-0.16142906E-10     REL. ERROR =  0.16138341E-10

STEPSIZE INCREASED AT X =  0.10352755E 00   NEW STEP SIZE =  0.30517572E-06
 LARGEST ERROR IN EQUATION  1  ERROR =-0.34769354E-10     REL. ERROR =  0.34748829E-10

STEPSIZE INCREASED AT X =  0.10352784E 00   NEW STEP SIZE =  0.61035144E-06
 LARGEST ERROR IN EQUATION  1  ERROR =-0.84439872E-10     REL. ERROR =  0.84338037E-10

STEPSIZE INCREASED AT X =  0.10352844E 00   NEW STEP SIZE =  0.12207029E-05
 LARGEST ERROR IN EQUATION  1  ERROR =-0.21855030E-09     REL. ERROR =  0.21801802E-09

STEPSIZE INCREASED AT X =  0.10352963E 00   NEW STEP SIZE =  0.24414057E-05
 LARGEST ERROR IN EQUATION  1  ERROR =-0.63578254E-09     REL. ERROR =  0.63267636E-09

STEPSIZE INCREASED AT X =  0.10353208E 00   NEW STEP SIZE =  0.48828115E-05
 LARGEST ERROR IN EQUATION  1  ERROR = 0.51657323E-09     REL. ERROR =  0.51153703E-09
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)


```
STEPSIZE INCREASED AT X =  0.10353696E 00   NEW STEP SIZE =  0.97656230E-05
 LARGEST ERROR IN.EQUATION  1  ERROR = 0.23841840E-09     REL. ERROR =  0.23380875E-09

STEPSIZE INCREASED AT X =  0.10356629E 00   NEW STEP SIZE =  0.19531246E-04
 LARGEST ERROR IN EQUATION  1  ERROR =-0.15894568E-09     REL. ERROR =  0.14913638E-09

STEPSIZE INCREASED AT X =  0.10366392E 00   NEW STEP SIZE =  0.39062492E-04
 LARGEST ERROR IN EQUATION  1  ERROR =-0.31789127E-09     REL. ERROR =  0.26261127E-09

STEPSIZE INCREASED AT X =  0.10436708E 00   NEW STEP SIZE =  0.78124984E-04
 LARGEST ERROR IN EQUATION  4  ERROR =-0.95367381E-09     REL. ERROR =  0.45819748E-09

STEPSIZE INCREASED AT X =  0.11046082E 00   NEW STEP SIZE =  0.15624997E-03
 LARGEST ERROR IN EQUATION  4  ERROR = 0.12715653E-08     REL. ERROR =  0.58404925E-09

STEPSIZE INCREASED AT X =  0.11186707E 00   NEW STEP SIZE =  0.31249993E-03
 LARGEST ERROR IN EQUATION  1  ERROR =-0.50862603E-08     REL. ERROR =  0.41335446E-09
TIME   1.2000E-01     YDOT  -1.2830E 03     V       8.6883E 02     THETA  4.2800E-02     X     -1.4218E 00     Y       4.6243E 00

STEPSIZE INCREASED AT X =  0.13718742E 00   NEW STEP SIZE =  0.62499987E-03
 LARGEST ERROR IN EQUATION  1  ERROR = 0.30517562E-07     REL. ERROR =  0.68509868E-09

STEPSIZE INCREASED AT X =  0.13843739E 00   NEW STEP SIZE =  0.12499997E-02
 LARGEST ERROR IN EQUATION  3  ERROR = 0.12715651E-08     REL. ERROR =  0.20127908E-09
TIME   1.4000E-01     YDOT  -1.2105E 03     V       8.4390E 02     THETA  4.2048E-02     X     -2.3123E 00     Y       5.3507E 00

TIME   1.6000E-01     YDOT  -1.1439E 03     V       8.2037E 02     THETA  4.1275E-02     X     -3.6863E 00     Y       6.0438E 00

TIME   1.8000E-01     YDOT  -1.0828E 03     V       7.9811E 02     THETA  4.0480E-02     X     -5.5171E 00     Y       6.7052E 00

TIME   2.0000E-01     YDOT  -1.0263E 03     V       7.7703E 02     THETA  3.9663E-02     X     -7.7803E 00     Y       7.3362E 00

TIME   2.2000E-01     YDOT  -9.7423E 02     V       7.5703E 02     THETA  3.8824E-02     X     -1.0453E 01     Y       7.9380E 00

STEPSIZE INCREASED AT X =  0.23499984E 00   NEW STEP SIZE =  0.24999995E-02
 LARGEST ERROR IN EQUATION  1  ERROR = 0.10172522E-06     REL. ERROR =  0.67830142E-09
TIME   2.4000E-01     YDOT  -9.2599E 02     V       7.3803E 02     THETA  3.7963E-02     X     -1.3515E 01     Y       8.5119E 00
```

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)

