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Computer Simulation of a Transport Aircraft Seat and Occupant(s) in a Crash Environment
Volume II - Program SOM-TA User Manuel

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FINAL REPORT

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16. Abstract

A mathematical model of a transport aircraft seat, occupants, and restraint system has been developed for use in analysis of transport aircraft crashworthiness. Because of the significant role played by the seat in overall system crashworthiness, a finite element model of the seat structure is included. The seat model can accommodate large plastic deformations and includes the capability for simulation of local buckling members. Because the program has been written for use primarily by engineers concerned with the design and analysis of seat and restraint systems, an effort has been made to minimize the input data required to describe the occupants. This report is Volume II of a two-volume document. Volume I discusses development of the mathematical model of the occupants, the finite element seat analysis, validation and organization of the computer program. Volume II contains instructions for preparing input data and operating the program, supported by detailed examples. Sample material properties and modeling parameters are also included.

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FOREWORD

This report was prepared by Simula Inc. under Contract No. DTFA3-83-C-00036 with the Federal Aviation Administration (FAA) Technical Center, where Mr. L. M. Neri acted as Technical Monitor. Under the same contract, computer simulation program SOM-TA (Seat/Occupant Simulation Model for Transport Aircraft) was developed.

The Simula Inc. Project Engineer has been Mr. Akif O. Bolukbasi. Dr. David H. Laananen of Arizona State University has provided consulting services during the development and validation of Program SOM-TA, and during the preparation of this report. Data for model validation have been provided by the Protection and Survival Laboratory, FAA Civil Aeromedical Institute, where the tests were conducted under the supervision of Mr. R. F. Chandler.

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1.0 INTRODUCTION

Program SOM-TA (Seat/Occupant Model - Transport Aircraft) combines a lumped parameter model of aircraft passengers with a finite element model of the seat structure. Its intent is to aid in the evaluation of the performance of aircraft seat and restraint systems in crash environments. Because the program has been written for use primarily by engineers concerned with the design and analysis of seats and restraint systems, an effort has been made to minimize the input required to describe the occupants. The program allows simulation of one, two, or three passengers, of the same or different sizes. Characteristics of two standard occupants, one dummy and one human, are included within the program, and an option is provided to simulate other occupants by providing additional input data. The structural model includes beam elements and has a maximum capacity of approximately 450 degrees of freedom, as determined by array dimensions within the program. The beam elements can accommodate large plastic deformations and include the capability for cross-section reduction due to local instabilities. As an option to reduce both modeling complexity and execution costs for cases where only the restraint system or cockpit configuration is of concern, or for cases where the details of the seat design may not yet be known, a rigid seat model, in which seat pan and back planes defined by input are maintained in fixed positions in the aircraft, is available.

The following sections of this report present instructions necessary for the use of Program SOM-TA and information to enable the user to operate the program most efficiently.

Sections 2.0 and 3.0 describe program input and output, respectively, including options available to the user. Section 4.0 outlines an efficient procedure for development of a mathematical model. Section 5.0 then provides detailed descriptions of the sample input case. Appendix A defines all input variables, line by line. Appendix B provides examples of material properties and occupant characteristics required as input data. Appendix C displays the complete set of output data for the input listed in Section 5.0 and Appendix A. Appendix D describes program organization and the functions of all subroutines.

(a lateral line) and two angles which specify their positions relative to horizontal and vertical planes, respectively. The length of the seat pan and the height of the seat back are used to determine the limits of the surfaces within which the seat pan and back can apply forces to the occupant. Cushions, of input-specified thicknesses, are included on top of the seat pan and seat back surfaces.

The type of seat (single-, double-, or triple-occupant) is specified on line 2, along with identification of the positions that are occupied. Seat row pitch, used in plotting, is also specified in line 2.

2.1.3 Occupant Degrees of Freedom. The NDIM parameter on line 2 permits selection of either two- (NDIM = 2) or three-dimensional (NDIM = 3) occupant response. The three-dimensional occupant model consists of 12 rigid segments, illustrated in figure 1, with rotational springs and dampers at the joints. Each of the torso joints possesses three rotational degrees of freedom, or, in other words, is a ball-and-socket type joint. Because of the hinge-type motion at elbow and knee joints, the position of a forearm or lower leg relative to an upper arm or thigh, respectively, is described by one additional angular coordinate. In total, this occupant model possesses 29 degrees of freedom.

The two-dimensional occupant model, specified by NDIM = 2 on line 2, consists of 11 segments, as shown in figure 2. Beam elements in the torso and neck are capable of flexural and axial deformation. Although restricted to two-dimensional response, this occupant option does permit more direct evaluation of accident severity by output of forces and moments in the spine and neck. Restraint system forces on the ellipsoidal contact surfaces are computed three-dimensionally, but only the X- and Z-components are used. Therefore, the two-dimensional model should be reserved for cases in which both the impact conditions and the restraint system are symmetrical.

2.1.4 Output Control Data. Ten blocks of program output can be selected on line 3. The data include time histories of the following variables, which are stored during solution at predetermined print intervals:

1. Occupant segment positions (X, Y, Z, pitch and roll).*

2. Occupant segment velocities (X, Y, and Z).

3. Occupant segment accelerations (x, y, z, and resultants).*

4. Restraint system loads.

5. Cushion loads.

6. Aircraft displacement, velocity, and acceleration.

7. Injury criteria, including spinal forces and moments.

8. Details of contact between the occupants and the seat in front of them.

*Upper case X, Y, Z refer to inertial or aircraft-fixed coordinate system; lower case x, y, z refer to segment-fixed coordinates.

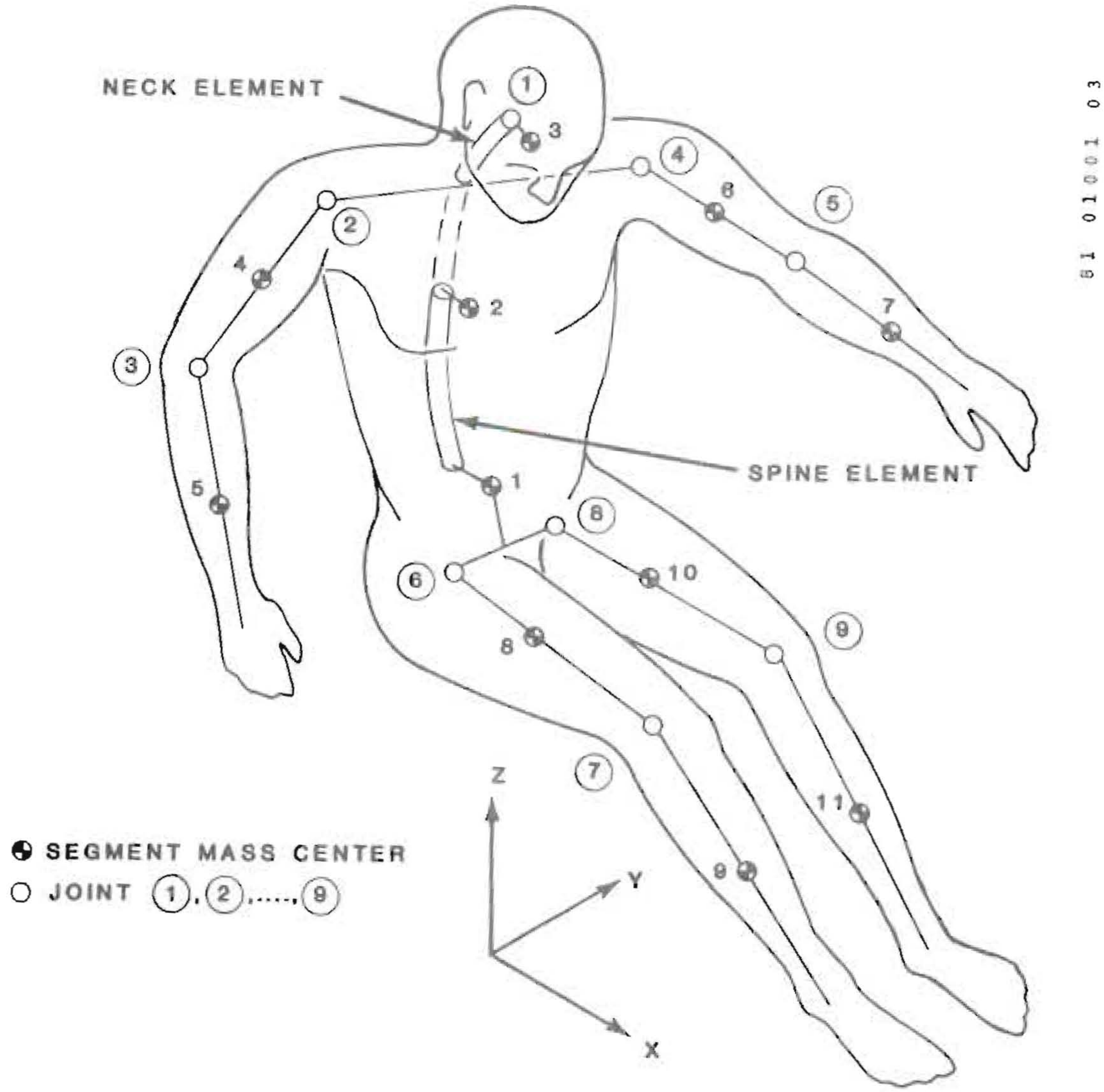


Figure 2. Eleven-segment (two-dimensional) occupant model.

