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UCIN VEHICLE-OCCUPANT/CRASH-VICTIM SIMULATION MODEL,(U)
JUN 76 R L HUSTON, C E PASSERELLO, M W HARLOW N00014-72-A-0027-0002

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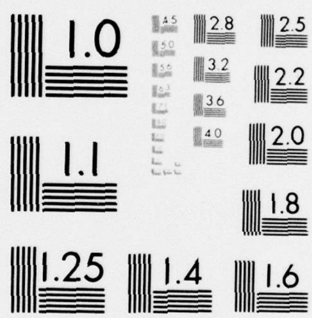

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NATIONAL BUREAU OF STANDARDS-1963-A

UCIN VEHICLE-OCCUPANT/CRASH-VICTIM SIMULATION MODEL

Report Date: 1 June 1976

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INTRODUCTION

Recently there have appeared a number of finite-segment computer models of the human body designed primarily to conduct crash-victim analyses. Indeed, there are currently as many as 10 distinct vehicle-occupant/crash-victim models available [1]. Perhaps the first of these was a two-dimensional computer code developed originally by McHenry [2] in 1963 and later refined in 1966 and 1968. More recent two-dimensional models include those developed by Segal [3], Danforth and Randall [4], Robbins, Bowman and Bennett [5], Glancy and Larsen [6], and Karnes, Tocher and Twigg [7]. The basic difference in these codes is the variety of input-output options available. The three-dimensional models include those developed by Robbins [8], Robbins, Bennett and Bowman [9], Young [10], Furusho and Yokoya [11], Bartz [12], Fleck, Butler and Vogel [13, 14], and Huston, Passerello, Harlow, Hessel and Winget [15-18]. There is more diversity among these codes because of their greater complexity. A summary of the various characteristics of these codes, their capabilities, and their formulation may be found in [1].

The objective of this paper is to present a description of the UCIN code with particular emphasis upon its options, capabilities, formulation and input-output procedures. The balance of the paper is divided into five parts with the first of those providing a description of the model and its capabilities. This is followed in the next three parts by listing of the input-output procedures and the final part provides a summary of the vital features of the code.

MODEL DESCRIPTION AND CAPABILITIES

The model consists of 12 rigid bodies representing the human limbs together with a vehicle cockpit as shown in Figure 1. The twelve bodies of the model are connected together with ball-and-socket joints as shown in Figure 2.

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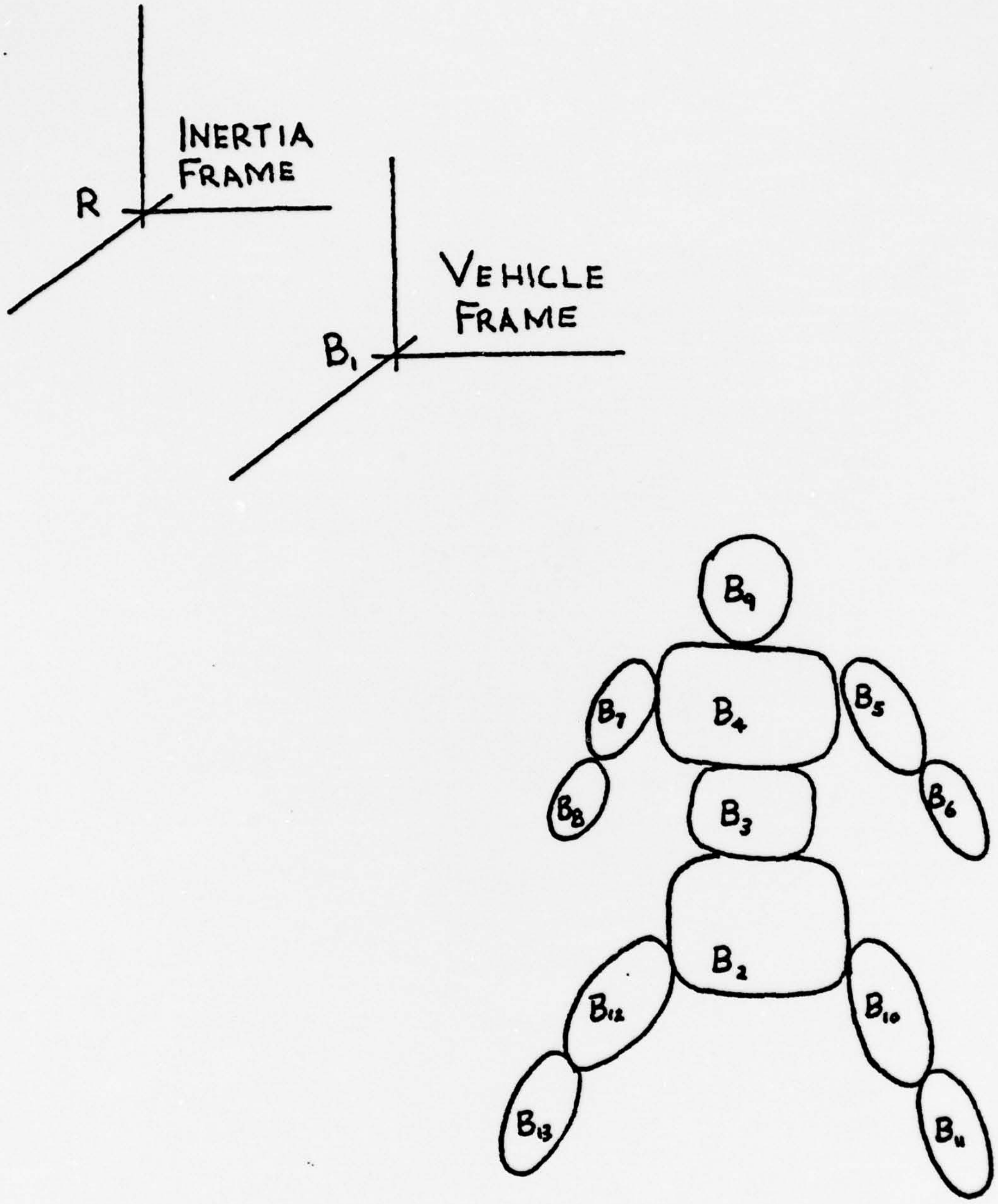

