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USAAVLABS TECHNICAL REPORT 70-71B
ANALYSIS OF HELICOPTER STRUCTURAL CRASHWORTHINESS
VOLUME II. USER MANUAL FOR "CRASH", A COMPUTER
PROGRAM FOR THE RESPONSE OF A SPRING-MASS
SYSTEM SUBJECTED TO ONE-DIMENSIONAL IMPACT
LOADING (UH-1D/H HELICOPTER APPLICATION)

By

Stuart E. Larsen
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January 1971

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-69-C-0030
DYNAMIC SCIENCE (THE AVSER FACILITY)
A DIVISION OF MARSHALL INDUSTRIES
PHOENIX, ARIZONA

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EUSTIS DIRECTORATE
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FORT EUSTIS, VIRGINIA 23604

This report was prepared by Dynamic Science (The AvSER Facility), A Division of Marshall Industries, under the terms of Contract DAAJ02-69-C-0030.

The purpose of this effort was to (1) document and classify the most hazardous factors concerning airframe crashworthiness, (2) seek methods of reducing vertical decelerations at the floor level in potentially survivable crashes, and (3) seek design methods for maintaining the "protective shell" around the occupants in an accident. The contractor achieved these objectives by conducting a study of 43 major accidents involving the UH-1D/H aircraft to determine what types of structural failure were contributing to injuries in helicopter accidents and by developing, programming, and verifying a 23-degree-of-freedom, nonlinear lumped mass mathematical model. This model was then used in a parametric study of the UH-1D/H aircraft to evaluate potential areas of crashworthiness improvement. This report contains a description of the accident data study, mathematical model, parametric study, full-scale drop test, and the results obtained.

The conclusions and recommendations submitted by the contractor are considered to be valid; however, the mathematical model developed has definite limitations, the most critical limitation being that the model considers only vertical impact loads and therefore does not consider the longitudinal and lateral components that are usually also present in the helicopter crash environment. A second limitation is that it would be extremely difficult to use this approach to model and analytically study the crashworthiness of future aircraft designs with any confidence. This is due to the problems that would be encountered in attempting to predict the necessary weight data to apply to the lumped mass simulation and the spring constant data necessary to apply to the various springs that connect the masses of the model.

It is the intent of this Command to expand this mathematical model to include dynamic response to combined crash loading; i.e., crash loads which possess vertical, longitudinal, and lateral components, thereby developing a more realistic and useful analytical tool.

This report is divided into two volumes. Volume I contains a description of the accident data study, mathematical model, parametric study, full-scale drop test, and the results obtained. Volume II is a user manual for the computer program developed.

SUMMARY

A mathematical model which may be used to determine the dynamic response of a helicopter airframe subjected to vertical crash loading has been developed.

This report is, in effect, a manual which will facilitate the use of the computer program "CRASH". The program was written to solve the equations and to handle the nonlinearities and constraints which result from use of the mathematical model.

The program was used to evaluate the response of the UH-1D/H helicopter to vertical impact loadings. Recommendations have been made which, when implemented, will reduce the forces transmitted to the floor and transmission of the aircraft.

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January 1971

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Final Report

AvSER Report 1520-70-31

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for

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INTRODUCTION

This "User Manual" provides the details and fundamental concepts required to execute "Program CRASH" in a productive manner. The mathematical background for Program CRASH is contained in Vol. I of this report.

Program CRASH is a computer simulation of a general rotary-wing aircraft. It represents an attempt to provide the engineer with a practical tool for investigating the dynamic response of such a structure when subjected to vertical crash conditions.

It is very important that the user understand the model description and limitations. As would be expected, the model's geometry, physical characteristics, and structural properties can be quite extensive. To facilitate the user's understanding of the program an example problem is demonstrated, illustrating the type of problem which can be solved. In this example, the generalized model is adjusted to represent the Army's UH-1D/H aircraft. The numerical input is discussed in detail. Representative output printer plots, directly from the computer, are also included to further illustrate the type and format available to the user.

Although most users will be interested in the attenuation of acceleration levels at particular locations due to the non-linear deformation of the structure, the available output is not so limited in scope. Velocities, absolute and relative deformations (both linear and angular), forces, bending moments, and the concept of energy absorption are also available output features.

The output takes three forms: a tabulation of input data, a tabulation of output parameters at selected time increments, and combination tabulation-plots of output parameters called for through the input. Dummy input coding sheets are also included to assist the beginning user in organizing the input.

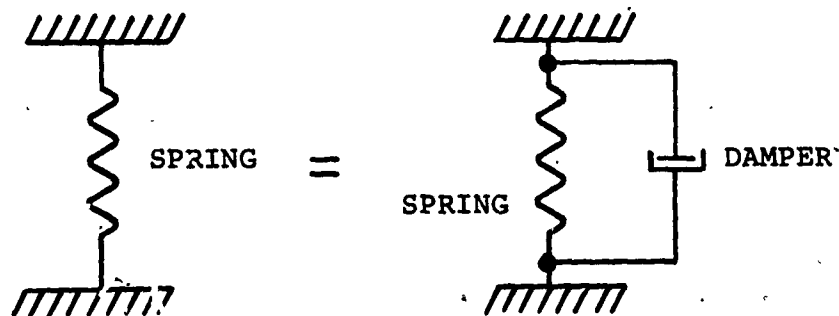
MATHEMATICAL MODEL DESCRIPTION

GENERAL

The mathematical model used in this study represents the airframe structure of a rotary-wing type aircraft. It is a non-linear lumped mass model having 23 degrees of freedom. To construct the model, the airframe structure is divided into four vertical and three longitudinal sections as shown in Figure 1. Individual masses are identified by number in Table I. The vertical section divisions are (1) transmission, engine, and rotor section, (2) mass above the floor section, (3) mass below the floor section, and (4) landing gear section. The longitudinal section divisions are (1) nose section, (2) central section, and (3) tail section. The 14 masses are spring connected into the model and are used to represent various sections of the airframe structure. Springs connecting the masses are shown in Figure 2 and identified in Table II. The vertical section masses permit a parametric study of the distribution of the load-limiting properties throughout the important vertical sections of the airframe structure. The longitudinal masses, shown in Figure 3, permit a study of plastic hinges and shear failures at four simulated airframe locations. All masses may not be required to represent a particular section of the airframe structure under study; however, the model is generalized to the degree that single- as well as multi-engine aircraft may be analyzed.

VERTICAL SECTION DESCRIPTION

The masses representing the four vertical sections, when connected into the model, simulate load-deflection characteristics. They are connected into the model with 16 direct- and seven far-coupled springs. Each spring is combined in parallel with a damper as shown below.