Program output data are described further in Chapter 3.

2.1.5 Solution Control Data. The occupant model utilizes an Adams-Moulton predictor-corrector solution procedure with a variable time step. Data on line 4 control the step size and error bounds for the solution.

At every solution step, the system central processor time is checked and compared with the TMAX parameter on line 4. Allowing time for output, the solution will be terminated once system time reaches TMAX, whether or not the final solution time, TF, has been reached. Therefore, the permitted execution time in the job control language should be at least TMAX seconds, in order to ensure that through 41. Data for the standard occupants, a 50th-percentile U.S. male and a 50th-percentile (Part 572) anthropomorphic dummy, are included within the program. For nonstandard occupants, additional data may be provided (for each occupant) following line 41 to define segment lengths, center of mass locations, weights, moments of inertia, contact surface radii, properties for the spine and neck, and compliances for the chest and abdomen under restraint system loading. Examples of these data are included in Appendix B.

The angular orientations of the torso, head, and arm segments are provided as input on lines 39 through 41, along with the X-coordinate of the heels. Static equilibrium is then used to seat the occupant in the cushions.

2.7 SEAT DESIGN INFORMATION

2.7.1 Rigid Seat Option. For cases where the details of seat response are not important or not worth the greater execution costs that would be incurred by the use of the finite element structural model, a rigid seat option is provided. Plane surfaces representing the seat pan and seat back support the cushions and remain fixed in the aircraft coordinate system, except where the energy-absorbing option is used.

2.7.2 Simplified Energy-Absorbing Seat Option. If the SEATM parameter on line 43 is greater than 0, a simplified, two-degree-of-freedom seat model is used. Intended for use in simulation of a guided energy-absorbing seat, this model permits the stroking of a rigid seat bucket in a prescribed direction. Because elastic bending of the supporting frame has been observed in testing of such seats and may influence occupant response, the second degree of freedom is added to simulate rotational elasticity of the frame.

Although the finite element analysis can provide a complete evaluation of a seat's crashworthy performance, the simple stroking seat model can prove useful in other aspects of seat design. For example, the two-degree-of-freedom model can aid in economically estimating the optimum energy absorber limit load for protection of occupants of various size, as well as in evaluating alternative restraint system configurations.

Input data for this seat model include the weight of the movable part of the seat, the direction along which it will stroke, the movement of inertia with respect to a lateral axis, force-deflection characteristics, and unloading slopes.

2.7.3 Finite Element Structural Analysis. The finite element seat model contained in Program SOM-TA uses beam elements. The beam elements can accommodate large, plastic deformations and localized buckling of elements with hollow cross sections. The program has a capacity for 150 nodes and 450 degrees of freedom. However, a more severe restriction is placed on the size, N, of the master stiffness matrix, given by:

$$N = MEQ + MUD * (2 * MEQ - MUD - 1)/2 \qquad (2)$$

3.0 PROGRAM OUTPUT DATA

Program SOM-TA output data are available from the following four sources:

1. Printer (unit 6)
2. Occupant position plots (unit 14)
3. Seat structure plots (unit 20)
4. Plots of other data (unit 26)

which are described further in the following sections.

3.1 PRINTED OUTPUT

Printed data can be selected from the ten blocks listed in section 2.1.4. The interval at which these data are printed is selected in subroutine INPT, based on the total solution time. The interval is sized to provide a maximum of 51 lines for each variable. For example, a solution time between 0.100 and 0.150 sec results in a print interval of 0.003 sec, a solution time between 0.250 and 0.300 sec, an interval of 0.006 sec, etc.

Accelerations, severity indices, vertebral forces and moments, and restraint system forces are printed in tabular and graphical formats. Other data are provided in tabular form only. Acceleration output data are computed each 0.001 sec, equivalent to a 1 KHz sampling rate. Input line 3 provides the option of applying Class 180 (300 Hz) or Class 60 (100 Hz) filter to the data prior to their printing.

3.2 OCCUPANT POSITION PLOTS

If specified in input line 3, data for up to eight plots of occupant position, can be stored on external file 14. The times for these plots are defined on input line 3A. Viewing angles, illustrated in figure 3, are defined on line 3B. The right-side view of figure 4 was obtained using an angle of zero degrees. The front view of figure 5 was obtained using an angle of 90 degrees.

The IOUT(4) parameter on line 3 can be used to draw the image of the seat in front of that being modeled. A value of 0 causes no seat to be drawn. A value of 1 or 2 respectively, produces a plot of the forward seat in its undeformed or deformed position and uses subroutine IMPACT for prediction of contact with the forward seat. The seat image is spaced according to the SPITCH parameter.

The job control language used in executing SOM-TA must define external file 14 as a permanent file to be saved. The occupant plotting program can then be executed using this same permanent file as input.

3.3 SEAT STRUCTURE PLOTS

Just as described in section 3.2 for occupant position, data for up to eight plots of the seat structure can be requested on line 3. As shown in figure 6,

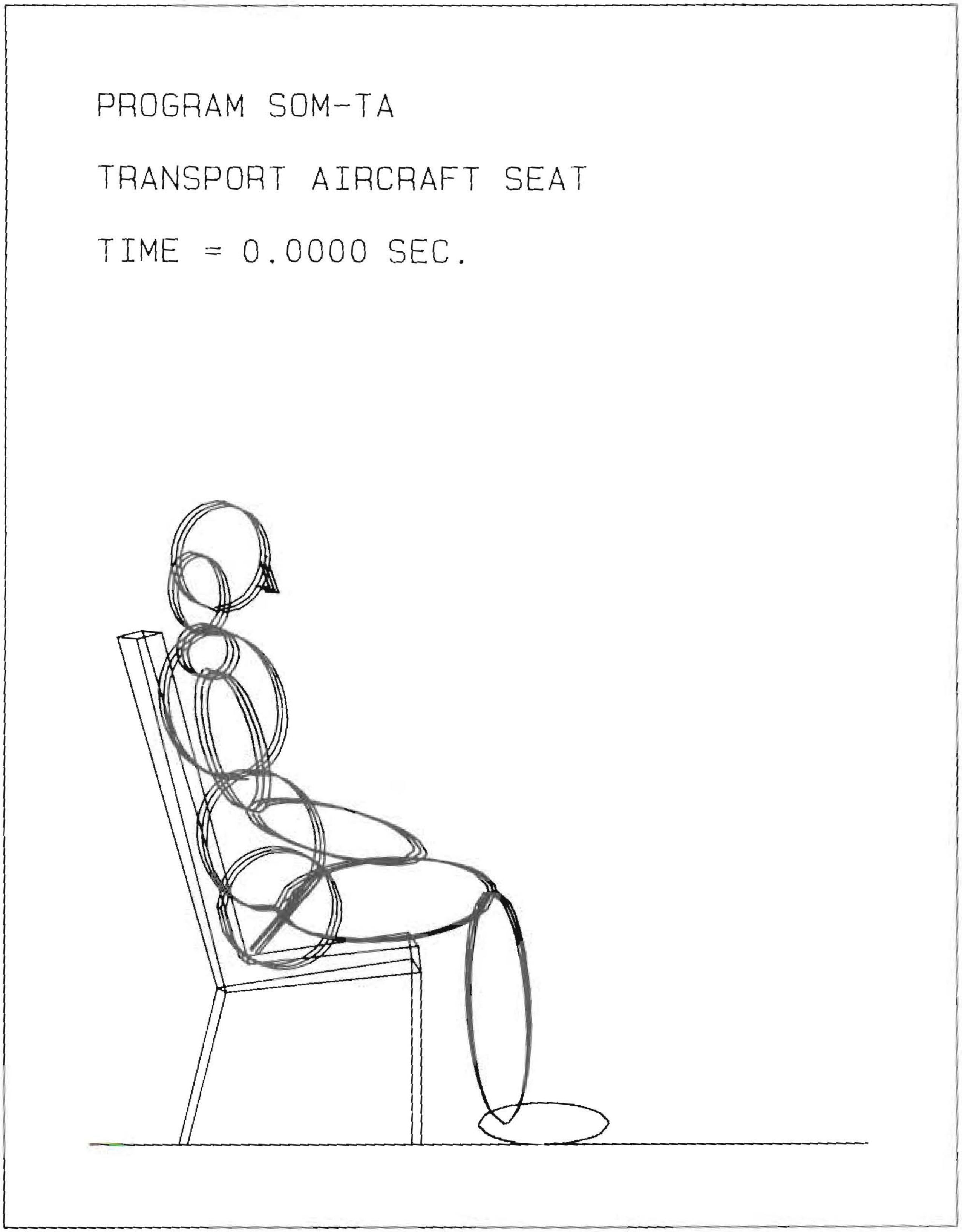


Figure 4. Sample case occupant plot (side view) at time = 0 sec.