Figure 1. The Model and the Vehicle Cockpit

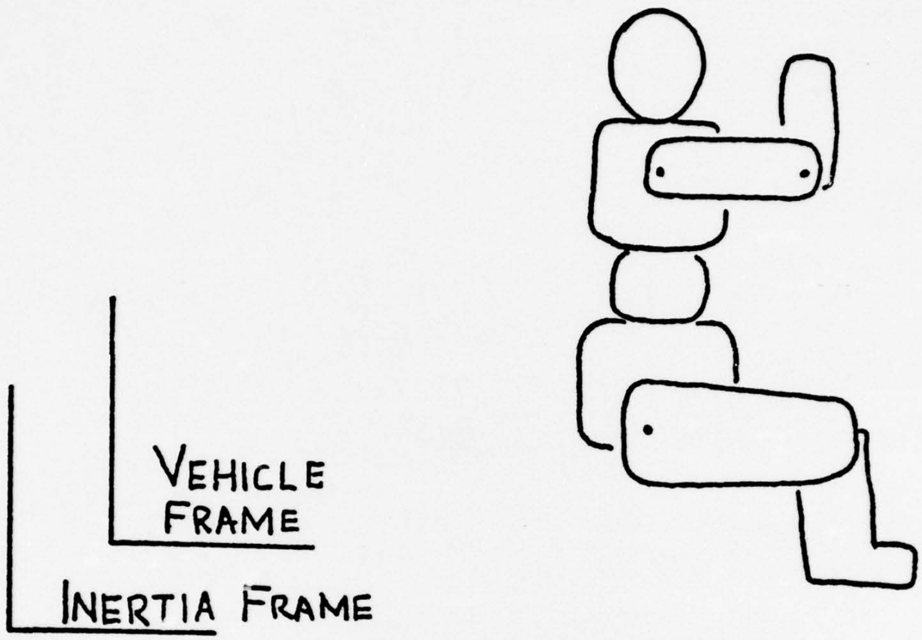

Figure 2. Side View of the Model in Sitting Configuration

Forty-eight variables are required to describe the position and orientation of the model. These are:

x_1, x_2, x_3	position of the vehicle relative to an inertial frame
x_4, x_5, x_6	orientation of the vehicle relative to an inertial frame
x_7, x_8, x_9	position of a reference point in B_2, the lower torso relative to the origin of the vehicle frame
x_{10}, x_{11}, x_{12}	orientation of B_2, the lower torso, relative to the vehicle frame
x_{13}, x_{14}, x_{15}	orientation of B_3, the middel torso, relative to B_2, the lower torso
x_{16}, x_{17}, x_{18}	orientation of B_4, the upper torso, relative to B_3, the middel torso
x_{19}, x_{20}, x_{21}	orientation of B_5, the upper left arm, relative to B_5, the upper left arm
x_{22}, x_{23}, x_{24}	orientation of B_6, the lower left arm relative to B_5, the upper left arm

x_{25}, x_{26}, x_{27}	orientation of B_7, the upper right arm, relative to B_4, the upper torso
x_{28}, x_{29}, x_{30}	orientation of B_8, the lower right arm, relative to B_7, the upper right arm
x_{31}, x_{32}, x_{33}	orientation of B_9, the head, relative to B_4, the upper torso
x_{34}, x_{35}, x_{36}	orientation of B_{10}, the upper left leg, relative to B_2, the lower torso
x_{37}, x_{38}, x_{39}	orientation of B_{11}, the lower left leg, relative to B_{10}, the upper left leg
x_{40}, x_{41}, x_{42}	orientation of B_{12}, the upper right leg, relative to B_2, the lower torso
x_{43}, x_{44}, x_{45}	orientation of B_{13}, the lower right leg, relative to B_{12}, the upper right leg
x_{46}, x_{47}, x_{48}	position of a reference point in B_9, the head, relative to an attach point in B_4, the upper torso

All of these variables, except for the position variables, x_1, x_2, x_3, x_7, x_8, x_9, x_{46}, x_{47} and x_{48}, are orientations angles generated by successive rotation of adjacent bodies relative to each other. The model thus uses "relative coordinates" (ie. orientation between bodies) as opposed to "absolute coordinates" (orientation in space) to define its configuration. These orientation angles are in turn defined as follows: Imagine two adjacent bodies of the system oriented relative to each other so that coordinate axes (X,Y,Z) unbedded in each are respectively aligned. Next, imagine the second body rotated dextrally, relative to the first body, through an angle α, about its X axis. Then imagine successive dextral rotations of the second body about its Y and Z axes through angles β and γ. This brings the second body into general orientation relative to the first defined by the relative orientation angles α, β, and γ. The orientation variables, listed above in sets of three, are respectively α, β, and γ relative orientation angles.

The first six variables listed above define the motion of the cockpit or vehicle frame relative to inertia space. These variables must be specified in input data. Also, variables x_{22}, x_{24}, x_{28}, x_{30}, x_{37}, x_{39}, x_{43}, and x_{45} are usually specified as zero to simulate hinge joints at the elbows and knees. The remaining 31 variables may be either specified or left as unknowns. If the variables are specified (eg. $x_{16} = 0$), the required moment needed to maintain that specification (eg, M_{16}) is determined.

The model allows for the arbitrary specification of external forces and moments on each of its bodies. These forces and moments are represented on each body as a single force passing through its mass center, together with a couple. These forces and the moments of the couples are part of the input data.

The model's initial position is generally in an erect sitting position as shown in Figures 2 and 3. In this poistion, all the body coordinate axes and the vehicle frame are aligned and thus all the orientation angles are zero. The model has a seat which in turn is modelled by springs as shown in Figure 2. Essentially, there are seven springs which may exert forces on the model with the points of contact being the mass centers of bodies 2, 3, 4, 9, 10 and 12. Viscous damper stops are used to provide limited seat deflection. The amount of seat deflection and spring constants are input data.

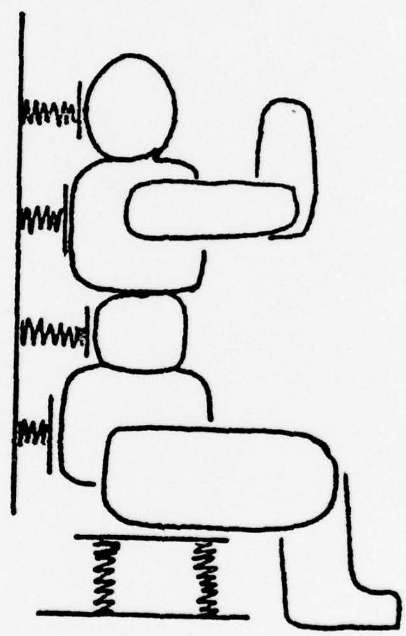

Figure 3. The Model and Seat in Initial Configuration

The computer model provides for the use of up to ten restraining belts attached at arbitrary points between the cockpit and the bodies of the model. These belts are modelled as springs with the spring constants and attach points as part of the input data.