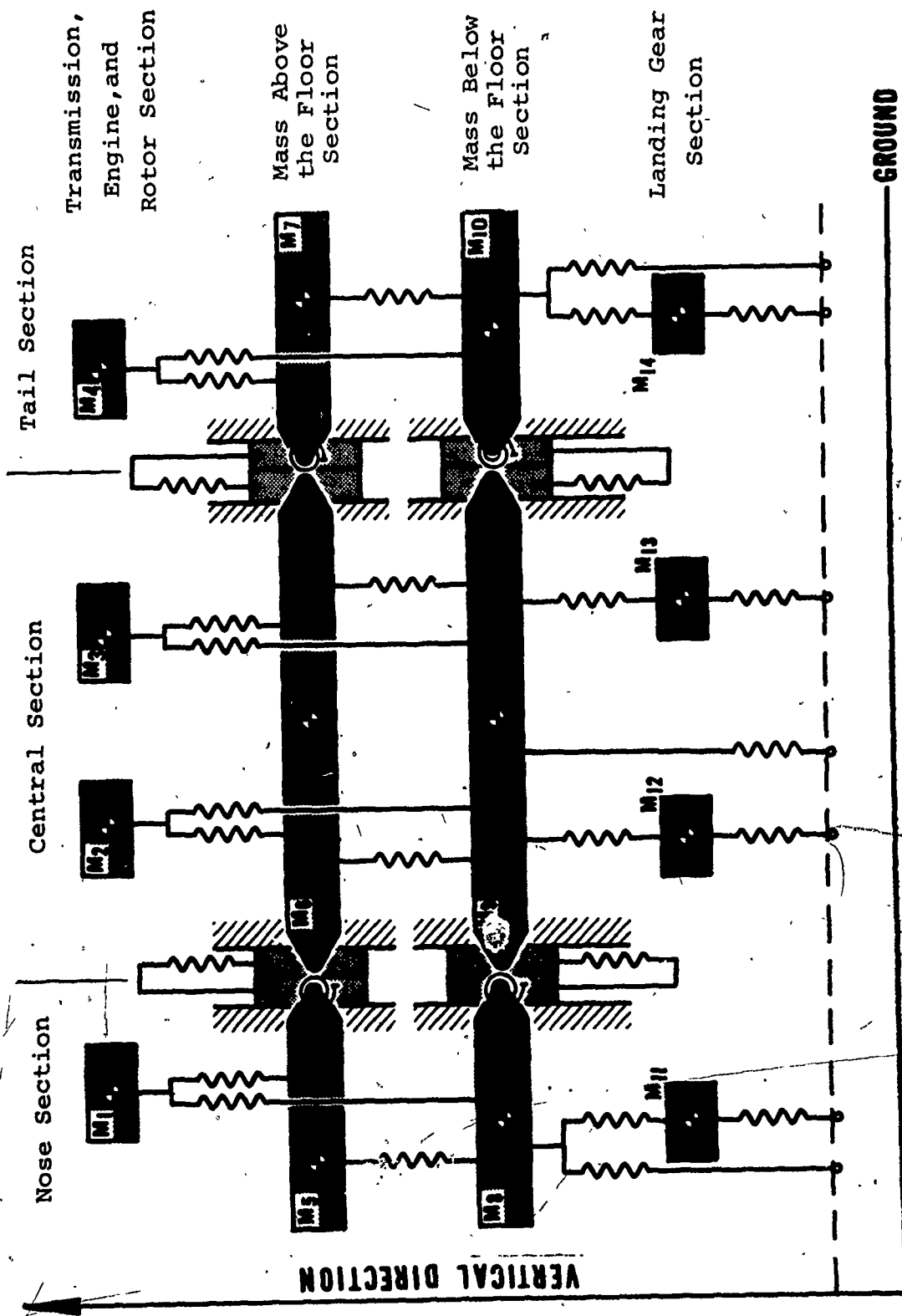


Figure 1. Model Description (Lumped Masses).

TABLE I. MODEL DESCRIPTION (LUMPED MASSES)	
Mass No.	Description
M1	Rotor Assembly, Transmission Assembly, and/or Engine Assemblies
M2	
M3	
M4	
M5	Airframe Structure Above Floor Level
M6	
M7	
M8	Airframe Structure Below Floor Level and Floor Dead Loads
M9	
M10	
M11	Landing Support System
M12	
M13	
M14	

The viscous damping is assumed to be proportional to velocity.

Two types of spring damping are considered in the model: internal (hysteresis) damping and external (viscous) damping. Internal damping is introduced into the model through the load-deflection curve shown in Figure 4. By assigning different slope values to the unloading portion of the generalized load-deflection curve, a hysteresis cycle can be generated which will absorb energy. The degree to which the load-deflection curves will reproduce the aircraft structure is dependent upon the quality of data available for the particular aircraft to be studied, and upon the user's ability to interpret available data and comprehend the dynamics of the deforming structure.

External damping is introduced by the use of a constant applied to the rate-of-change of spring deformation. The numerical value of this constant may be determined by an analytical

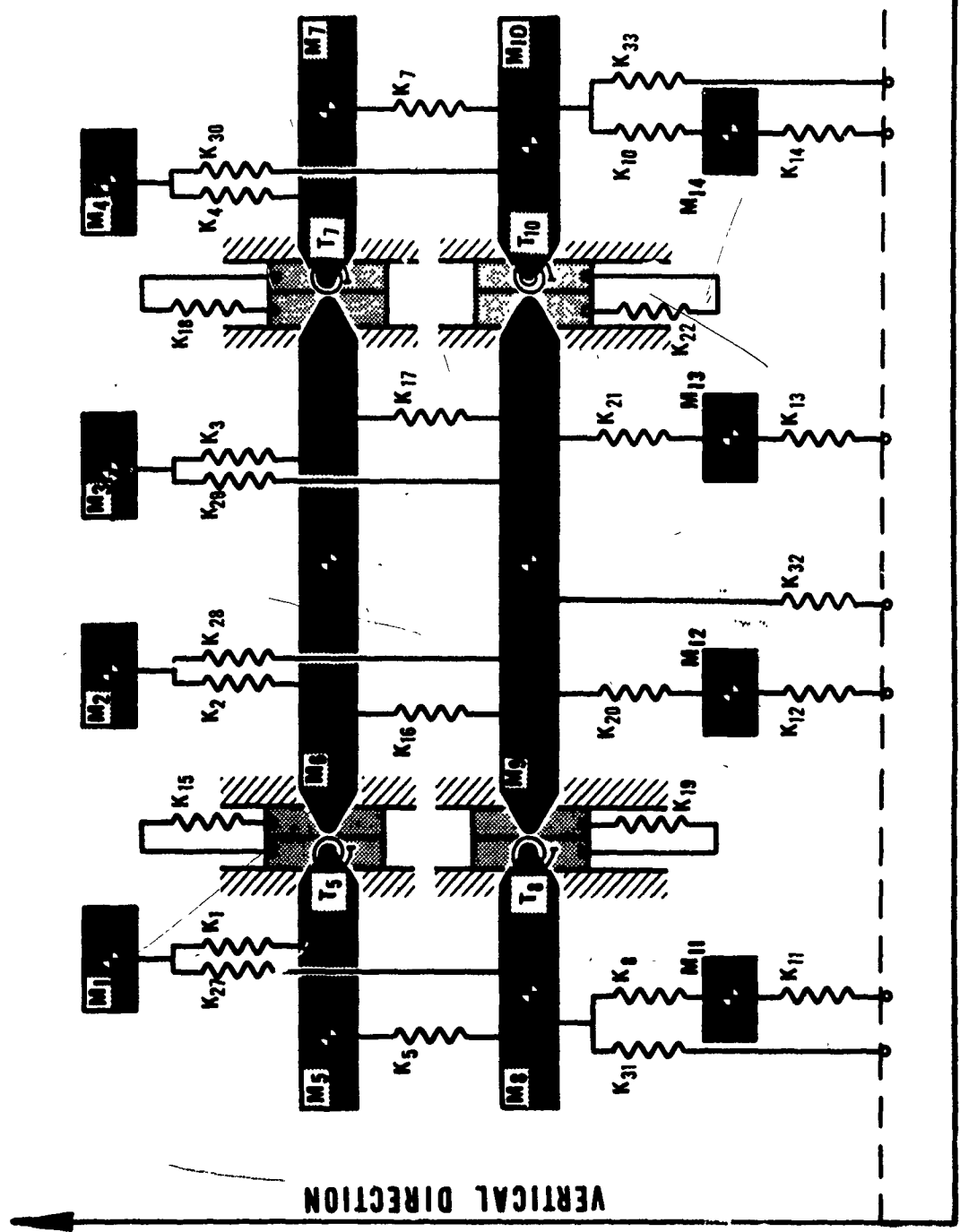


Figure 2. Spring Identification Diagram.

TABLE II. MODEL SPRING IDENTIFICATION	
Spring No.	Description
K1	Direct-Coupled Load-Deflection Characteristics of Rotor/Transmission and/or Engine Support System to Upper Fuselage
K2	
K3	
K4	
K5	Direct-Coupled Load-Deflection Characteristics of Airframe Structure Above Floor Level
K7	
K16	
K17	
K8	Direct-Coupled Load-Deflection Characteristics of Landing Support System
K10	
K11	
K12	
K13	
K14	
K20	
K21	
K15	Direct-Coupled Load-Deflection Characteristics of Airframe Structure Above Floor Level During Shear
K18	
K19	Direct-Coupled Load-Deflection Characteristics of Airframe Structure Below Floor Level During Shear
K22	
K27	Far-Coupled Load-Deflection Characteristics of Rotor/Transmission and/or Engine Support System to Floor
K28	
K29	
K30	

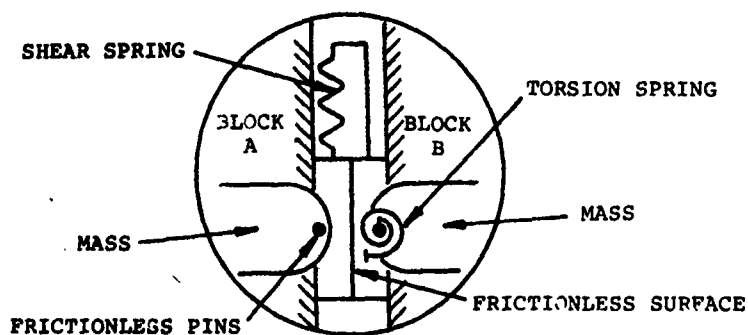
TABLE II. Continued	
Spring No.	Description
K31	Far-Coupled Load-Deflection
K32	Characteristics of Airframe Struc-
K33	ture Below Floor Level
T5	Torsional Load-Deflection
T8	Characteristics of Forward Fuselage Section
T7	Torsional Load-Deflection
T10	Characteristics of Rear Fuselage Section

estimate, based on theoretical data, or by performing a series of computer runs using various estimated values for these constants and comparing the results to experimental data.