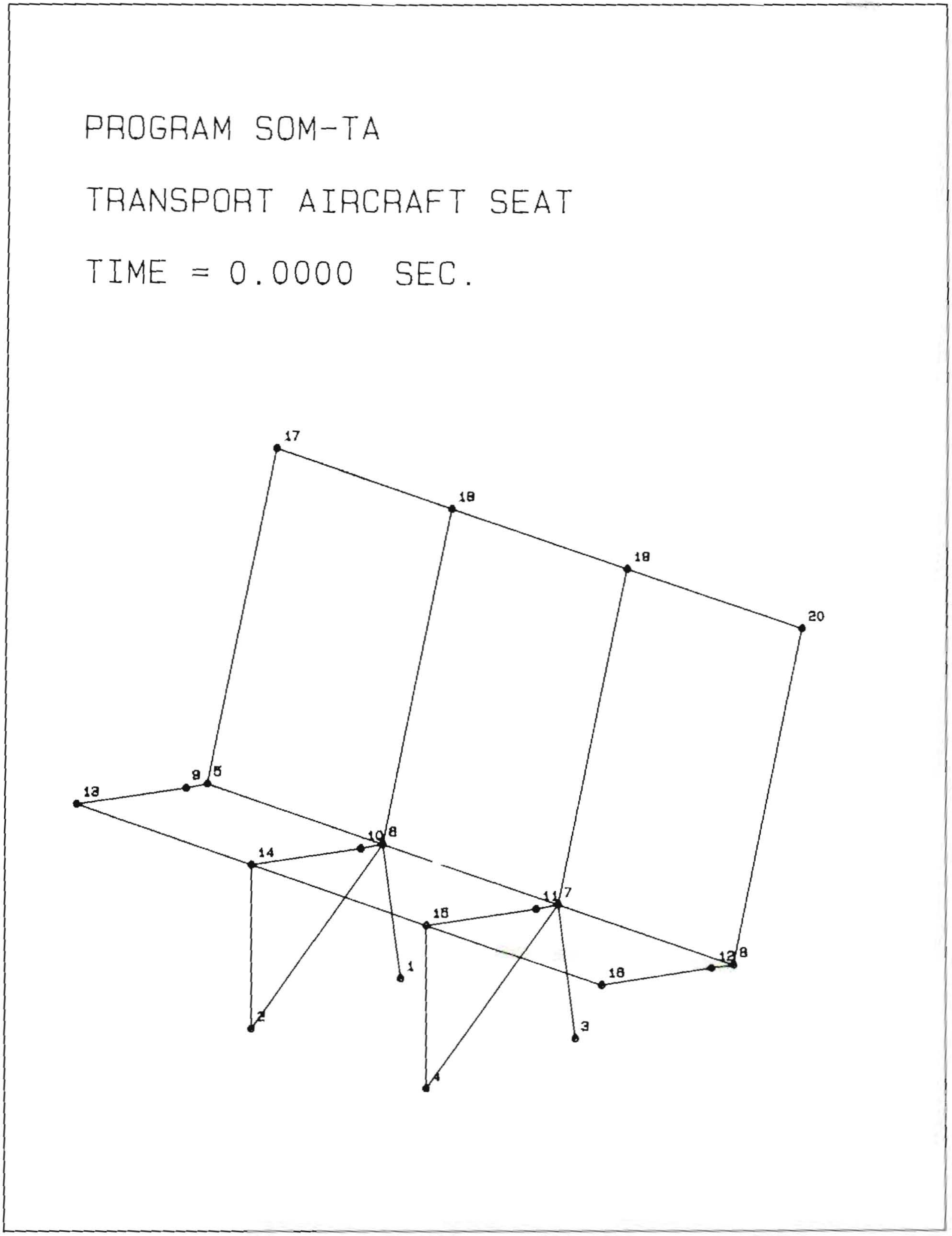
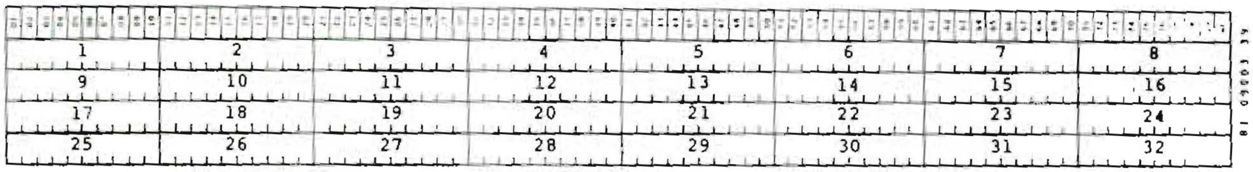


Figure 6. Sample case seat plot at time = 0 sec.



Field	Format	Variable	Field	Format	Variable
1	F10.5	Time (sec)	17	F10.5	Pelvis x-accel (G)
2	F10.5	Aircraft X-accel (G)	18	F10.5	Pelvis z-accel (G)
3	F10.5	Aircraft Z-accel (G)	19	F10.5	Pelvis res. accel (G)
4	F10.5	Aircraft res. accel (G)	20	F10.3	Lumbar axial load (lb)
5	F10.5	Aircraft res. vel. (ft/sec)	21	F10.3	Lumbar y-moment (in.-lb)
6	F10.5	Aircraft res. displ. (in.)	22	F10.3	Neck axial load (lb)
7	F10.5	Seat X-accel (G)	23	F10.3	Neck y-moment (in.-lb)
8	F10.5	Seat Z-accel (G)	24	F10.3	Back cushion force (lb)
9	F10.5	Head x-accel (G)	25	F10.3	Right lap belt force (lb)
10	F10.5	Head z-accel (G)	26	F10.3	Left lap belt force (lb)
11	F10.5	Head res. accel (G)	27	F10.3	Right shoulder belt force (lb)
12	F10.5	Chest x-accel (G)	28	F10.3	Left shoulder belt force (lb)*
13	F10.5	Chest z-accel (G)	29	F10.3	Energy absorber force (lb)
14	F10.5	Chest res. accel (G)	30	F10.5	Seat displacement (in.)
15	F10.5	DRI	31	F10.3	Footrest X-force (lb)
16	F10.3	Seat cushion force (lb)	32	F10.3	Footrest Z-force (lb)