The ball-and-socket connection joints of the model are provided with angle-stops, modelled by one-way dampers, to simulate motion constraints of the human limbs. The angle limits and the damping coefficients are part of the input data.

The model also has the provision of a "stretching" or extending neck. Neck stretch is modelled by a spring and a damper between attach points in bodies 4 and 9. The spring constant and the damping coefficient are input data.

Finally, the computer model provides for the use of 12 intrusion surfaces to simulate the cockpit or vehicle interior. These intrusion surfaces are planes and the output of the code records when a body or limb of the model collides with or passes through an intrusion surface. The intrusion surfaces are listed as follows:

1)	Left windshield	5)	Lower left door	9)	Firewall
2)	Front windshield	6)	Upper right door	10)	Top dash
3)	Right windshield	7)	Lower right door	11)	Front dash
4)	Upper left door	8)	Roof	12)	Bottom dash

The locations and inclination of these intrusion surfaces are also part of the input data.

COMPUTER CODE: INPUT/OUTPUT

The following brief paragraphs provide a general description of the input data required and the output provided by the computer code. The specific format used is described in detail in the next two parts of the paper.

The input consists of the following:

Physical parameters. These are the masses, inertia dyadics, mass center positions connection point positions, and orientation angle limits, for each of the 12 bodies of the human model.

Cockpit geometry. This consists of a normal vector and a location point for each of the 12 intrusion surface planes. Also the floor position and supporting spring force constant are part of the cockpit specifications.

Cockpit motion. The cockpit displacement and rotation relative to an inertia frame are required as input ($x_1,\ldots,x_6$). Typically, it is desired to express this in the form of linear and angular acceleration of the cockpit. The computer program is written so that the cockpit acceleration components may be "read in" by simply specifying the acceleration at selected time intervals of the acceleration profile. (This is, in effect, a straight line approximation to an acceleration curve). Six (three translation and three rotation) such acceleration profiles or curves may be employed.

Spring and damping constants. This includes the seat, restraining belt, orientation angle constants, and neck parameters. Also, the attach points of the restraining belts are included.

Initial conditions. This includes the initial values of the unknown variables and their derivatives. Also the external forces and moments (if any) which are applied to the bodies of the models must be specified.

The output consists of two parts: The first part is simply an "echo" or copy of the input data. The second part contains at each output time the following:

1. The values of all variables and their first derivatives.
2. The joint and mass center positions in both inertia space and relative to the vehicle.
3. The mass center velocities and accelerations.
4. The moments and forces associated with variables which are specified.
5. Restraining belt forces.

SPECIFIC INPUT DATA

Data may be entered into the program either by following the instructions of the interrogating-terminal version of the program or by batch (or remote job entry). The following paragraphs provide the details of the required input card images for batch input. This is followed by a sample listing of input data.

1) Error Set

The first card is a blank card. (It is associated with a debugging subroutine of the program. This card must be included, but being blank, it disengages the debugging routine).

2) Mass of the 12 Bodies

Next, there are 12 data entries on 3 cards for the masses of the 12 bodies. They are read sequentially for the 12 bodies in a 5F10.9 format. The usual units are slugs.

3) Inertia Dyadics

Following this, there are 12 (3 x 3) inertia matrices read sequentially, one for each body. Each matrix requires three cards. Each card contains a row of an inertia matrix. The matrices are referenced to the axis system as shown in Figure 4. They are read in a 5F10.9 format. The usual units are slugs-in^2. These are a 36 cards for this entry.

4) R Vectors

There are 12 of these. They are vectors referenced to the body co-ordinate systems which locate the mass center of a body relative to the connection point for that body with its adjacent lower numbered body, or in the case of B_2 relative to the chosen references point in B_2. (See Figure 5). They are read sequentially one vector per card in a 5F10.9 format. There are 12 cards. The usual units are inches.

5) XI-Vectors

There are eleven of these. They are vectors referenced to body co-ordinate systems which locate the relative positions of connection points (See Figure 5). They are read sequentially one vector per card in a 5F10.9 format. The usual units are inches. There are eleven cards.

6) Cockpit Geometry-Intrusion Surfaces

The first card (the first card in this sequence) contains either a zero of 12 read in I5 format. If a zero is read the intrusion surface option is omitted, and no additional cards should be read in this section. If a 12 is read, 12 additional cards should be read (one for each of the 12 intrusion planes).

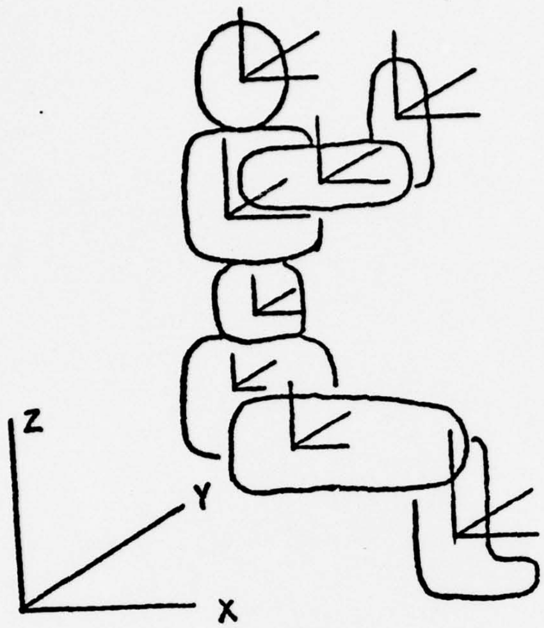

Figure 4.

Axis System for the Model

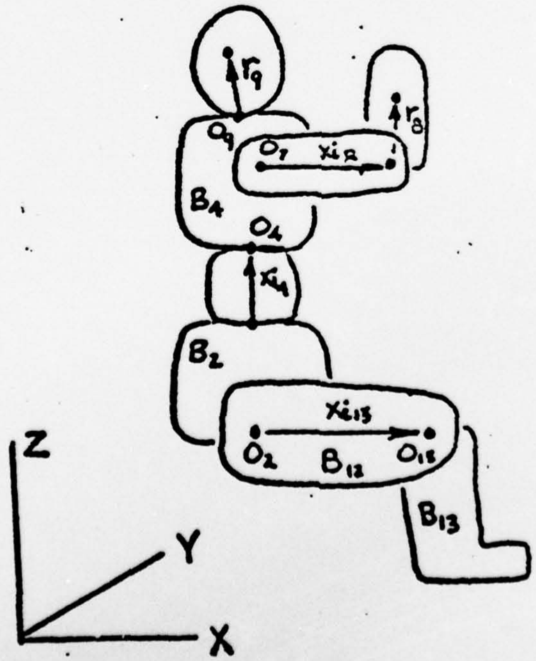

Figure 5.