The extensional springs in the model are classified into two types, depending upon the ability of the structure represented to restrain a tensile rebound. A type 1 spring is one which can restrain tensile rebound, while a type 2 spring cannot. Refer to Figure 4 and the definition of SD(I,7).

LONGITUDINAL SECTION DESCRIPTION

The masses simulating the three longitudinal sections of the airframe structure are connected into the model with four torsional springs and four shear-type springs. Connection details are shown below.



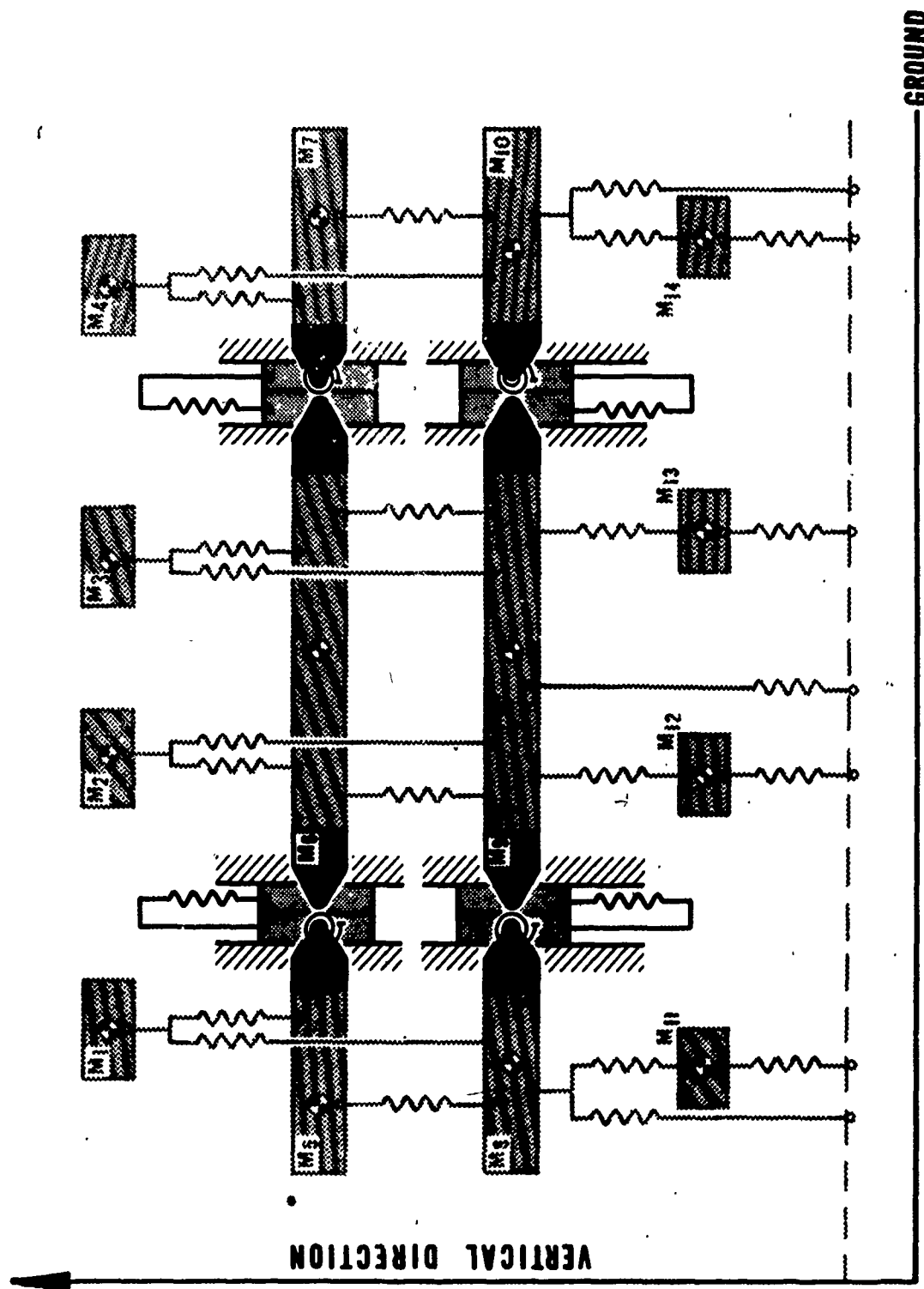


Figure 3. Longitudinal Section Spring Connection Diagram.

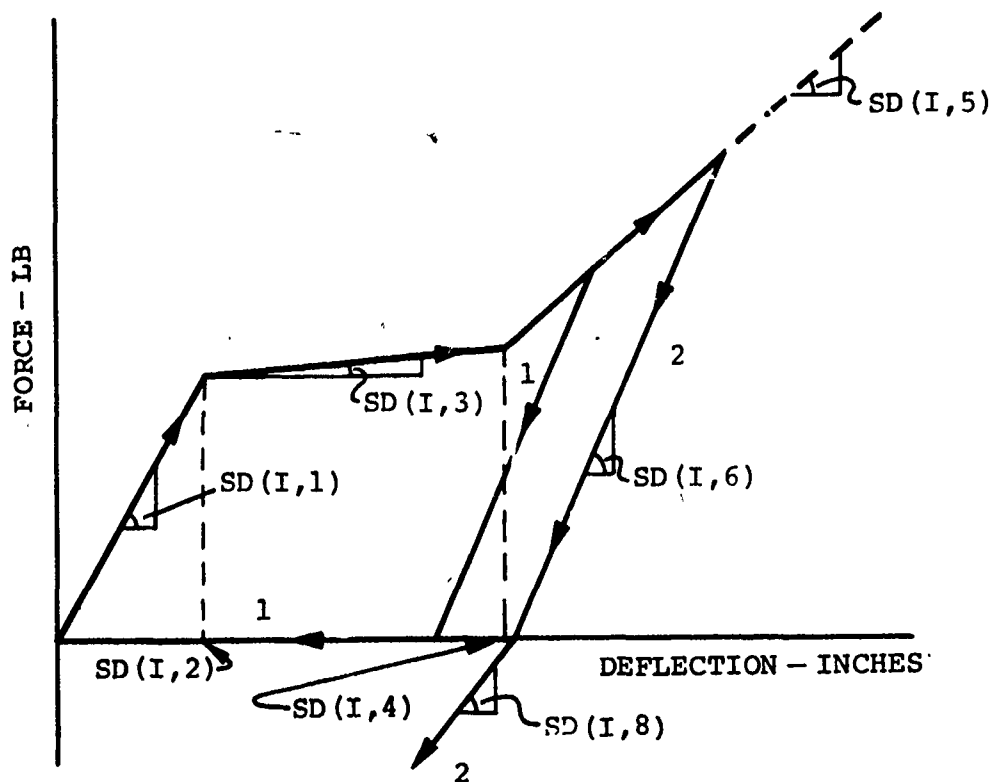


Figure 4. Description of Load-Deflection Curve.

PARAMETER	DESCRIPTION
SD(I,1)	Slope of linear elastic portion of curve.
SD(I,2)	Deflection which causes yielding to occur.
SD(I,3)	Slope of first plastic portion.
SD(I,4)	Deflection at which plastic slope changes.
SD(I,5)	Slope of second plastic portion of curve.
SD(I,6)	Unloading slope.
SD(I,7)	1 { Spring type } , Type "1" follows curve 1 2 { Spring type } , Type "2" follows curve 2
SD(I,8)	Proportionality constant for viscous damping (applies to entire curve).