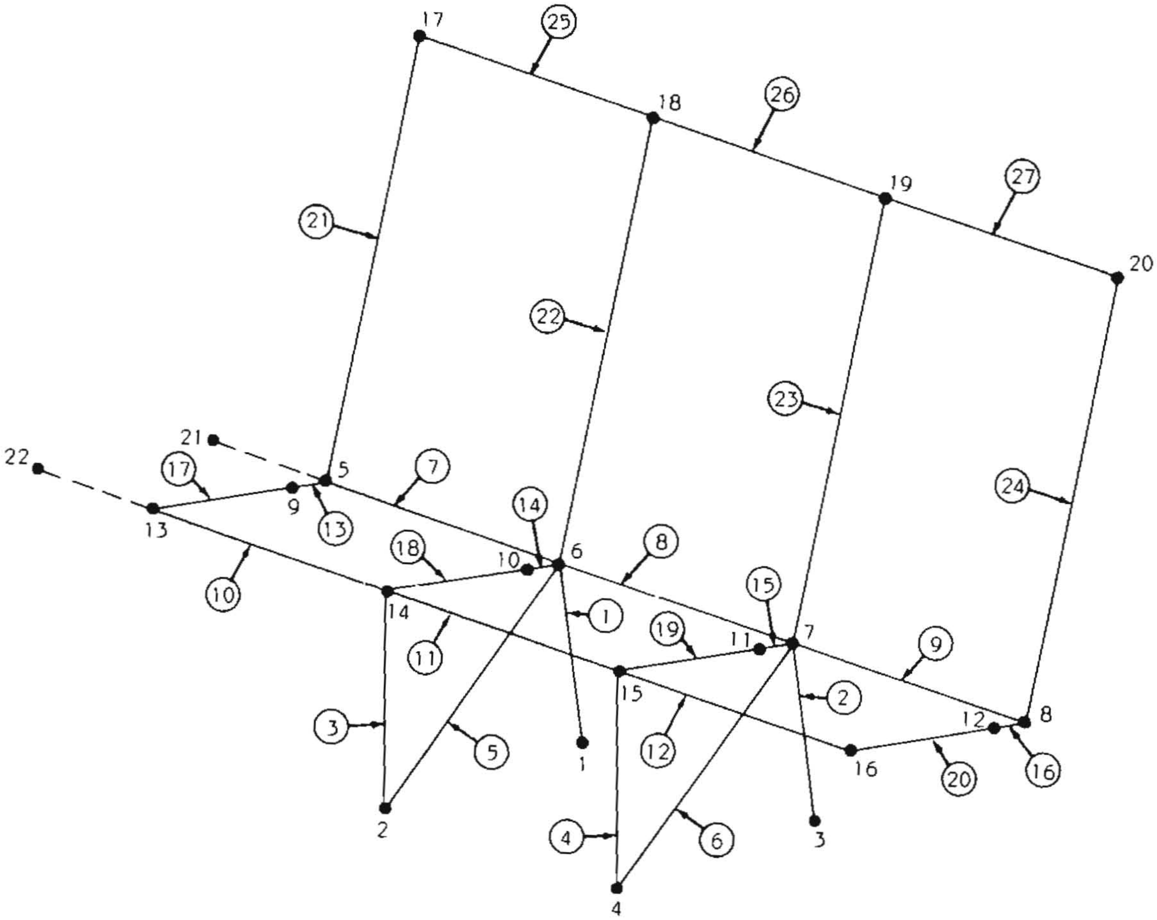
*Replaced by seat angular displacement (deg) for energy-absorbing seat model (with NSEAT = 0 and SEATM > 0).

Figure 8. Data format for external file 26.

In order to be certain that the occupant initial position is reasonable for the configuration being studied, it is wise to run a short rigid seat case prior to adding the seat structure input. Starting with a small value of final time, TF, on line 4, such as 0.010 sec, the initial position and accelerations of the occupant segments and the external forces can be checked prior to initiating a more expensive case. The plot data saved on unit 14 by SOM-TA can then be input to the occupant plot program and the initial position of all the occupant segments reviewed. If the occupant's initial position, as calculated by subroutine INITIL, is geometrically impossible, the program will be stopped and informative messages printed. An example of this type of error, commonly encountered in initially running a case, is in attempting to locate the heel position beyond the reach of the legs. If the input parameters yield a geometrically feasible initial position and NOPLOT > 0 on line 3 and TPLOT = 0 on line 3A, then data for a plot of the initial position will be stored.

Once the desired initial position has been achieved for the occupant, the input data for the finite element seat structure model can be added. The NSEAT parameter on line 2 should then be changed from 0 to 1 to signify modeling a non-rigid seat. Once again, prior to running a complete simulation, a case with a small TF should be run in order to check the seat structure plot at the initial time.

When it has been determined that both the occupant initial position and the seat structure configuration are as desired, a complete simulation case can be run. The user should take care that the TMAX parameter in decimal seconds on line 4 corresponds to the time allotted for the run in the job control language (which may be an octal number). Within the program, an allowance is made for printing of the stored output data. Should the run be terminated at TMAX prior to the solution reaching completion at TF, the output data already generated will be printed, including the final generalized coordinates, which can be used in restarting the solution.



84 08004 07

1, 2, ..., 22 Node numbers

1, 2, ..., 27 Beam element numbers

Figure 9. Sample case airline seat finite element model.

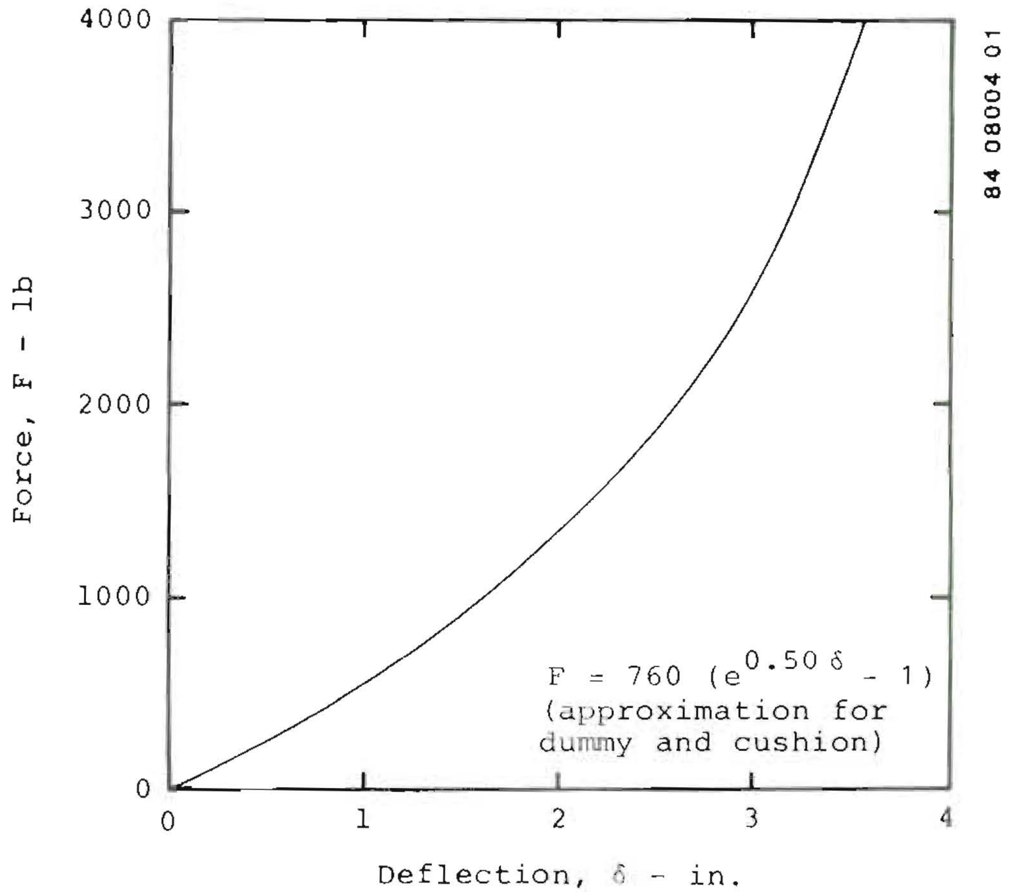


Figure 10. Exponential approximation of force-deflection characteristics for dummy and 1.5-in.-thick cushion.

Line 40: Initial position for passenger 2. Same as line 39 except YPASS(2) = 0 in.

Line 41: Initial position for passenger 3. Same as line 39 except YPASS(3) = 20 in.

Line 42: Coordinate system was located under the rear edge of the seat pan, so that XSEAT = 10 in.; the height of the seat pan is 12 in.; seat pan and back angles are 8 and 16 degrees, respectively. Seat pan length and width are 15.15 in. and 20 in. respectively. The height of the seat back is 39 in. The seat back is the same width as the seat pan. (These coordinates are illustrated in figure A-9).