Position Vectors in the Model

One each of these cards six values are read. The first three values are the coordinates (X,Y,Z) of any point in the intrusion plane relative to 0, the cockpit origin. The last three values are the components of the outward directed vector normal to the intrusion plane. The format is 6F10.9. The 12 intrusion planes are to be entered in the following order:

Left windshield	Lower right door
Front windshield	Roof
Right windshield	Firewall
Upper left door	Top dash
Lower left door	Front dash
Upper right door	Bottom dash

(If a number less than 12 but greater than zero is read on the first card, then the intrusion plane geometry for those planes not read will default to the YZ plane).

7) Magnetic Tape Card

This card allows the user to write all the output data on magnetic tape by writing the tape unit number in I5 format. If a zero is read, or a blank card is used, no magnetic tape is written.

8) Heading Card

On this card the user writes anything he desires as a heading.

9) Floor Spring Constant and Distance

This is a spring constant for the floor and the vertical distance from the reference point in body 2 to the floor of the vehicle when the model is in the reference position. They are read sequentially on a single card in a 5F10.9 format. The usual units are lbs/in and inches.

10) Acceleration Input for the Cockpit

The computer program has been written so that the cockpit acceleration components (three translation and three rotation) may be "read in" by simply specifying the acceleration at selected time intervals of an acceleration profile. The program has the capability of including up to 25 points of the acceleration curve.

To be more specific, consider a straight line approximation to the acceleration curve. The acceleration, velocity and displacement during the i^{th} time interval are then:

$$a = a_i + \left(\frac{a_{i+1}-a_i}{t_{i+1}-t_i}\right)(t-t_i)$$

$$v = v_i + a_i(t-t_i) + \left(\frac{a_{i+1}-a_i}{t_{i+1}-t_i}\right)\frac{(t-t_i)^2}{2}$$

$$d = d_i + v_i(t-t_i) + a_i\frac{(t-t_i)^2}{2} + \left(\frac{a_{i+1}-a_i}{t_{i+1}-t_i}\right)\frac{(t-t_i)^3}{6}$$

where a_i, v_i, d_i and t_i are the acceleration, velocity, displacement and time at the beginning of the i^{th} interval. The kinematical profile of the cockpit is thus determined when the a_i are specified and when v_1 and d_1, the initial velocity and displacement are given.

The computer cards are coded as follows: The first card contains the number of profiles (up to 6) that are used in 10I5 format.

The next cards contain the number of points (up to 25) and the variable numbers (i.e. 1 for x, 2 for y, 3 for z, 4 for α, 5 for β, 6 for γ) of the respective acceleration profile curve for each acceleration profile used. They are read sequentially in a 10I5 format.

The next group of cards contain the time and acceleration ordinate for each point of the respective profile curves which are used. The first card of each subgroup (i.e. for each profile used) also contains the initial velocity and displacement for that profile. The data on these cards are in 5F10.9 format.

11) Neck Spring and Damping Constants

These constants must be included in the input data even if the neck is to remain unstretched during the motion. (A blank card may be used if the neck is to remain unstretched). These constants (spring and damping respectively) are entered on a single card in a 5F10.9 format. The units are usually lb/in and lb.sec/in respectively.

12) <u>Orientation Angle Limits</u>

There are 66 of these--a maximum and a minimum angle displacement for each of the 33 internal orientation angles. For example, the first card defines the limits on the orientation of B_3 relative to B_2 by containing the following data:

$$[\alpha_{23\ max}, \beta_{23\ max}, \gamma_{23\ max}, \alpha_{23\ min}, \beta_{23\ max}, \gamma_{23\ min}]$$

or (see the variable list)

$$[x_{13\ max}, x_{14\ max}, x_{15\ max}, x_{13\ min}, x_{14\ min}, x_{15\ min}]$$

Each card contains 6 data entries in a 6G10.9 format in the above order. There are a total of 11 cards. The units are degrees.

13) <u>Damping Coefficient for the Joints (CDAMP1)</u>

This is the value of the damping coefficient to be used for all connecting joints of the human body model. It is entered on a single card in a 5F10.9 format. The usual units are lb sec/rad.

14) <u>Damping Coefficient for the Joint Limits (CDAMP2)</u>

This is usually a large number which is required to model a joint angle displacement unit. It is read on a single card in a 5F10.9 format. The usual units are lb sec/rad.

15) <u>Spring Constants for the Seat (ESEAT[2])</u>

There are two spring constants: one for the seat and one for the back of the seat. ESEAT1 is for the back of the seat and ESEAT2 is for the seat. They are read sequentially on a single card in a 5F10.9 format. The usual units are lbs/in.

16) <u>Displacement Limits for the Seat (SEATM[2])</u>

There are two max deflections: one for the back of the seat and one for the bottom of the seat. They are read sequentially on a single card, in a 5F10.9 format. The usual units are inches.

switch 5) Floor constraints

switch 6) Impulses--(always should be off [zero])

switch 7) Neck forces--(usually off)

switch 8) Intrusion surfaces (cockpit geometry)

8 cards are read

20) NOUT

The total number of unknown variables (maximum of 34) is read on a single card in I5 format.

21) JFX1 Array

JFX1 is the array of unknown variables. The total number of these is NOUT. The unknown variable indices (eg. x_{17} index is 17) are read sequentially on the cards in a 10I5 format.

22) Plot Variables

A blank card must be included here. (This option when employed, is used to make printer plots of specified variables when a printer plot subroutine is available on the computer system being used).

23) Initial Values of the Unknown Variables

The first card in this sequence contains two values in 2I5 format. These numbers (zero, positive or negative) determine the manner in which the initial values of the unknown variables and their derivatives are read. (The first number pertains to the variable and the second number pertains to the derivative of the variable).

Zero

If a zero is read, the initial value of all variables is read in a sequence of cards in 5F10.9 format. hence, the number of cards read depends upon NOUT read above.