The interface between blocks A and B is frictionless, permitting relative vertical displacements. The resistance against such a vertical displacement is provided by a shear spring. This simulates the possibility of a shear-type failure occurring in the fuselage, the severity of which is controlled by the shear spring. The two masses are connected to blocks A and B by frictionless pins, thereby permitting relative angles to form between the two masses. Resistance to such rotation is offered by the torsion spring. This simulates the formation of a plastic hinge in the fuselage. The generalized load-deflection curve used for all springs is shown in Figure 4.

MODEL DIMENSIONS

The general coordinates and model dimensions are shown in Figures 5 and 6. These dimensions and physical properties are consistent with the data provided in the Input Description section herein. If the application of the generalized model to a specific problem does not require all of the lumped masses, the weight of the omitted mass should be assigned a value of 1.0 pound and the dimensions describing its location omitted. If the omitted mass happens to be one which has rotational properties, its mass moment of inertia should also be assigned a nominal value of one unit.

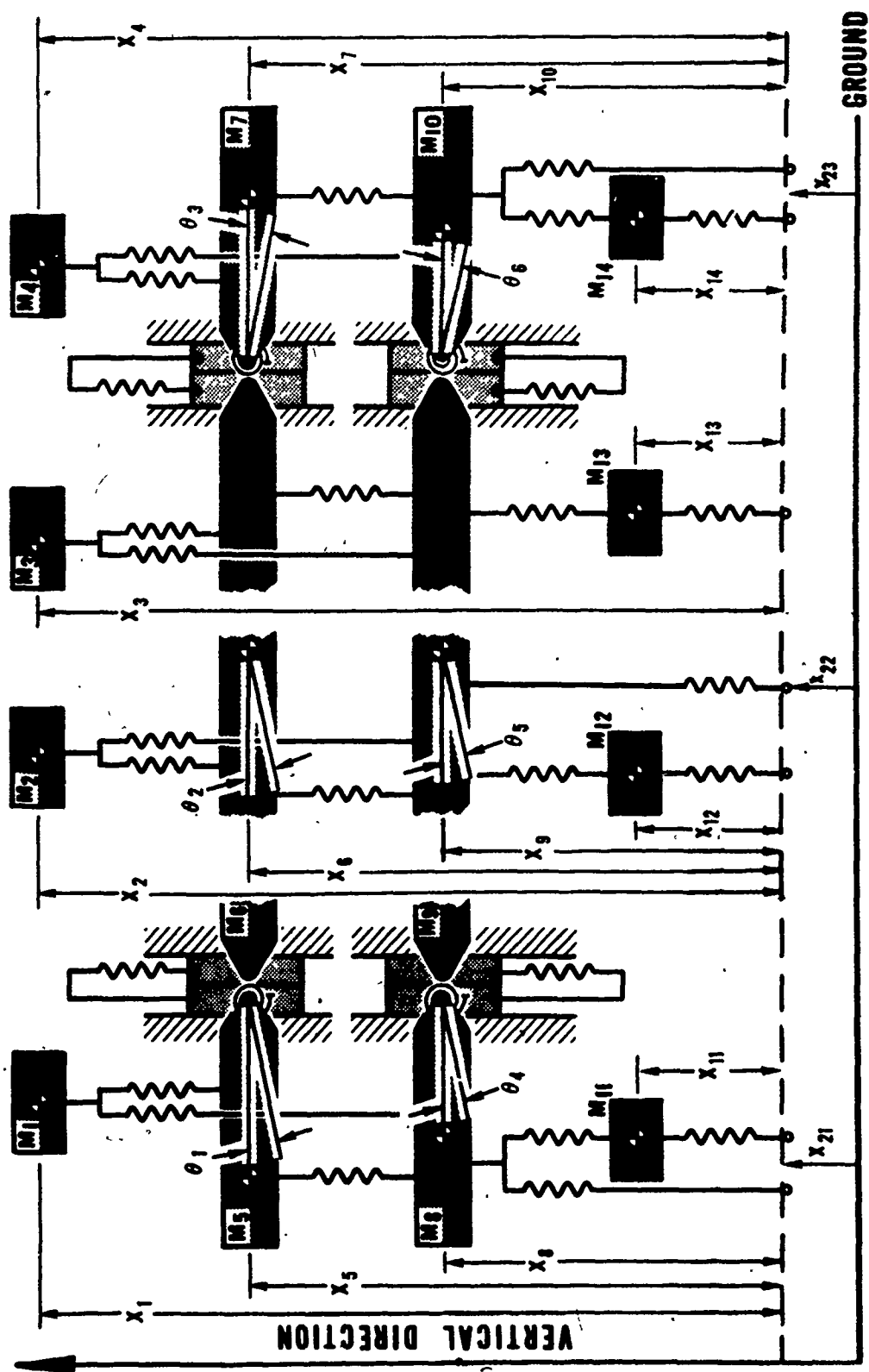


Figure 5. Model Coordinates.

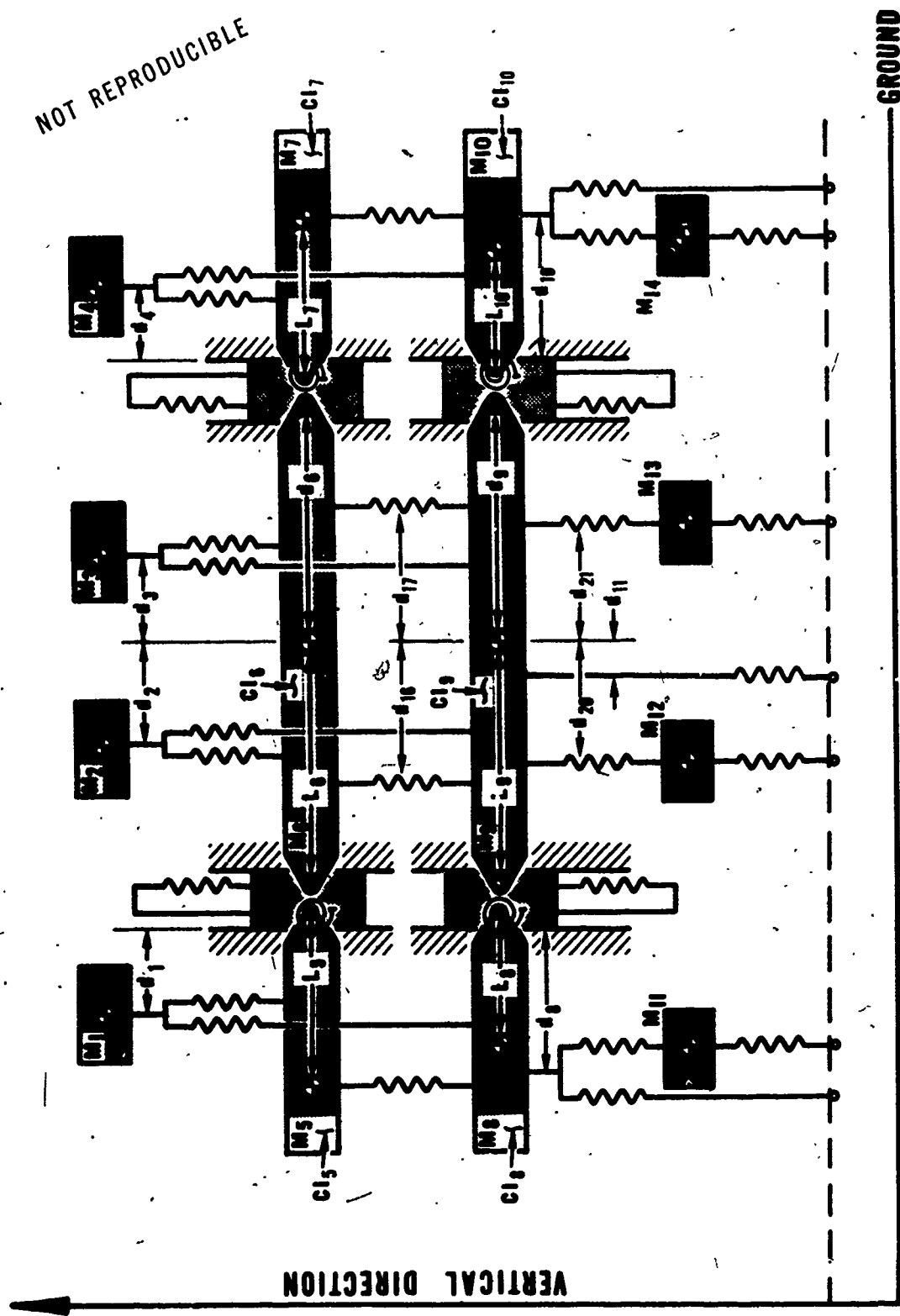


Figure 6. Model Dimensions.