TIME	2.6000E-01	YDOT	-8.8124E 02	V	7.1996E 02	THETA	3.7080E-02	X	-1.6947E 01	Y	9.0588E
TIME	2.8000E-01	YDOT	-8.3965E 02	V	7.0276E 02	THETA	3.6175E-02	X	-2.0731E 01	Y	9.5790E 00
TIME	3.0000E-01	YDOT	-8.0094E 02	V	6.8636E 02	THETA	3.5248E-02	X	-2.4850E 01	Y	1.0076E 01
TIME	3.2000E-01	YDOT	-7.6484E 02	V	6.7071E 02	THETA	3.4299E-02	X	-2.9289E 01	Y	1.0548E 01
TIME	3.4000E-01	YDOT	-7.3113E 02	V	6.5575E 02	THETA	3.3329E-02	X	-3.4033E 01	Y	1.0996E 01
TIME	3.6000E-01	YDOT	-6.9960E 02	V	6.4145E 02	THETA	3.2336E-02	X	-3.9069E 01	Y	1.1422E 01
TIME	3.8000E-01	YDOT	-6.7006E 02	V	6.2775E 02	THETA	3.1322E-02	X	-4.4384E 01	Y	1.1826E 01
TIME	4.0000E-01	YDOT	-6.4235E 02	V	6.1463E 02	THETA	3.0286E-02	X	-4.9967E 01	Y	1.2208E 01
TIME	4.2000E-01	YDOT	-6.1632E 02	V	6.0205E 02	THETA	2.9227E-02	X	-5.5807E 01	Y	1.2570E 01
TIME	4.3900E-01	YDOT	-5.9782E 02	V	5.9294E 02	THETA	2.8419E-02	X	-6.0348E 01	Y	1.2829E 01

SAMPLE PROBLEM 3 - TOTAL RUNNING TIME 3.6 MINUTES

Figure A-3.6. Pilot Ejection Execution Phase Printout, (Contd)

SAMPLE PROBLEM 4: BINARY CODED DECIMAL (BCD) COUNTER

The BCD counter is used as an example for several reasons:

1. It shows that MIDAS can be used for simulation of purely logical networks that do not involve integrators.
2. It shows the use of the memory element.
3. It shows that memory and relay element switching occurs before the results are printed.

The following figures show the printouts for the precompiler phase and the execution phase of the BCD counter.

TOTAL RUNNING TIME 2.4 MINUTES

```
SAMPLE PROBLEM 4   BINARY CODED DECIMAL COUNTER
      CON     TR,T1,K1,K2
      AG1     ME3C,ME4,ME1C
      AG2     ME3,ME4
      AG3     ME2C,ME3,ME4
      AG4     ME2,ME3,ME4
      AG5     ME1C,ME2,ME3,ME4
      AG6     ME1,ME4
      S1      IT,K2
      IR1     DE16,ME2,S1
      DE16    IR1,K1
      ME1     AG5C,AG6C,TR
      ME2     AG3C,AG4C,TR
      ME3     AG1C,AG2C,TR
      ME4     ME4C,ME4,TR
      FIN     IT,T1
      RO      DE16,ME1,ME2,ME3,ME4
      HDR     DEL,MEM1,MEM2,MEM3,MEM4
      END
```

Figure A-4.1. BCD Counter Precompiler Phase Printout


```
CONSTANTS C(I) ARE ..
     0.1000000E 01   0.2000000E 02   0.7000000E 01   -0.1000000E 02   0.0          0.0

NEQ=NUMBER OF DIFFERENTIAL EQUATIONS=  0
```

DEL	0.0	MEM1	0.0	MEM2	0.0	MEM3	0.0	MEM4	1.0000E 00
DEL	0.0	MEM1	0.0	MEM2	0.0	MEM3	1.0000E 00	MEM4	0.0
DEL	0.0	MEM1	0.0	MEM2	0.0	MEM3	1.0000E 00	MEM4	1.0000E 00
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	0.0	MEM4	0.0
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	0.0	MEM4	1.0000E 00
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	1.0000E 00	MEM4	0.0
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	1.0000E 00	MEM4	1.0000E 00
DEL	0.0	MEM1	1.0000E 00	MEM2	0.0	MEM3	0.0	MEM4	0.0
DEL	0.0	MEM1	1.0000E 00	MEM2	0.0	MEM3	0.0	MEM4	1.0000E 00
DEL	0.0	MEM1	0.0	MEM2	0.0	MEM3	0.0	MEM4	0.0
DEL	0.0	MEM1	0.0	MEM2	0.0	MEM3	0.0	MEM4	1.0000E 00
DEL	1.0000E 00	MEM1	0.0	MEM2	0.0	MEM3	1.0000E 00	MEM4	0.0
DEL	1.0000E 00	MEM1	0.0	MEM2	0.0	MEM3	1.0000E 00	MEM4	1.0000E 00
DEL	1.0000E 00	MEM1	0.0	MEM2	1.0000E 00	MEM3	0.0	MEM4	0.0
DEL	1.0000E 00	MEM1	0.0	MEM2	1.0000E 00	MEM3	0.0	MEM4	1.0000E 00
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	1.0000E 00	MEM4	0.0
DEL	0.0	MEM1	0.0	MEM2	1.0000E 00	MEM3	1.0000E 00	MEM4	1.0000E 00
DEL	0.0	MEM1	1.0000E 00	MEM2	0.0	MEM3	0.0	MEM4	0.0
DEL	0.0	MEM1	1.0000E 00	MEM2	0.0	MEM3	0.0	MEM4	1.0000E 00
DEL	1.0000E 00	MEM1	0.0	MEM2	0.0	MEM3	0.0	MEM4	0.0
DEL	1.0000E 00	MEM1	0.0	MEM2	0.0	MEM3	0.0	MEM4	1.0000E 00

Figure A-4.2 BCD Counter Execution Phase Printout