Positive Number

If a positive number, say N, is read the initial value of the first N variables is read in a sequence of cards in 5F10.9 format. All remaining initial values are then automatically set equal to zero.

Negative Number

If a negative number, say -N, is read, the initial values of N variables are read randomly on N cards. Each of these cards contains two values. The first value identifies the variable number and the second variable is the initial value of the variable. The format for these two values is I5, F15.9. All initial values not read are automatically set equal to zero.

In all three cases above, all initial values of the variables are read before the initial values of the derivatives. The manner for reading the initial values of the derivatives is the same as for the initial values of the variables. (Mixed modes may be employed).

The usual units are inches and inches/sec for displacement variables and degrees and degrees/sec for angular variables.

24) Printing Priority

On a single card in I5 format, a number is read between -100 and +100 determining the amount of print-out for a given run as follows:

If 0 all print-out (the "standard print-out") for every printing time (see 26 below) is given.

If > 10 printing of X and DX in radians is omitted.

If > 20 printing of absolute velocity and acceleration of all bodies is omitted.

If > 30 printing of position of all bodies is omitted.

If > 40 printing joint moments is omitted.

If > 50 printing of DDX in degrees is omitted.

If > 95 All printing is omitted.

If < 0 (negative) the corresponding print-out is given for all integration steps, and all print-out at every print time (see 26 below) is given. (For example -100 gives the maximum possible print-out).

25) Printing Time

This is a value read on a single card in F10.9 format determining the time increment for print-out. This may be the same or different (usually greater) than the integration time increment PRMT(3).

26) <u>PRMT</u>

This is an array of 4 numbers needed for this integration subroutine RKGS. They are entered on a single card in 5F10.9 format. The first number is the integration starting time, the second number is the integration ending time, the third number is the integration time interval, and the fourth number is the desired upper bound on the error of the integration.

SAMPLE LISTING OF INPUT DATA

1.	*	Error Print - - -	- - - - -		- - - -		Error Set-Blank
2.	*0.916	0.916	0.75		0.178	0.143- -	Masses of the 12 Bodies
3.	*0.178	0.143	0.433		0.555	0.358	
4.	*0.555	0.358- - -	- - - - -		- - - - -	- - - - -	
5.	*15.7	0.0	0.0				
6.	*0.0	9.593	0.0	I_1			
7.	*0.0	0.0	15.33				
8.	*15.7	0.0	0.0				
9.	*0.0	9.595	0.0	I_2			
10.	*0.0	0.0	15.33				
11.	*11.225	0.	0.0				
12.	*0.	7.74	0.	I_3			
13.	*0.	0.	11.163				
14.	*.0087						
15.	*	2.8156		I_4			
16.	*		2.8156				
17.	*3.059						
18.	*0.	3.059	0.	I_5			
19.	*0.0	0.0	.0588				Inertia Dyadics
20.	*.0087						
21.	*	2.8156		I_6			
22.	*		2.8156				
23.	*8.059						
24.	*0.	3.059	0.	I_7			
25.	*0.0	0.0	.0588				
26.	*4.643	0.	0.				
27.	*0.	4.643	0.	I_8			
28.	*0.	0.	2.302				
29.	*0.065	0.0	0.0				
30.	*0.	10.162	0.	I_9			
31.	*0.0	0.0	10.162				
32.	*12.2315	0.	0.				
33.	*0.	12.388	0.	I_{10}			
34.	*0.	0.	0.1711				
35.	*0.085	0.0	0.0				
36.	*0.	10.162	0.	I_{11}			
37.	*0.0	0.0	10.162				
38.	*12.2316	0.	0.				
39.	*0.	12.388	0.	I_{12}			
40.	*0.	0.	0.1711				

```
41.   *0.         0.          0. - - - - ┐
42.   *0.0        0.0         4.05       │
43.   *0.0        0.0         3.95       │
44.   *4.46                              │
45.   *                       7.025      │
46.   *4.46                              │   R Vectors
47.   *                       7.025      │
48.   *0.         0.          6.35       │
49.   *9.8738     0.0         0.0        │
50.   *0.         0.          -9.0       │
51.   *9.8738     0.0         0.0        │
52.   *0.         0.          -9.0 - - - ┘
53.   *0.0        0.0         4.05 - - - ┐
54.   *0.         0.          8.1        │
55.   * 0.         8.35       5.8        │
56.   *11.7                              │
57.   *0.         -8.35       5.8        │
58.   *11.7                              │   XI Vectors
59.   * 0.        0.          7.9        │
60.   * 0.        3.07        -.65       │
61.   *18.6       0.0         0.0        │
62.   * 0.        -3.07       -.65       │
63.   *18.6       0.0         0.0- - - - ┘
64.       12 Cockpit Surfaces- - - - - - - - - - - - - - - - - - - - ┐
65.   *18.0       12.0        24.0       1.0        0.1        0.3   │
66.   *18.0       0.0         24.0       1.0        0.0        0.3   │
67.   *18.0       -12.0       24.0       1.0        -0.1       0.3   │
68.   *0.0        18.0        0.0        0.0        1.0        0.0   │
69.   *0.0        18.0        0.0        0.0        1.0        0.0   │
70.   *0.0        -18.0       0.0        0.0        -1.0       0.0 Intrusion
71.   *0.0        -18.0       0.0        0.0        -1.0       0.0 Surfaces
72.   *0.0        0.0         36.0       0.0        0.0        1.0   │
73.   *30.0       0.0         0.0        1.0        0.0        0.0   │
74.   *20.0       0.0         8.0        0.70711    0.0        -0.70711
75.   *20.0       0.0         8.0        1.0        0.0        0.0   │
76.   *20.0       0.0         4.0        0.0        0.0        1.0- -┘
77.   *   No Mag Tape - - - - -Magnetic Tape Card
78.   *Sample Data - - - - - - - - - - - - - - Heading Card
79.   *2010.0     18.6- - - - - - - -Floor Spring And Distance
80.   *   1 - - - - - - - - - - - - - - - - - - - - ┐
81.   *   10      1                                 │
82.   *0.0        0.0         525.0      0.0 <- Initial
83.   *0.003      -11592.0    ↖Initial      Displacement
84.   *0.006      -3864.0      Velocity             │
85.   *0.01       -15456.0                          Acceleration Input For
86.   *0.015      -3864.0                               The Cockpit
87.   *0.02       0.0                               │
88.   *0.025      -4636.8                           │
89.   *0.07       -5796.0                           │
90.   *0.09       -9660.0                           │
91.   *0.1        0.0 - - - - - - - - - - - - - - - ┘
92.   *600.0      10.0- - - - - - - -Neck Spring And Damping Constant
93.   *30.0       70.0        5.0        -30.0      -90.0      -5.0 - - - ┐
94.   *4.5        4.5         4.5        -4.5       -4.5       -4.5       │
95.   *120.0       85.0        90.0       0.0        -60.0      -45.0     │
96.   *0.          90.0       0.         0.          -45.0     0.      Orientati
```

```
97.  *0.0        85.0       90.0       -120.0      -60.0     -45.0   Angle
98.  *0.         90.        0.         0.          -45.0     0.      Limits
99.  *45.        80.        60.        -45.        -60.      -60.         |
100. *15.        45.        45.        -15.        -80.      -5.          |
101. *0.         30.        0.         0.          -90.      0.           |
102. *15.        45.        5.         -15.        -80.      -45.         |
103. *0.         30.        0.         0.          -90.      0. - - - - - ┘
104. *10.0- - - - - - - - -Damping Coefficient For The Joints
105. *2000000. - - - - - -Damping Coefficient For The Joint Limits
106. *639.60     639.60 - - -Spring Constants For The Seat
107. *4.0        4.0 - - - -Displacement Limits For The Seat
108. *    2 Belts - - - - -Seat Belts
109. *    2 - - - - - - - - - - - - - - - - - - - - - - ┐
110. *4.0        6.85       3.0        (Q)                  |
111. *-12.       7.85       -7.        (RHO)                |
112. *4296.0                                                |
113. *    2                                            Belt Data
114. *4.0        -6.85      3.0                             |
115. -12.        -7.85      -7.                             |
116. *4296.0 - - - - - - - - - - - - - - - - - - - - - - - ┘
117. * - - - - - - - - - - - - - - - - Blank Card
118. *    1    Belt - - - - - - - - - - - - - - - - ┐
119. *    1 Seat                                      |
120. *    1 Gravity                                  |
121. *    1 Angle Constraints                        |
122. *      No Floor Force                      Switches
123. *      No Impulse                               |
124. *      No Neck                                  |
125. *    1 Surf. - - - - - - - - - - - - - - - - - ┘
126. *   28- - - - - - - - - - - - - - - - - - - - - Nout
127. *    7    8    9    13   14   15   16   17   18   19- ┐
128. *   20   21   23   25   26   27   29   31   32   33   |  JFXI ARRAY
129. *   34   35   36   38   40   41   42   44- - - - - - - ┘
130. *    0 No Plots - - - - - - - - - - - - - - - Blank Card For Plots
131. *   -5    2 # Read Y.DY - - - - - - - - - - ┐
132. *    3        -1.84  ┐                          |
133. *   11        77.350 |                          |
134. *   15        77.350 }  Y          Initial Values Of
135. *   22        -6.360 |             The Unknown Variables
136. *   26        -6.360 ┘                          |
137. *0.0  0.0          DY - - - - - - - - - - - - ┘
138. *   11 Print- - - - - - - - - - - - - - - - - Printing Priority
139. *0.005     Del Print- - - - - - - - - - - - - Printing Time
140. *0.0       2.00      .1953125-2.01 - - - - PRMT
141. **End Of Data
```