PROGRAM DESCRIPTION

The computational scheme of Program CRASH is controlled by a small main program which calls upon 10 subroutines. Not only does the nature of the problem permit its dissection into input and output phases, but even the computational phase of the problem is uniquely suited for the building block technique provided by subroutines. This type of program structure also lends itself to overlay techniques if the user finds it necessary. Nine of the 10 subroutines are linked together by numbered common, using approximately 7,600 decimal locations. The plotting subroutine uses the formal call sequence to transfer data. The source deck is composed of 827 cards, requiring approximately 24,600 decimal core locations. The program as listed in Appendix I is compatible with an IBM 360-40 computer.

Data is read into the program in two locations. First, the main program is informed how many individual uses of data will be processed, and, thereafter, data is entered into the program only through subroutine "READ". The following section provides a detailed description of this subroutine. The input data can be grouped into four categories:

INPUT

1. Physical Properties: This involves the dimensions, mass distribution, and structure stiffness properties of the model. This group of input comprises about 90 percent of the input data.
2. Crash Conditions: The vertical velocity and pitch rates of all masses must be specified at impact, along with the ground conditions.
3. Output Requested: There are a possible 129 printer plots which can be requested. Of these parameters, as many as three may be plotted simultaneously on the same plot for comparison. This is the feature of the program which enables the engineer to analyze a large amount of data. The parameters to be plotted and their sequence must be specified. The details of this output feature and the required instructions are found in the Input Description section herein.
4. Numerical Integration: The total time duration of the numerical integration, T_{max} , and the delta time increment, DT , must be specified. The times for which the program stores data for future plotting must also be specified.

MODELING THE AIRCRAFT

The aircraft is modeled by dissecting it into its major structural or weight components. The generalized model, Figure 1, is composed of a number of lumped masses, defined by Table I, which are used to represent the major weight components of the aircraft. The plastic hinges provided by the model permit certain masses to break and rotate with respect to each other. The location of these plastic hinges is guided by the user's knowledge of the structure's ability to resist bending moments, or past accident histories of postcrash configurations. All of the lumped masses, 14 in all, may not be needed to properly describe a particular aircraft. In those cases where a mass is omitted from the generalized model, its weight, $CM(I)$, must be assigned a nominal value of 1.0.

The load deflection characteristics of the model are represented by 33 nonlinear springs as shown in Figure 2 and Table II. The load deflection characteristics are assigned by the curve illustrated in Figure 4.

Note: If a spring is to be omitted, the blank input card for that spring must be present in the input sequence. The program checks the spring-type parameter, $SD(I,7)$, to see if the spring is present.

Note: If the spring-type $SD(I,7) = 0.0$, the spring has been omitted from the program. If the spring-type $SD(I,7) = 1.0$, the spring is unable to hold a tensile load or to elongate. If the spring-type $SD(I,7) = 2.0$, the spring is capable of resisting a tensile load and may elongate.

The ability of the simulator to duplicate a crash condition depends upon the degree of realism that the user can incorporate into the model through the use of realistic load-deflection spring characteristics. The user is limited only by his ability to idealize desired nonlinear load-deflection properties by the series of straight lines provided by Figure 4.

An additional feature of Program CRASH is to limit the deflection of certain springs. This is accomplished by an adjustment to the elastic portion of the load-deflection curve when the spring exceeds the user-supplied limiting deformation value. This requires the numerical procedure to be stopped and re-started at a former time, extending the program both in complexity and computational time required for a run sequence. To help reduce the excessive time required, the number of restarts required should be reduced. Toward this end, the program is constantly projecting 50 time increments ahead,

estimating with the information on hand if these conditions will occur. If these projections indicate that the program will have to be re-started 50 time increments in the future, adjustments are initiated in an attempt to correct the situation before it happens. If the original load-deflection slope is too large, the projection will be conservative, thus decreasing the slope for the next iteration. If the slope is too small, the projection will indicate a future violation and the slope will be increased for the next time increment. The amount of increase or decrease in this slope is provided by the user. If the user supplies a very small delta slope change, the program may not be able to correct within the available 50 time increments, thus forcing a re-start condition. This condition will continue until the deformation limitations are achieved. This can develop into a rather time-consuming process, especially if there are more than three springs being limited. The beginning user is cautioned against excessive use of this program feature in the early stages of developing a particular model. Once an idea of the model's general behavior is obtained, the user should have a better idea of what restrictions to impose in this limiting process. The user is reminded that this technique does not provide a "unique" load-deflection curve which restricts the spring deformation within the desired range, since there are many possible curves which will satisfy the required condition. This technique determines one of the many possible answers.

Note: The program is written to handle up to 10 limiting springs simultaneously.

CRASH CONDITIONS

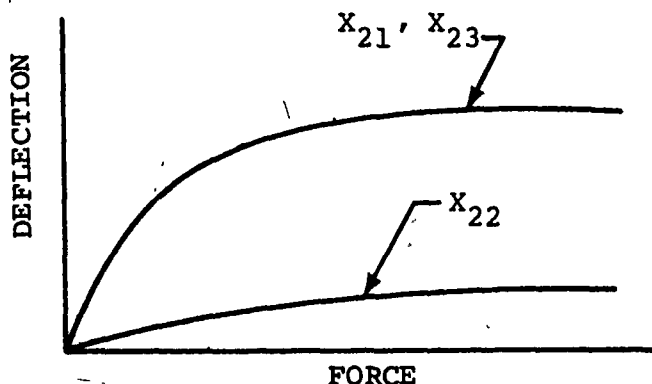
A vertical impact with a positive or negative pitch rate is permitted. Each single-degree-of-freedom mass is assigned an impact velocity in ft/sec. If the mass has rotational properties, the mass is given a vertical velocity and also a possible nonzero angular velocity. Whatever the velocity condition is at impact, it must represent a kinematically consistent system. The example provided represents the simplest system possible, namely, pure vertical input, all linear velocities being equal, and all angular velocities being zero.

GROUND CONDITIONS

The ground is modeled by a deflection-force equation of fourth order or less. For example:

$$\text{Ground Deflection} = \text{GD}(I,1) (\text{force}) + \text{GD}(I,2) (\text{force})^2 \\ + \text{GD}(I,3) (\text{force})^3 + \text{GD}(I,4) (\text{force})^4$$

where $I = 1, 2, 3$ represents the three possible contact points between the fuselage and ground, X_{21} , X_{22} , X_{23} , of Figure 5. The deflection of the ground for the contact point may be quite high since a possible landing skid may produce high soil bearing stresses. However, when the fuselage contacts the ground, these soil bearing stresses are drastically reduced due to the large increase in bearing surface. The general example of this concept is shown by the following diagram:



The parametric study (Vol. I of this report) was performed assuming an infinitely rigid ground condition, attempting to approximate the worst condition.