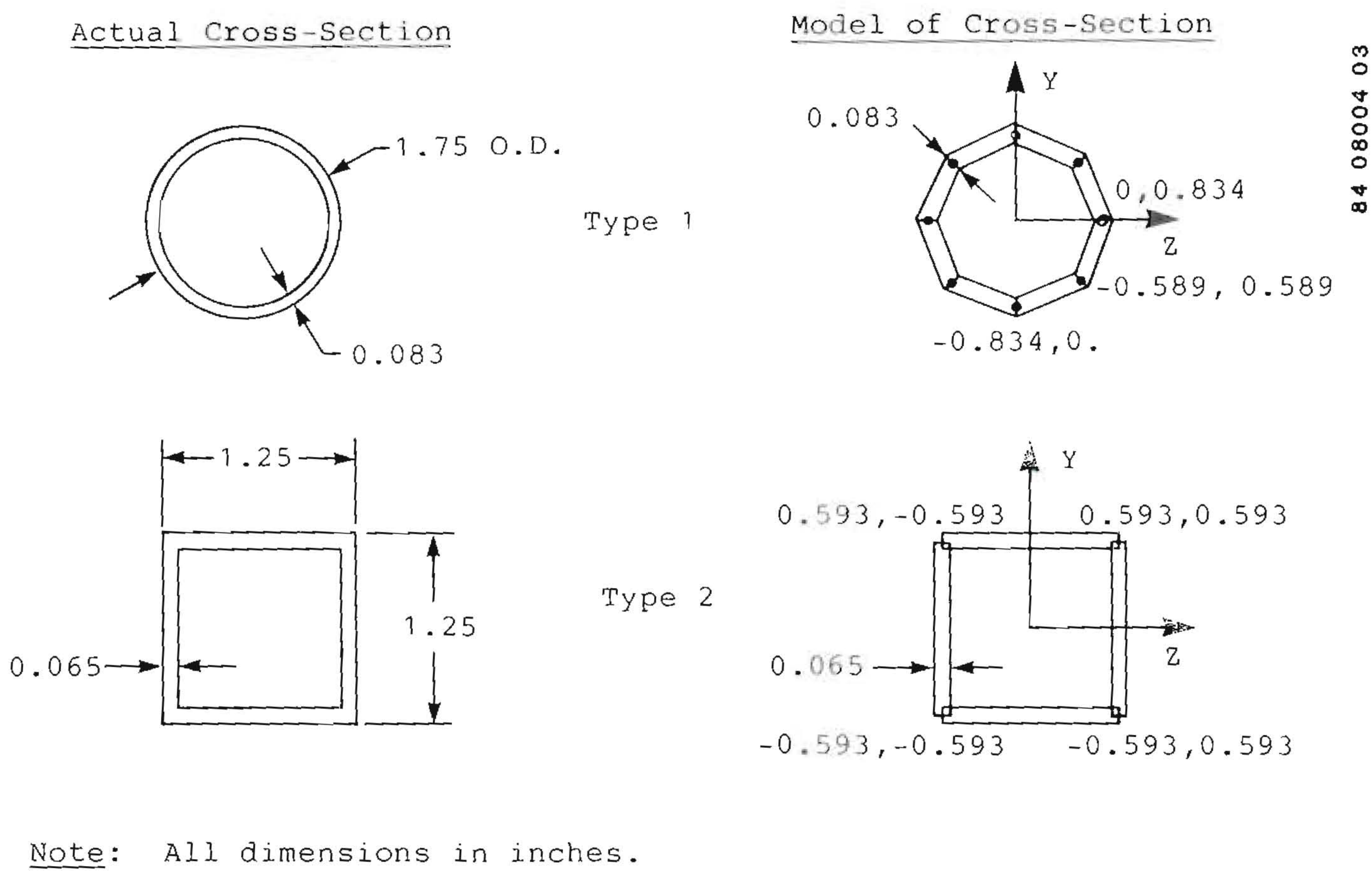


Figure 12. Element cross-section models used for seat structure beam elements.

Line 51: Twenty-seven lines of beam element data corresponding to NELE = 27. Beam element connectivity and numbers are shown in figure A-13.

Line 52: Seat pan cushion load is distributed on nodes (5, 6, 13, 14) for the first (right) occupant, (6, 7, 14, 15) for the second (middle) occupant, and (7, 8, 15, 16) for the third (left) occupant. The order in which the seat pan nodes are specified is shown in figure A-14.

Line 53: Back cushion load is distributed on nodes (5, 6, 17, 18) for the first (right) occupant, (6, 7, 18, 19) for the second (middle) occupant, and (7, 8, 19, 20) for the third (left) occupant. The order in which the seat back nodes are specified is shown in figure A-14.

Line 54: Lap belt loads are applied at nodes (9, 10) for the first (right) occupant, (10, 11) for the second (middle) occupant, and (11, 12) for the third (left) occupant.

```
TRANSPORT AIRCRAFT SEAT
    1    1    2    3    3    1    1    1    2
    1    1    2    0    1    1    2    1    1    1    8    8.00050.025
       0.       .025       .050       .075       .100       .125       .150       .175
       0.        0.         0.         0.         0.         0.         0.         0.
      20.       20.        20.        20.        20.        20.        20.        20.
      45.       45.        45.        45.        45.        45.        45.        45.
    1   20
    1   27
     300.      .0005      .0005       0.1      0.001        0.       .176      .0005
     760.       0.50       2.40       1.5
     760.       0.50       2.40       1.5
    0    0    1    0    1
     760.       0.50       2.40       3.0
     550.      1300.      2750.    0.0403     0.1048     0.1613        0.         0.
     12.5      -30.0       15.0      12.5      -10.0       15.0
     12.5      -10.0       15.0      12.5       10.0       15.0
     12.5       10.0       15.0      12.5       30.0       15.0
       0.       -6.0       -6.0       0.0        0.0

       0.       .010       .155      .165       .175




      30.         0.         0.
       0.         0.         0.
    1           0.18       0.25
     -16.       -16.         7.      -16.        60.        32.       -20.
     -16.       -16.         7.      -16.        60.        32.         0.
     -16.       -16.         7.      -16.        60.        32.        20.
      10.        12.         8.       16.      15.15        20.        39.        20.
```

Figure 13. Listing of input data for sample case.

```
  8   6   7                   1  22   2   1
  9   7   8                   1  22   2   1
 10  13  14                   1  21   2   1
 11  14  15                   1  21   2   1
 12  15  16                   1  21   2   1
 13   5   9                   2  21   2   1
 14   6  10                   2  21   2   1
 15   7  11                   2  21   2   1
 16   8  12                   2  21   2   1
 17   9  13                   2  21   2   1
 18  10  14                   2  21   2   1
 19  11  15                   2  21   2   1
 20  12  16                   2  21   2   1
 21   5  17                   2  21   2   1
 22   6  18                   2  21   2   1
 23   7  19                   2  21   2   1
 24   8  20                   2  21   2   1
 25  17  18                   2  21   2   1
 26  18  19                   2  21   2   1
 27  19  20                   2  21   2   1
  5   6  13  14   6   7  14  15   7   8  15  16
  5   6  17  18   6   7  18  19   7   8  19  20


  9  10  10  11  11  12
1111001
2112001
    -.5
3111001
4111001
```

Figure 13 (contd). Listing of input data for sample case.