OUTPUT DATA

The output data is labeled on the computer print-out and thus is primarily self-explanatory. It consists of two parts: The first part is simply an "echo" or copy of the input data. (In the input motion section, the velocity and position at the beginning of each acceleration interval is computed and also listed.) The second part contains at each output time (depending upon the printing priority (See 24 and 25 in the foregoing section.):

i) All variables and the first derivative of the variables (angles are in radians).

ii) Joint positions (in both inertia space and relative to the vehicle).

iii) Mass center positions (in both inertia space and relative to the vehicle).

iv) Mass center velocities and accelerations.

v) All variables and the first and second derivatives of the variables (angles are in degrees).

vi) Moments and forces associated with variables which are specified.

vii) Seat belt forces.

A sample listing of output data at a particular time interval is as follows:

ROBBINS CHECK WITH INTRUSION SURFACES

TIME = 45.410 MILLISEC

ANGLE IN RADIANS

X(1) = 17.552	X(2) = 0.0	X(3) = 0.0	X(4) = 0.0	X(5) = 0.0	X(6) = 0.0
X(7) = 3.7727	X(8) = 3.82523E-08	X(9) = -2.4067	X(10) = 0.0	X(11) = 0.0	X(12) = 0.0
X(13) =-1.69793E-09	X(14) = 0.24030	X(15) =-8.82886E-08	X(16) = 1.66948E-08	X(17) = 9.17529E-02	X(18) = 1.89119E-07
X(19) =-9.82492E-07	X(20) = 1.2135	X(21) = 6.70634E-07	X(22) = 0.0	X(23) = 6.19250E-02	X(24) = 0.0
X(25) = 3.65605E-06	X(26) = 1.2135	X(27) = 2.97360E-06	X(28) = 0.0	X(29) =-6.19252E-02	X(30) = 0.0
X(31) =-3.93702E-08	X(32) =-0.21546	X(33) =-7.40853E-08	X(34) = 5.07219E-10	X(35) =-0.12384	X(36) =-2.06143E-09
X(37) = 0.0	X(38) =-0.18522	X(39) = 0.0	X(40) = 3.21006E-10	X(41) =-0.12384	X(42) =-2.12388E-09
X(43) = 0.0	X(44) =-0.18522	X(45) = 0.0	X(46) = 0.0	X(47) = 0.0	X(48) = 0.0

DX(1) = 276.23	DX(2) = 0.0	DX(3) = 0.0	DX(4) = 0.0	DX(5) = 0.0	DX(6) = 0.0
DX(7) = 62.006	DX(8) =-9.38753E-07	DX(9) = -29.551	DX(10) = 0.0	DX(11) = 0.0	DX(12) = 0.0
DX(13) =-1.74235E-08	DX(14) = 15.116	DX(15) = 2.36479E-06	DX(16) =-1.50728E-06	DX(17) =-0.30412	DX(18) = 4.26771E-06
DX(19) = 3.46686E-05	DX(20) = -14.490	DX(21) =-4.53036E-05	DX(22) = 0.0	DX(23) = -5.8343	DX(24) = 0.0
DX(25) = 9.48340E-05	DX(26) = -14.490	DX(27) =-4.04603E-05	DX(28) = 0.0	DX(29) = -5.8343	DX(30) = 0.0
DX(31) =-1.99987E-06	DX(32) = -20.373	DX(33) =-3.40996E-06	DX(34) =-2.78852E-08	DX(35) = 0.25372	DX(36) =-3.40655E-09
DX(37) = 0.0	DX(38) = -14.839	DX(39) = 0.0	DX(40) =-3.95815E-08	DX(41) = 0.25372	DX(42) =-7.11785E-09
DX(43) = 0.0	DX(44) = -14.839	DX(45) = 0.0	DX(46) = 0.0	DX(47) = 0.0	DX(48) = 0.0