OUTPUT

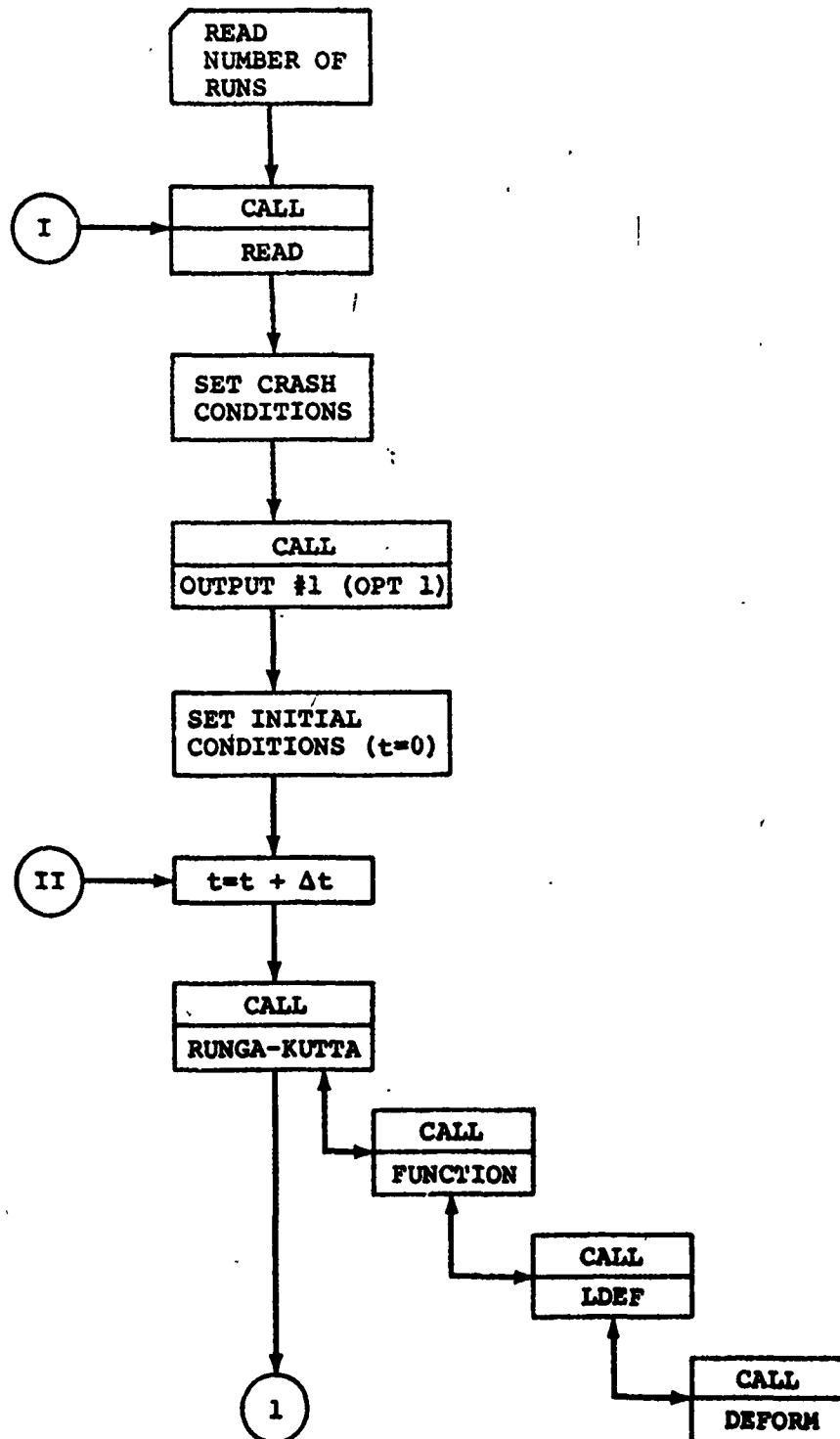
Full digital output is automatic. This is composed of the following information at each requested plot time:

1. Generalized coordinate motion, both vertical and angular, during impact, taken from a zero reference.
2. Vertical and angular velocities of each mass during impact.
3. Vertical and angular accelerations of each mass during impact.
4. Relative spring deformation of each spring during impact.
5. The force in each spring during impact.

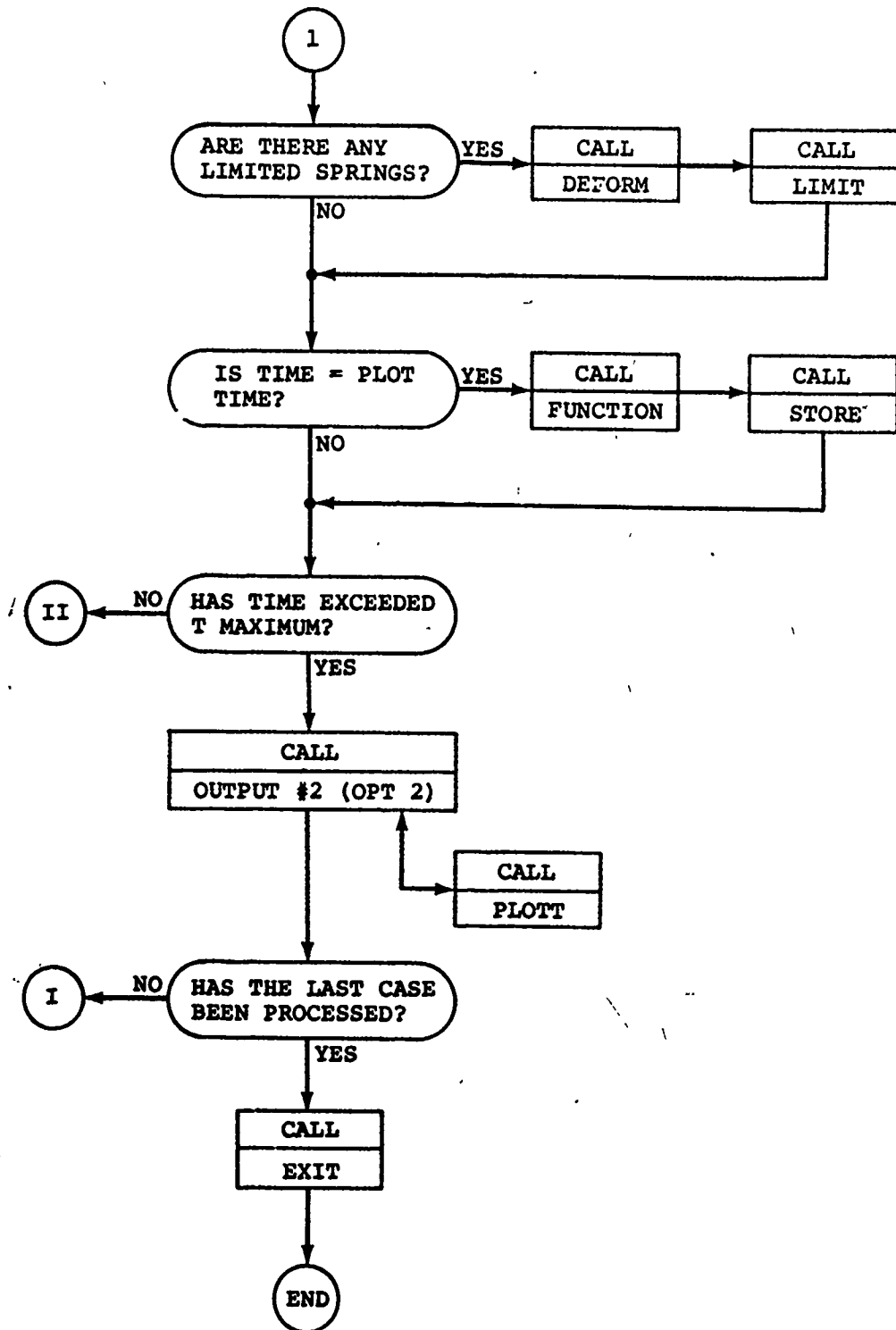
There are 129 parameters, any of which can be requested to appear in the form of a printer plot (described in tabular form in the Output Description section herein). Up to three parameters may be plotted simultaneously for comparison.

Note: If more than one parameter is requested on the same plot, thought should be given to the expected magnitude of these parameters since the plotting subroutine automatically defines the scale factor. This scale factor will be applied to all the parameters appearing on a particular plot. Large-magnitude differences between the parameters destroy the engineering usefulness of this feature.

GENERAL FLOW DIAGRAM OF PROGRAM CRASH



GENERAL FLOW DIAGRAM OF PROGRAM CRASH (CONTD)



GENERAL DESCRIPTION OF SUBROUTINES

ITEM 1, SUBROUTINE "READ": All necessary data for the analysis of a crash configuration enters Program CRASH through this subroutine. Fixed and floating point data must be formatted for an I5 and E10.0 specification, respectively. The order of the read statements is consistent with the Input Description (next section herein). Coding sheet examples in proper format and a numerical example are provided in the sections on Input Description and Example Problem.

ITEM 2, SUBROUTINE "OPT1": All input data entered through subroutine "READ" is printed out by this subroutine. For a detailed description of its format and a numerical example, see the Output Description section and illustrations therein. This subroutine is one of four subroutines capable of outputting information to the user.