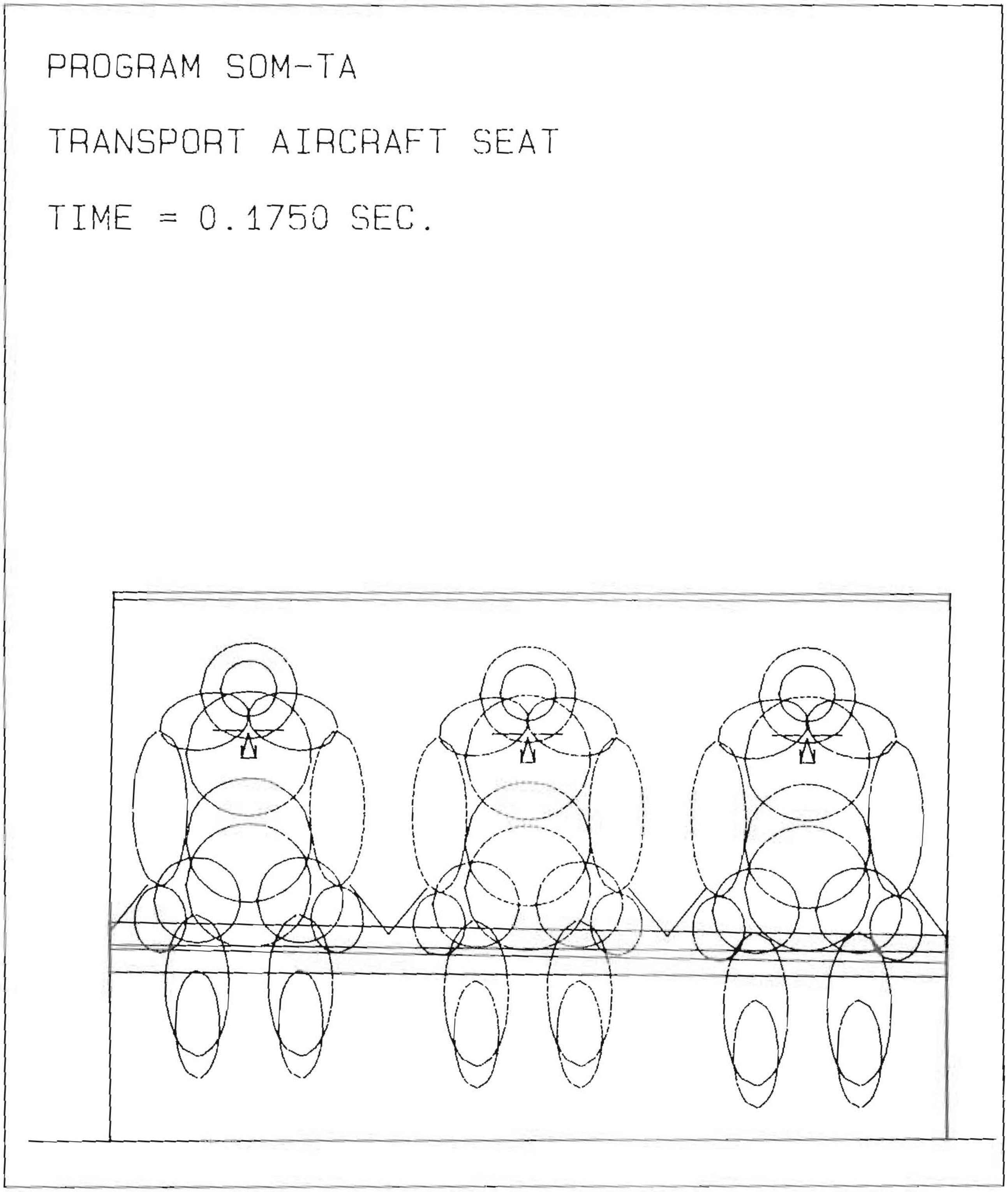


Figure 15. Sample case occupant plot (front view) at time = 0.175 sec.

APPENDIX A

PROGRAM SOM-TA INPUT DATA REQUIREMENTS

In this Appendix a line-by-line description of input data required by Program SOM-TA is presented. As described in section 2, there are a number of optional lines of data, each of which is suffixed by an alphabetic character, such as line 6A, which is used only if the seat includes a headrest.

LINE 2: Seat Type and Occupant Location

DESCRIPTION: Seat pitch, type, and locations of passengers.

FORMAT AND EXAMPLE:

NUNIT	NSEAT	NDIM	NOCC	ITYPE	ISEAT(1)	ISEAT(2)	ISEAT(3)	IPASS	
1	1	2	3	3	1	1	1	2	

FIELD	FORMAT	CONTENTS
NUNIT	I5	System of units NUNIT = 0 : SI units NUNIT = 1 : English units.
NSEAT	I5	Seat model NSEAT = 0 : Rigid seat model NSEAT = 1 : Finite element seat model.
NDIM	I5	Definition of occupant degrees of freedom NDIM = 2 : Two-dimensional simulation NDIM = 3 or 0 : Three-dimensional simulation.
NOCC	I5	Number of occupants to be modeled
ITYPE	I5	Seat type in terms of occupant positions. ITYPE = 1 : Single seat ITYPE = 2 : Two-passenger seat ITYPE = 3 : Three-passenger seat.
ISEAT	3I5	Locations of occupants, specifying whether a given seat position is occupied (1) or empty (0) ISEAT(1) : Right-most position ISEAT(2) : Center position for three-passenger seat,left position for two-passenger seat ISEAT(3) : Left position for three-passenger seat

LINE 3: Output Selection

DESCRIPTION: Definition of output data to be stored for printing and number of plots.

FORMAT AND EXAMPLE:

IOUT(1)	IOUT(2)	IOUT(3)	IOUT(4)	IOUT(5)	IOUT(6)	IOUT(7)	IOUT(8)	IOUT(9)	IOUT(10)	NOPLOT	NSPLOT	DTPLT	TSEAT		
1	1	2	0	1	1	2	1	1	1	8	8	.0005	0.025		

FIELD	FORMAT	CONTENTS
IOUT	10I5	Vector of 0's, 1's, 2's and 3's indicating which output data are to be printed (1, 2, or 3) or not printed (0)

IOUT(1) : Occupant segment position
IOUT(2) : Occupant segment velocity
IOUT(3) : Occupant segment acceleration (1)
IOUT(4) : Secondary impact prediction (2)
IOUT(5) : Restraint system forces
IOUT(6) : Injury criteria
IOUT(7) : Seat external loads (cushions, floor) (1)
IOUT(8) : Seat structure deflections (3)
IOUT(9) : Seat structure support reactions
IOUT(10): Stresses in seat structure beam elements (4).

FIELD	FORMAT	CONTENTS
NOPLOT	I5	Number of requested occupant position plots (up to 8). Lines 3A and 3B must be inserted if NOPLOT 0.
NSPLOT	I5	Number of requested seat position plots (up to 8). Lines 3A, 3C, and 3D must be inserted if NSPLOT 0.

---

(1) For IOUT(3) and IOUT(7), an input value of 1 results in unfiltered output. A value of 2 or 3 results in application of a class 180 (300 Hz) or class 60 (100 Hz) filter, respectively.

(2) IOUT(4) = 0 : No secondary impact prediction and the forward seat is not plotted.
IOUT(4) = 1 : Subroutine IMPACT is called for prediction of contact with the seat back and occupant plots show the forward seat in its undeformed position.
IOUT(4) = 2 : Subroutine IMPACT is called for prediction of contact with the seat back and occupant plots show the forward seat deformation as the seat being modeled.

(3) If IOUT(8) = 1, line 3E must be included to select the nodes for seat structure deflections.

(4) If IOUT(10) = 1, line 3F must be included to select the beam elements for seat structure loads and stresses.

LINE 3A: Plot Times (only if NOPLOT > 0 or NSPLOT > 0)

DESCRIPTION: Times when plots of occupant or seat position are desired. The first NOPLOT fields are read, as defined on line 2.

Occupant and seat plot data are stored on external file numbers 14 and 20, respectively. Therefore, if plots are requested, the job control language must define files 14 and/or 20 as permanent files to be saved. These permanent files can then be used as input to occupant and seat plotting programs.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
TPLOT(1)	TPLOT(2)	TPLOT(3)	TPLOT(4)	TPLOT(5)	TPLOT(6)	TPLOT(7)	TPLOT(8)
0.	0.025	0.050	0.075	0.100	0.125	0.150	0.175

FIELD	FORMAT	CONTENTS
TPLOT	8F10.0	Plot times, seconds.