JOINT POSITION VECTORS

	IN INERTIA SPACE			IN COCKPIT		
LOWER TORSO	21.324	0.38252E-07	1.6433	3.7727	0.38252E-07	1.6433
BACK	23.252	0.51610E-07	9.5105	5.7005	0.51610E-07	9.5105
LEFT SHOULDER	24.110	8.3500	15.247	6.5589	8.3500	15.247
LEFT ELBOW	26.535	8.3500	3.8006	8.9832	8.3500	3.8006
LEFT HAND	40.073	8.3500	7.5569	22.522	8.3500	7.5569
RIGHT SHOULDER	24.110	-8.3500	15.247	6.5589	-8.3500	15.247
RIGHT ELBOW	26.535	-8.3500	3.8006	8.9832	-8.3500	3.8006
RIGHT HAND	40.073	-8.3500	7.5569	22.522	-8.3500	7.5569
NECK	24.421	-0.25518E-08	17.324	6.8697	-0.25518E-08	17.324
HEAD TOP	23.572	0.13089E-06	29.995	6.0205	0.13089E-06	29.995
LEFT HIP	21.324	3.0700	-3.0567	3.7727	3.0700	-3.0567
LEFT KNEE	39.782	3.0700	-0.75920	22.230	3.0700	-0.75920
LEFT FOOT	45.257	3.0700	-17.906	27.705	3.0700	-17.906
RIGHT HIP	21.324	-3.0700	-3.0567	3.7727	-3.0700	-3.0567
RIGHT KNEE	39.782	-3.0700	-0.75920	22.230	-3.0700	-0.75920
RIGHT FOOT	45.257	-3.0700	-17.906	27.705	-3.0700	-17.906

POSITION VECTORS OF BODY SEGMENTS AND MASS CENTERS

	IN INERTIA SPACE			IN COCKPIT		
LOWER TORSO	21.324	0.38252E-07	-2.4067	3.7727	0.38252E-07	-2.4067
BACK	22.288	0.44931E-07	5.5769	4.7366	0.44931E-07	5.5769
SHOULDER	23.837	0.24529E-07	13.417	6.2851	0.24529E-07	13.417
LEFT UPPER ARM	25.035	8.3500	10.883	7.4830	8.3500	10.883
LEFT LOWER ARM	33.304	8.3500	5.6788	15.752	8.3500	5.6788
RIGHT UPPER ARM	25.035	-8.3500	10.883	7.4830	-8.3500	10.883
RIGHT LOWER ARM	33.304	-8.3500	5.6788	15.752	-8.3500	5.6788
HEAD	23.997	0.64167E-07	23.659	6.4451	0.64167E-07	23.659
LEFT UPPER LEG	31.123	3.0700	-1.8371	13.571	3.0700	-1.8371
LEFT LOWER LEG	42.519	3.0700	-9.3328	24.968	3.0700	-9.3328
RIGHT UPPER LEG	31.123	-3.0700	-1.8371	13.571	-3.0700	-1.8371
RIGHT LOWER LEG	42.519	-3.0700	-9.3328	24.968	-3.0700	-9.3328

	MASS CENTER VELOCITIES			MASS CENTER ACCELERATIONS		
LOWER TORSO	338.24	-0.93875E-06	-29.551	-8620.5	-0.24680E-02	431.32
BACK	397.70	-0.89495E-06	-44.120	-6058.2	0.44790E-03	-1149.3
SHOULDER	515.02	0.43825E-05	-67.349	-1486.6	0.21037E-02	-3906.7
LEFT UPPER ARM	540.72	-0.17331E-04	-71.701	118.04	-0.61212E-03	-4316.9
LEFT LOWER ARM	528.09	0.50148E-05	-34.863	275.49	0.85301E-03	-1571.6
RIGHT UPPER ARM	540.72	0.15083E-03	-71.701	118.04	0.20682E-02	-4316.9
RIGHT LOWER ARM	528.09	-0.18386E-03	-34.863	275.50	-0.13891E-02	-1571.6
HEAD	537.64	0.76398E-05	-78.369	430.68	-0.87658E-03	-5286.6
LEFT UPPER LEG	338.55	-0.93712E-06	-32.037	-8393.8	-0.83241E-03	-1395.3
LEFT LOWER LEG	463.87	-0.14712E-05	5.6924	-3064.1	-0.50386E-04	637.94
RIGHT UPPER LEG	338.55	-0.95996E-06	-32.037	-8393.8	-0.82591E-03	-1395.3
RIGHT LOWER LEG	463.87	-0.16215E-05	5.6924	-3064.2	-0.55289E-04	637.94

DEGREES

X(1) = 17.552	X(2) = 0.0	X(3) = 0.0	X(4) = 0.0	X(5) = 0.0	X(6) = 0.0
X(7) = 3.7727	X(8) = 3.82523E-08	X(9) = -2.4067	X(10) = 0.0	X(11) = 0.0	X(12) = 0.0
X(13) =-9.72839E-08	X(14) = 13.768	X(15) =-5.05856E-06	X(16) = 9.56540E-07	X(17) = -5.2571	X(18) = 1.08357E-05
X(19) =-5.62926E-05	X(20) = 69.530	X(21) = 3.84245E-05	X(22) = 0.0	X(23) = -3.5480	X(24) = 0.0
X(25) = 2.09465E-04	X(26) = 69.530	X(27) =-1.70375E-04	X(28) = 0.0	X(29) = -3.5480	X(30) = 0.0
X(31) =-2.25574E-06	X(32) = -12.345	X(33) =-4.24478E-06	X(34) = 2.90615E-08	X(35) = -7.0954	X(36) =-1.18111E-07
X(37) = 0.0	X(38) = -10.612	X(39) = 0.0	X(40) = 1.83923E-08	X(41) = -7.0954	X(42) =-1.21689E-07
X(43) = 0.0	X(44) = -10.612	X(45) = 0.0	X(46) = 0.0	X(47) = 0.0	X(48) = 0.0