ITEM 3, SUBROUTINE "RUNGA": This subroutine executes the fourth-order Runge-Kutta method for solving first-order ordinary differential equations. The four required functional evaluations are obtained by calling subroutine "FUNCT". Briefly, this subroutine accepts the values of the dependent parameters and their derivatives at $t = t^*$ and calculates the values of the dependent parameters and their derivatives at $t = t^* + \Delta t$.

ITEM 4, SUBROUTINE "FUNCT": This subroutine contains the equations of motion for the generalized model. The transformed equations of motion are of the form

$$\frac{dx(I)}{dt} = \text{FUNCT}(I)$$

Vol. I of this report presents a more detailed description of this set of equations. Physically, this subroutine accepts the forces and moments within each of the springs of the generalized model (Figure 2) and calculates the acceleration and velocity of each mass. This subroutine supplies subroutine "RUNGA" with required information.

ITEM 5, SUBROUTINE "LDEF": Subroutine "LDEF" is the "load-deflection" subroutine. Knowing the physical characteristics of each spring of the generalized model, it accepts the relative deformation and elongation rate of each spring and calculates the forces required to produce these relative deformations. It tracks the load history of each spring so that hysteresis during unloading may be achieved. This subroutine supplies subroutine "FUNCT" with required information.

ITEM 6, SUBROUTINE "DEFORM": Subroutine DEFORM (deformation) contains the equations of kinematics of the generalized model. Given the current positions and velocities of the generalized coordinates, this subroutine calculates the relative deformation and elongation rate of each spring. This subroutine supplies subroutine "LDEF" with required information.

ITEM 7, SUBROUTINE "LIMIT": Subroutine "LIMIT" uses current spring elongation rates and relative deformations to estimate requested spring deformations 50 time increments in the future, i.e., $t_{\text{future}} = t_{\text{current}} + 50 \Delta t$. If these estimated relative spring deformations exceed user-supplied limits, adjustments in that spring's load-deflection characteristics are made in an attempt to correct the projected excessive spring deformation. If these adjustments are not sufficient to correct the excessive spring deformation, subroutine "LIMIT" stops the numerical process, resets time and the necessary initial conditions, and recycles the program. If this occurs, subroutine "LIMIT" informs the user of the time the program was stopped and the restart time.

ITEM 8, SUBROUTINE "STORE": This subroutine stores all of the 129 possible output quantities at the requested printer plot times. A list of these quantities can be found in the Output Description section.

ITEM 9, SUBROUTINE "OPT2": This subroutine first prints out the results previously set aside in subroutine "STORE" with the exception of the ground displacements X_{21} , X_{22} , and X_{23} . This digital output is not optional. Second, this subroutine sorts out the results as directed by the user-supplied "plot codes" and presents the data in the proper sequence to subroutine "PLOTT". This output display is a user's option. (Further details are provided in the Output Description section.) Third, this subroutine sorts out the load-deflection history of those springs which have had their deformation restricted and presents this information in the proper sequence for digital output display. This output display is not a user's option.

ITEM 10, SUBROUTINE "PLOTT": This subroutine can accept up to three dependent one-dimensional arrays and simultaneously plot their elements against an evenly incremented, independent array. In our case, the independent array is composed of the plot times stipulated by the user and the dependent arrays are the desired calculated results as stipulated by the user-supplied "plot codes". Up to three curves may be requested simultaneously on one plot (see Output Description section). No scale factors are required, as the length of the plot is determined by the time duration of the run and the number of time increments.

INPUT DESCRIPTION

The detailed description of the input which follows is consistent with the order in which the input is read by the computer. It is suggested that the reader simultaneously review this section with the input example provided in the Example Problem section.

The programmer has attempted whenever possible to form acronyms of the input parameters to ease the confusion. The parameter name in quotes should help the user in recognizing the computer notation acronym. All input data is floating point unless stated otherwise.

INPUT TO MAIN PROGRAM

NRUN A fixed point number informing the main program of the "number" of cases to be "run" in an uninterrupted sequence. This card should be followed by NRUN number of input cases, each describing a particular crash or aircraft.

INPUT TO SUBROUTINE "READ"

XI(I) "Initial X" generalized coordinate of the model at impact. XI(1),...XI(14) describe the height above the ground in inches of the $X_1...X_{14}$ generalized coordinates. XI(15), XI(16),...XI(20) represent the initial angles of $\theta_1, \theta_2, ... \theta_6$ in radians (see Figure 5). These parameters are not used in the computation scheme since we are interested in relative coordinate motion; however, they are necessary for a complete description of the model.

XDI(I) "Initial Derivative" with respect to time. XDI(1), XDI(2),...XDI(14) represent the vertical impact velocity of generalized coordinates $X_1, X_2, ... X_{14}$ in inches/sec, and XDI(15), XDI(16),...XDI(20) represent the initial angular velocity of mass $M_5, M_6, ... M_{10}$ in radians/sec (see Figure 5). For example, XDI(2) = 360.0 and XDI(3) = 360.0 would imply that a possible rotor and engine configuration had a 360-inch/sec velocity at impact. The user is reminded here that, if a pitch rate is desired at impact, the center of gravity of the aircraft and desired pitch rate must be used in a pre-run calculation to determine the XDI(I) input. Non-zero XDI(15),...XDI(20) would imply that certain portions of the aircraft were bending with respect to one another at impact, or that these portions had previously failed and acquired an angular velocity. This input must be kinematically consistent.

SD(I,J) "Spring Data". The J elements completely describe the load-deflection characteristics of spring I. There are a possible 33 springs, each requiring 8 pieces of information for its description. Refer to Figure 4 for a detailed definition of the J elements in SD(I,J). For example, SD(3,1) = 20,000, SD(3,2) = 0.5, SD(3,3) = 0.0, and SD(3,4) = 100.0, indicating that spring 3 has an elastic load-deflection slope of 20,000 pounds/inch up to a relative deformation of 0.5 inch, at which time its load-deflection slope becomes zero. If the weight of mass 3 was 1000 pounds, CM(3) = 1000.0, then spring 3 would be programmed as a 10G load limiter. SD(3,4) is set at 100.0 inches as a highly improbable deformation level, thus defining the entire load-deflection curve for the expected limits. Note that SD(23,J) through and including SD(26,J) are used to input the torsional spring data.

CL(I) A "characteristic length" in inches. Necessary to describe the model's dimensions. CL(5), CL(6),... CL(10) are identified in Figure 6.

CM(I) "Characteristic Weight" of the I mass. CM(1), CM(2), ...CM(14) represent the weight in pounds of masses M(1), M(2), ...M(14) (refer to Figure 1). If any mass is omitted from the model, its CM(I) value is assigned a nominal value of one (1).

CI(I) "Characteristic" moment of "inertia" of the I mass. CI(5), CI(6), ...CI(10) represent the mass moment of inertia in (in.-lb-sec²) about their respective mass centers. If a rotational mass is omitted from the model, its CM(I) and CI(I) values are assigned a nominal value of one (1).

D(I) Model dimensions in inches. D(1) through D(4), D(6), D(8) through D(11), D(16), D(17), D(20), and D(21) are indicated by lowercase letters in Figure 6.

DT "Delta Time" increment. This is the delta time increment in seconds, used in the numerical integration scheme. The magnitude of the time increment depends on the crash conditions and properties of the model. It is suggested that the user use the example of the Example Problem section as a guide. A value of DT = 0.0001 sec (1/10 millisecond) was found to be a reasonable compromise between time required and convergence for this example.

TMAX "Time Maximum". The numerical integration process will terminate at TMAX seconds.

PLT "Plot Time". The first time, in seconds, that calculated results will be stored for output.

DPLT "Delta Plot Time". Results will be stored every DPLT seconds, starting at PLT seconds and ending at TMAX seconds. For example, if TMAX = 0.1, PLT = 0.001, and DPLT = 0.002, the results will be stored at time 0.001 second into the impact and every .002 second thereafter until the run is complete at 0.1 second.

Note: Detailed digital output is automatically provided at these specified times; therefore, the PLT and DPLT parameters must be specified even if no printer plots are to be requested.

NPR "Number of Plots Requested". A fixed-point number informing subroutine "OPT2" how many individual plots have been requested. There is no limit on the size of NPR.