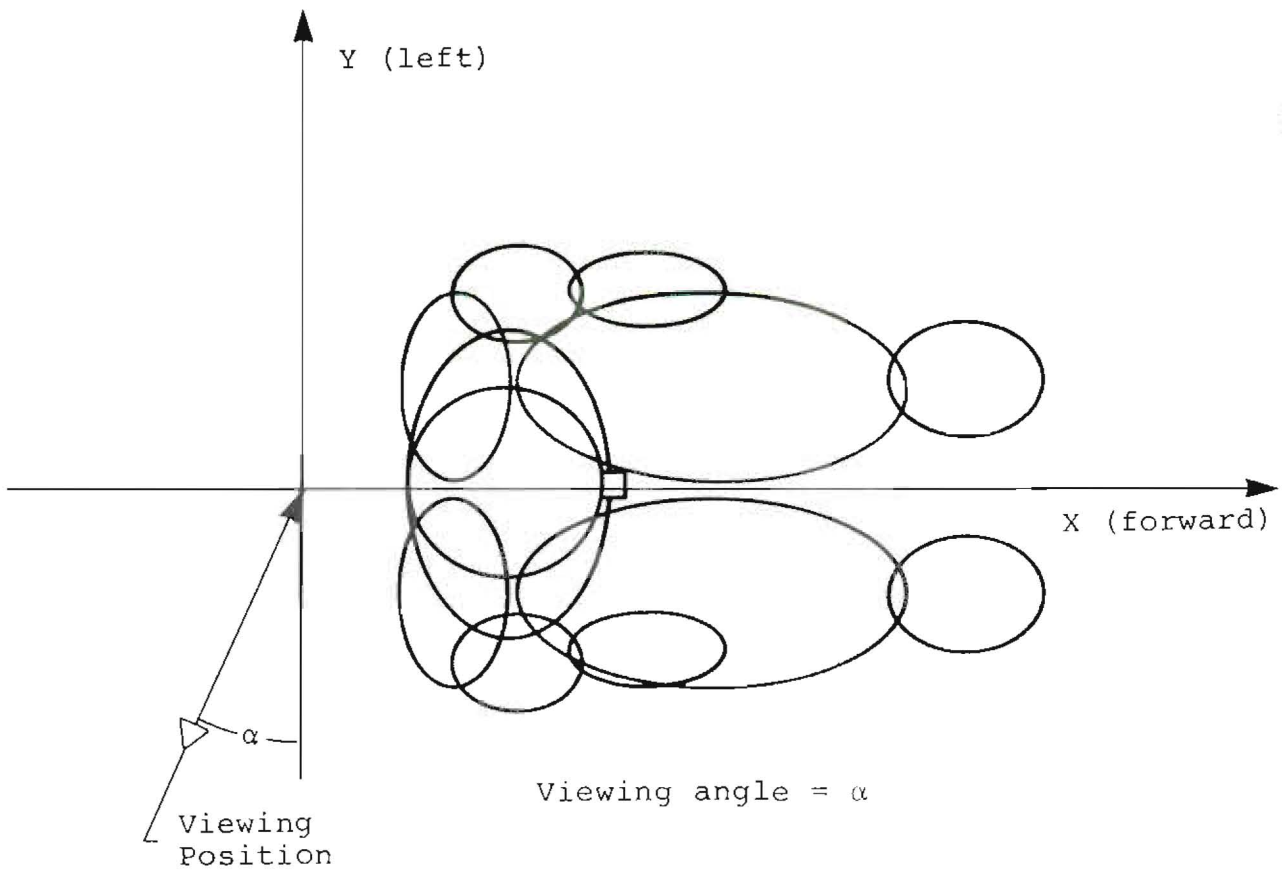
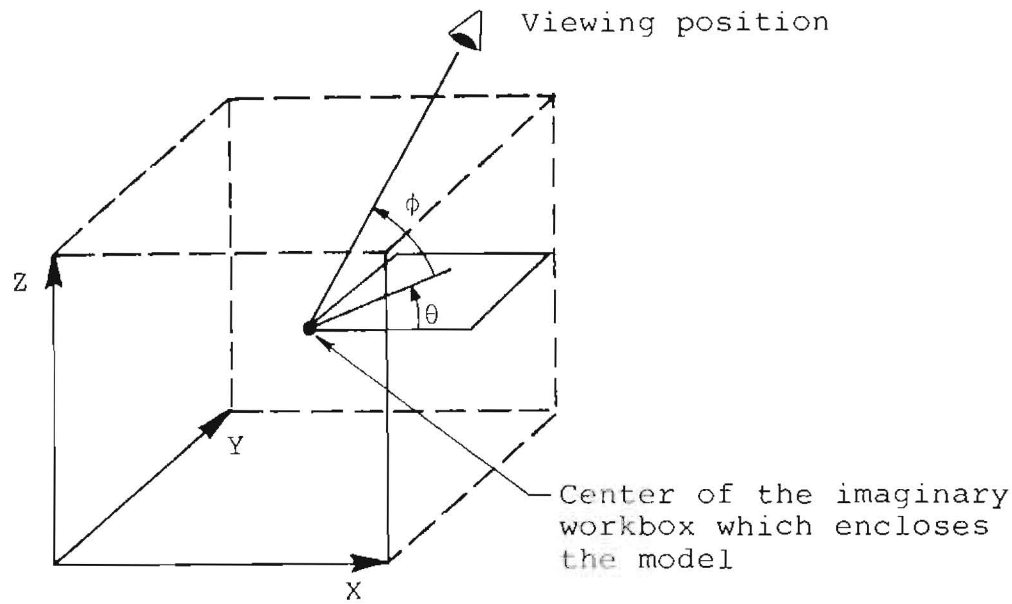


Figure A-1. Definition of occupant plot viewing angle.



θ = Azimuth angle in X-Y plane in degrees ($-180° \leq \theta \leq +180°$)

ϕ = Elevation angle in degrees ($-90° \leq \phi \leq +90°$)

Figure A-2. Angular coordinates for viewing of seat models.

LINE 3E: Nodal Output Selection (only if IOUT(8) > 0)

DESCRIPTION: Node numbers, in pairs, to specify which X, Y, Z displacements are to be printed. (The node numbers are defined on line 50.)

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890

KNODE(1)	KNODE(2)	KNODE(3)	KNODE(4)	KNODE(5)	KNODE(6)	KNODE(7)	KNODE(8)	KNODE(9)	KNODE(10)
1	20								

FIELD	FORMAT	CONTENTS
KNODE	5(2I5)	Nodal displacements printed for nodes beginning with KNODE(I) through KNODE(I+1), inclusive. Up to 5 pairs of nodes are permitted.

LINE 4: Simulation Control Data

DESCRIPTION: Parameters for control of solution duration, step size, and error bounds.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
TMAX	DMAX	DMIN	EUR	ELR	TI	TF	DTI
300.	0.0005	0.0005	0.10	0.001	0.	0.176	0.0005

FIELD	FORMAT	CONTENTS
TMAX	F10.0	The maximum time allotted for the run on the job card in decimal seconds. This will ensure that the solution is terminated in time to permit printing of the output already computed.
DMAX	F10.0	Maximum step size. A value of 0.001 sec has been used successfully.
DMIN	F10.0	Minimum step size. A value as large as 0.001 sec has been used successfully, but the use of very stiff restraint system webbing or seat cushions may require a smaller value, such as 0.00001. The solution can be accomplished with a fixed step size by setting DMIN = DMAX.
EUR	F10.0	Maximum bound on error between predictor and corrector. A value of 0.05 to 0.10 is suggested, corresponding to a range of 5 to 10 percent. If the error in any variable is larger than this value, the step size is halved, maintaining solution accuracy.
ELR	F10.0	Lower bound on error between predictor and corrector. A value of 0.001 is suggested, corresponding to 0.1 percent. If the error in all variables is smaller than this value, the step size is doubled, preventing the computer execution cost from becoming excessively high. Note: Because doubling the step size multiplies the truncation error in the Adams-Moulton integrator by a factor of 2^5, ELR should be chosen less than EUR/32 if the advantages of doubling are not to be short-lived.
TI	F10.0	Initial solution time in seconds. Normally taken as 0.
TF	F10.0	Final solution time in seconds.
DTI	F10.0	Initial step size, normally set equal to DMIN.

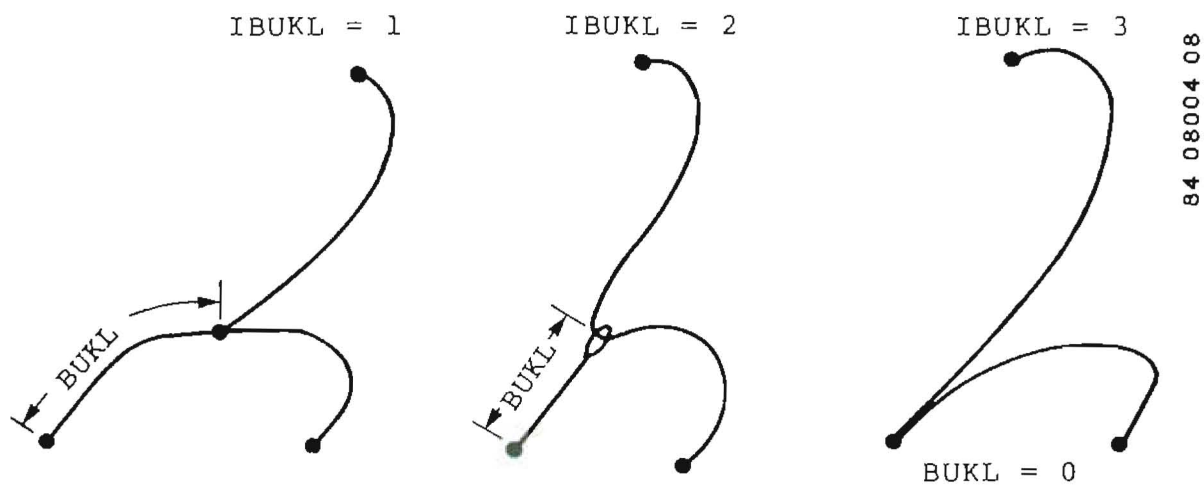
LINE 6: Back Cushion Properties

DESCRIPTION: Force-deflection characteristics, damping, and thickness for back cushion. These characteristics should be measured using an indenter with the form of the occupant torso. If a dummy torso is used in measurement, the deflection should be based on the chest accelerometer location. The force, F, is computed from cushion deflection, δ, according to $F = C(e^{B\delta} - 1)$.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
CBC	BBC	DPBC	THBCE				
760.	0.50	2.45	1.50				

FIELD	FORMAT	CONTENTS
CBC	F10.0	Coefficient C in above equation (lb).
BBC	F10.0	Coefficient B in above equation (in.$^{-1}$).
DPBC	F10.0	Damping coefficient at zero load (lb-sec/in.).
THBCE	F10.0	Unloaded thickness of cushion in center of seat back (in.).