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DX( 1) =  276.23     DX( 2) = 0.0          DX( 3) = 0.0          DX( 4) = 0.0          DX( 5) = 0.0          DX( 6) = 0.0
DX( 7) =  62.006     DX( 8) =-9.38753E-07  DX( 9) = -29.551      DX(10) = 0.0          DX(11) = 0.0          DX(12) = 0.0
DX(13) =-9.98292E-07 DX(14) =  866.06      DX(15) = 1.35493E-04  DX(16) =-8.63606E-05  DX(17) = -17.425      DX(18) = 2.44522E-04
DX(19) = 1.98636E-03 DX(20) = -830.23      DX(21) =-2.59570E-03  DX(22) = 0.0          DX(23) = -334.28      DX(24) = 0.0
DX(25) = 5.43359E-03 DX(26) = -830.23      DX(27) =-2.31820E-03  DX(28) = 0.0          DX(29) = -334.28      DX(30) = 0.0
DX(31) =-1.14584E-04 DX(32) = -1167.3      DX(33) =-1.95376E-04  DX(34) =-1.59770E-06  DX(35) =  14.537     DX(36) =-1.95181E-07
DX(37) = 0.0         DX(38) = -850.20      DX(39) = 0.0          DX(40) =-2.26785E-06  DX(41) =  14.437     DX(42) =-4.07823E-07
DX(43) = 0.0         DX(44) = -850.20      DX(45) = 0.0          DX(46) = 0.0          DX(47) = 0.0          DX(48) = 0.0


DDX( 1) = -5162.6    DDX( 2) = 0.0         DDX( 3) = 0.0         DDX( 4) = 0.0         DDX( 5) = 0.0         DDX( 6) = 0.0
DDX( 7) = -3457.9    DDX( 8) =-2.46799E-03 DDX( 9) =  431.32     DDX(10) = 0.0         DDX(11) = 0.0         DDX(12) = 0.0
DDX(13) =-4.25183E-02DDX(14) =  40529.     DDX(15) = 2.10229E-02 DDX(16) = 5.93529E-02 DDX(17) = -9178.4     DDX(18) =-3.93467E-02
DDX(19) =-0.26927    DDX(20) = -40066.     DDX(21) = 0.19933     DDX(22) = 0.0         DDX(23) = -13067      DDX(24) = 0.0
DDX(25) =-0.84366    DDX(26) = -40066.     DDX(27) = 0.92410     DDX(28) = 0.0         DDX(29) = -13067.     DDX(30) = 0.0
DDX(31) =-1.68781E-02DDX(32) = -32301.     DDX(33) = 3.42873E-02 DDX(34) =-6.02160E-03 DDX(35) =  10681.     DDX(36) = 8.74258E-03
DDX(37) = 0.0        DDX(38) = -48850.     DDX(39) = 0.0         DDX(40) =-6.14233E-03 DDX(41) =  10681.     DDX(42) = 8.76770E-03
DDX(43) = 0.0        DDX(44) = -48850.     DDX(45) = 0.0         DDX(46) = 0.0         DDX(47) = 0.0         DDX(48) = 0.0


DDX( 1) = -5162.6    DDX( 2) = 0.0         DDX( 3) = 0.0         DDX( 4) = 0.0         DDX( 5) = 0.0         DDX( 6) = 0.0
DDX( 7) = -3457.9    DDX( 8) =-2.46799E-03 DDX( 9) =  431.32     DDX(10) = 0.0         DDX(11) = 0.0         DDX(12) = 0.0
DDX(13) =-4.25183E-02DDX(14) =  40529.     DDX(15) = 2.10229E-02 DDX(16) = 5.93529E-02 DDX(17) = -9178.4     DDX(18) =-3.93467E-02
DDX(19) =-0.26927    DDX(20) = -40066.     DDX(21) = 0.19933     DDX(22) = 0.0         DDX(23) = -13067.     DDX(24) = 0.0
DDX(25) =-0.84366    DDX(26) = -40066.     DDX(27) = 0.92410     DDX(28) = 0.0         DDX(29) = -13067.     DDX(30) = 0.0
DDX(31) =-1.68781E-02DDX(32) = -32301.     DDX(33) = 3.42873E-02 DDX(34) =-6.02160E-03 DDX(35) =  10681.     DDX(36) = 8.74258E-03
DDX(37) = 0.0        DDX(38) = -48850.     DDX(39) = 0.0         DDX(40) =-6.14233E-03 DDX(41) =  10681      DDX(42) = 8.76770E-03
DDX(43) = 0.0        DDX(44) = -48850.     DDX(45) = 0.0         DDX(46) = 0.0         DDX(47) = 0.0         DDX(48) = 0.0


  F( 7) = 0.0          F( 8) = 0.0          F( 9) = 0.0          F(10) =-5.31783E-03  F(11) =  19296.      F(12) = 4.89261E-02
  F(13) =-5.45382E-06  F(14) = -151.16      F(15) =-2.27118E-05  F(16) = 1.89830E-05  F(17) =  8039.8      F(18) = 9.17244E-05
  F(19) = 7.77435E-05  F(20) =  144.90      F(21) = 1.60689E-05  F(23) =- 58.343      F(25) =-1.26272E-03  F(26) =  144.90
  F(27) = 6.71266E-04  F(29) =  58.343      F(31) = 1.27084E-05  F(32) =  203.73      F(33) = 2.52904E-05  F(34) = 2.74644E-07
  F(35) = -2.5372      F(36) = 3.25178E-08  F(38) =  148.39      F(40) = 3.87023E-07  F(41) = -2.5372      F(42) = 6.98190E-08
  F(44) =  148.39      F(46) =  498.47      F(47) =-3.12760E-04  F(48) = -2070.8

SEAT FORCE

 0.0          0.0          0.0          0.0          759.26          759.26          1539.3
```

SUMMARY

Name: UCIN-CRASH

Developers: C.E. Passerello, M.W. Harlow, and R.L. Huston, Department of Engineering Analysis, University of Cincinnati, Cincinnati, Ohio.

Date: May 1, 1974

Purpose and Use: To study the dynamics of crash victims.

Language: FORTRAN IV

Operation: Batch or time-sharing (TYMSHARE).

Hardware: Written and used with IBM System 370.

Documentation and Verification: See References [15-18].

User Manual: See Reference [16].

Availability: Available from authors on tape at cost of tape, handling, and mailing.

ACKNOWLEDGEMENT

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