1 = Shoulder belt fixed to buckle
2 = Shoulder belt and one side of lap belt are one length of webbing
3 = Shoulder belt and lap belt attached to fixed point

NOTE: BUKL parameter is defined on lines 11B, 11C, and 11D.

Figure A-3. Types of buckle connections specified by IBUKL on line 7.

LINE 8: Lap Belt Properties

DESCRIPTION: Tables of forces and deflections define an approximation to force-deflection curve by three linear segments, as illustrated in figure A-4. The force and deflection at point 1 are assumed to be zero.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
FFLB(2)	FFLB(3)	FFLB(4)	DDLB (2)	DDLB(3)	DDLB(4)	DPLB	SLAB
550.	1300.	2250.	0.0403	0.1048	0.1613	0.	0.

FIELD	FORMAT	CONTENTS
FFLB	3F10.0	Forces (lb).
DDLB	3F10.0	Strains corresponding to forces (in./in.).
DPLB	F10.0	Damping coefficient (lb-sec).
SLAB	F10.0	Slack in the total lap belt loop, the length that, if removed, would cause the belt to pass snugly over the occupant with zero load (in.).

LINE 9: Lap Belt Anchor Points and Footrest, Passenger No. 1*

DESCRIPTION: Coordinates of right and left lap belt anchor points in aircraft coordinate system; location of footrest.

FORMAT AND EXAMPLE:

1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
XLB(1,1)	YLB(1,1)	ZLB(1,1)	XLB(2,1)	YLB(2,1)	ZLB(2,1)		
12.5	-30.0	15.0	12.5	-10.0	15.0		

FIELD	FORMAT	CONTENTS
XLB(1,1) YLB(1,1) ZLB(1,1)	3F10.0	Coordinates of right-hand lap belt anchor point in aircraft coordinate system (in.).
XLB(2,1) YLB(2,1) ZLB(2,1)	3F10.0	Coordinates of left-hand lap belt anchor point in aircraft coordinate system (in.).

*Used only if ISEAT(1) = 1 on line 2.

LINE 11: Lap Belt Anchor Points and Footrest, Passenger No. 3*

DESCRIPTION: Coordinates of right and left lap belt anchor points in aircraft coordinate system; location of footrest.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
XLB(1,3)	YLB(1,3)	ZLB(1,3)	XLB(2,3)	YLB(2,3)	ZLB(2,3)		
12.5	10.0	15.0	12.5	30.0	15.0		

FIELD	FORMAT	CONTENTS
XLB(1,3) YLB(1,3) ZLB(1,3)	3F10.0	Coordinates of right-hand lap belt anchor point in aircraft coordinate system (in.).
XLB(2,3) YLB(2,3) ZLB(2,3)	3F10.0	Coordinates of left-hand lap belt anchor point in aircraft coordinate system (in.).

*Must be included. Used only if ITYPE = 3 and ISEAT(3) = 1 on line 2.

LINE 11B, 11C, 11D: Shoulder Belt Anchor Points (only if IRSYS > 0)*

DESCRIPTION: Coordinates of shoulder belt anchor point in aircraft coordinate system, along with other restraint system characteristics.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
XSH(1)	YSH(1)	ZSH(1)	BUKL(1)	XTRAL(1)			

FIELD	FORMAT	CONTENTS
XSH(1) YSH(1) ZSH(1)	3F10.0	Coordinates of shoulder belt anchor point in aircraft coordinate system, or point from which belt passes to shoulder in a straight line.
BUKL(1)	F10.0	Length of lap belt webbing attached to buckle, illustrated in figure A-3 (in.).
XTRAL(1)	F10.0	Length of shoulder strap beyond ($XSH^{(1)}$, $YSH^{(1)}$, $ZSH^{(1)}$) if strap not in straight line, as shown in figure A-5 (in.).

Lines 11C and 11D repeat Line 11B for passengers 2 and 3.

*Not present for sample case.

LINE 12 - 35: Aircraft Acceleration

DESCRIPTION: The time variation of each of the six components of the acceleration of the aircraft coordinate system is approximated by up to 16 points in acceleration and time.

FORMAT AND EXAMPLE: (Lines 12 - 15)

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
AX(1)	AX(2)	AX(3)	AX(4)	AX(5)	AX(6)	AX(7)	AX(8)
0.	-6.0	-6.0	0.	0.			
AX(9)	AX(10)	AX(11)	AX(12)	AX(13)	AX(14)	AX(15)	AX(16)
TX(1)	TX(2)	TX(3)	TX(4)	TX(5)	TX(6)	TX(7)	TX(8)
0.	0.010	0.155	0.165	0.175			
TX(9)	TX(10)	TX(11)	TX(12)	TX(13)	TX(14)	TX(15)	TX(16)

FIELD	FORMAT	CONTENTS
Lines 12 and 13:		
AX(J), J = 1-8	8F10.0	X-acceleration (G).
AX(J), J = 9-16	8F10.0	
Lines 14 and 15:		
TX(J), J = 1-8	8F10.0	X-time corresponding to lines 12 and 13 (sec).
TX(J), J = 9-16	8F10.0	
Lines 16 and 17:		Y-acceleration (G).
Lines 18 and 19:		Y-time (sec).
Lines 20 and 21:		Z-acceleration (G).
Lines 22 and 23:		Z-time (sec).
Lines 24 and 25:		Yaw acceleration (rad/sec/sec).
Lines 26 and 27:		Yaw time (sec).
Lines 28 and 29:		Pitch acceleration (rad/sec/sec).
Lines 30 and 31:		Pitch time (sec).
Lines 32 and 33:		Roll acceleration (rad/sec/sec).
Lines 34 and 35:		Roll time (sec).

LINE 37: Aircraft Initial Position

DESCRIPTION: Components of aircraft initial position, in earth-fixed coordinate system, and attitude.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
XA	YA	ZA	YAW	PITCH	ROLL		
0.	0.	0.	0.	0.	0.		

FIELD	FORMAT	CONTENTS
XA YA ZA	3F10.0	Position of aircraft coordinate system in inertial system (earth-fixed system in which gravity acts in the -Z direction) (in.). These initial coordinates are normally taken as (0., 0., 0.) unless displacement from a specific point is desired. For example, if the simulation is to be initiated at some horizontal distance from a barrier, such as 60 in., the initial position could be specified as (-60., 0., 0.). If the simulation is to begin 10 in. above the ground in a vertical drop, the initial position could be specified as (0., 0., 10.). These coordinates are not used in the simulation but only in output of aircraft position.
YAW PITCH ROLL	3F10.0	Initial attitude of aircraft relative to earth-fixed system (deg).

LINE 39: Occupant Initial Position, Passenger No. 1

DESCRIPTION: Initial position angles and heel X-position, as illustrated in figure A-6. The heels are assumed to begin at Z = 0. The torso is aligned according to GAM(1,1), GAM(2,1), and GAM(3,1), and the position is then determined from static equilibrium, allowing for compression of the cushions. Also, the Y-coordinate of the occupant plane of symmetry is included.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
GAM(1,1)	GAM(2,1)	GAM(3,1)	GAM(4,1)	GAM(5,1)	XHEEL(1)	YPASS(1)	
-16.	-16.	7.	-16.	60.	32.	-20.	

FIELD	FORMAT	CONTENTS
GAM(I,1)	5F10.0	Vector of initial position angular coordinates, as illustrated in figure A-6 (deg).
XHEEL(1)	F10.0	X-coordinate of heels in aircraft coordinate system (in.).
YPASS(1)	F10.0	Y-coordinate of mid-place (plane of symmetry) for occupant.

LINE 39: Occupant Initial Position, Passenger No. 1

DESCRIPTION: Initial position angles and heel X-position, as illustrated in figure A-6. The heels are assumed to begin at Z = 0. The torso is aligned according to GAM(1,1), GAM(2,1), and GAM(3,1), and the position is then determined from static equilibrium, allowing for compression of the cushions. Also, the Y-coordinate of the occupant plane of symmetry is included.

FORMAT AND EXAMPLE:

0 1	2	3	4	5	6	7	8
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
GAM(1,1)	GAM(2,1)	GAM(3,1)	GAM(4,1)	GAM(5,1)	XHEEL(1)	YPASS(1)	
-16.	-16.	7.	-16.	60.	32.	-20.	

FIELD	FORMAT	CONTENTS
GAM(I,1)	5F10.0	Vector of initial position angular coordinates, as illustrated in figure A-6 (deg).
XHEEL(1)	F10.0	X-coordinate of heels in aircraft coordinate system (in.).
YPASS(1)	F10.0	Y-coordinate of mid-place (plane of symmetry) for occupant.