KP(I,J) "Code" for "Plotting". A fixed-point array providing instructions for plotting. Each of the 129 possible output parameters is assigned a plotting code as tabulated in the Output Description section. The dimension of KP(I,J) is KP(NPR,3). Up to three parameters may be plotted simultaneously on one plot. A brief example would be:

KP(3,1) = 41

KP(3,2) = 42

KP(3,3) = 0

The third plot would be a comparison of the acceleration time-history of masses 1 and 2. Notice that KP(3,3) = 0 tells the computer that a third possible parameter will be omitted. Additional examples are presented in the following section, Output Description.

NIS "Number of Limited Springs". NIS is a fixed-point number which tells the program the number of springs which have had limitations placed upon their relative deformation. The program is presently dimensioned for 10 limited springs.

IGR "Is Ground Rigid"? A fixed-point number specifying the ground conditions

IGR = 0 = Yes

IGR = 1 = No

If IGR is valued at 1, the program will expect the necessary ground data to follow. If IGR = 0, the ground data is assumed to be zero, thus producing an infinitely rigid ground.

ISN(I) "Limited Spring Number". A fixed-point number which identifies the springs which have had limitations placed upon their relative deformations. The dimension of ISN is ISN(NIS). If there are two limited springs, NIS = 2, then ISN(1) and ISN(2) must be specified.

DFE(I) "Deflection Limit". This is the maximum allowable deformation in inches that spring I will be permitted. There must be NIS deflection limits specified.

DSD(I) "Delta Spring Data". If the limited spring ISN(1) exceeds the allowable maximum deformation DFE(1), the slope of the elastic portion of its load-deflection curve SD(ISN,1) is changed to SD(ISN,1) + DSD(1). Further description of ISN(I), DFE(I), and DSD(I) has been presented in the Program Description section.

GD(I,J) "Ground Data". There are three contact points between the fuselage or landing gear and the ground (see Figure 5). GD(1,J), GD(2,J), and GD(3,J) represent the respective J coefficients of a possible fourth-order polynomial describing the deflection load characteristics of contact points X₂₁, X₂₂, and X₂₃. The general form of these equations is:

$$\text{Ground Deflection} = \text{GD}(I,1) (\text{force}) + \text{GD}(I,2) (\text{force})^2 + \text{GD}(I,3) (\text{force})^3 + \text{GD}(I,4) (\text{force})^4$$

where the deflection is in inches and the force is in pounds.

OUTPUT DESCRIPTION

Four subroutines are capable of providing output information to the user. These four subroutines are:

1. Subroutine OPT1
2. Subroutine FUNCT
3. Subroutine LIMIT
4. Subroutine OPT2

Detailed descriptions of these outputs follow.

OUTPUT FROM SUBROUTINE "OPT1": Output from subroutine OPT1 consists of a tabulation of all input data. This tabulation is formatted to be self-descriptive. This output is not a user's option. This output first reviews the plotting sequence requested by the user. Notice in the example output (Figure 7) that the fifth plot has requested a comparison of plotting parameters 88, 91, and 92. This means that the input data for the fifth plot was $KP(5,1) = 88$, $KP(5,2) = 91$, $KP(5,3) = 92$. This will provide a printer plot comparing the relative elongation of far-coupled springs 28, 31, and 32 (see Figure 2 and Table III). The actual printer plot resulting from this instruction is shown in Figure 8. The output of subroutine OPT1 continues by discussing the limitations imposed on any springs, a detailed listing of information about each of the 14 masses, and a discussion of ground conditions. Detailed information concerning spring data follows. The notation is defined at the top of the page with listings of each of the 33 springs. This is illustrated in Figures 7 and 9.

OUTPUT FROM SUBROUTINE "FUNCT": This is an error message output feature that informs the user that he has attempted to divide by zero. This has occurred because either the weight or mass moment of inertia of one of the lumped masses is zero. It is an input error, as explained in the Input Description section.

OUTPUT FROM SUBROUTINE "LIMIT": If restrictions are placed upon the allowable deformation of certain springs, the program may find it necessary to stop and re-start in order to satisfy these imposed limitations. If this re-start cycle occurs, the user is informed of the time at which the program failed to meet these imposed limitations and the time of the re-start. This output will occur for each re-start process. This information will aid the user in obtaining an intuitive feel for the severity of the restrictions he is imposing on the problem.

AIRFRAME CRASHWORTHINESS STUDY, MODEL NO. 1
 THE FOLLOWING PLOTS HAVE BEEN REQUESTED

PLOT NO. PLOTTING PARAMETERS
 1 42 43 44
 2 62 63 0
 3 45 46 47
 4 48 49 0
 5 88 91 92
 6 116 117 118
 7 121 124 125
 RELATIVE DEFORMATIONS IS RESTRICTED FOR
 THE FOLLOWING SPRINGS

SPRING RELATIVE DELTA
 NUMBER ALLOWABLE SLOPE

 3 2.50 200.00
 26 3.00 300.00

		LUMPED MASS NUMBER													
		1	2	3	4	5	6	7							
WEIGHT OF MASS (LB)-		1.00	980.00	1072.00	60.00	250.00	2147.00	230.00							
HALF LENGTH (IN) -		-	-	-	-	45.00	65.00	120.00							
MOMENT OF INERTIA -		-	-	-	-	437.00	7833.00	2856.00							
VERT POSITION (IN) -		-	-	-	-	70.00	70.00	75.00							
INITIAL ANGLE (RAD)-		-	-	-	-	0.0	0.0	0.17800							
VERT VELOCITY (T=0)-		240.00	240.00	240.00	240.00	240.00	240.00	240.00							
ANG VELOCITY (T=0) -		-	-	-	-	0.0	0.0	0.0							

		8	9	10	11	12	13	14
WEIGHT OF MASS (LB)-		2951.00	1370.00	1.00	60.00	60.00	1.00	1.00
HALF LENGTH (IN) -		45.00	45.00	0.0	-	-	-	-
MOMENT OF INERTIA -		5160.00	5727.00	1.00	-	-	-	-
VERT POSITION (IN) -		30.00	30.00	0.0	20.00	0.0	20.00	0.0
INITIAL ANGLE (RAD)-		0.0	0.0	0.0	-	-	-	-
VERT VELOCITY (T=0)-		240.00	240.00	240.00	240.00	240.00	240.00	240.00
ANG VELOCITY (T=0) -		0.0	0.0	0.0	-	-	-	-

THE GROUND IS CONSIDERED RIGID

Figure 7. Output From Subroutine "OPT1" (Tabulation of Input Data).

TABLE III. DESCRIPTION OF PLOTTING CODE
USED FOR COMPUTER OUTPUT

KP(I,J) = CODE I = Plot number J = Number of curve on plot I; J = 1, 2, 3		
CODE	OUTPUT PARAMETER	
0	Curve Omitted	
1	Vertical Deflection of Coordinate	1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10		10
11		11
12		12
13		13
14		14
15	Angle of Mass Number	5
16		6
17		7
18		8
19		9
20		10
21	Vertical Velocity of Coordinate	1
22		2
23		3
24		4
25		5
26		6
27		7
28		8
29		9
30		10
31		11
32		12
33		13
34		14

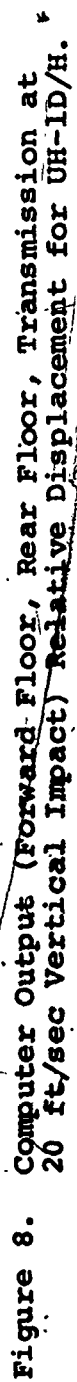
TABLE III. Continued		
CODE	OUTPUT PARAMETER	
35	Angular Velocity of Mass Number	5
36		6
37		7
38		8
39		9
40		10
41	Acceleration of Coordinate Number	1
42		2
43		3
44		4
45		5
46		6
47		7
48		8
49		9
50		10
51		11
52		12
53		13
54		14
55	Angular Acceleration of Mass Number	5
56		6
57		7
58		8
59		9
60		10
61	Elongation of Spring Number	1
62		2
63		3
64		4
65		5
67		7
68		8
70		10
71		11
72		12
73		13
74		14

TABLE III. Continued		
CODE	OUTPUT PARAMETER	
75	Elongation of Spring Number	15
76		16
77		17
78		18
79		19
80		20
81		21
82		22
83	Angular Rotation of Torsional Spring	5
84		7
85		8
86		10
87	Elongation of Far-Coupled Spring Number	27
88		28
89		29
90		30
91		31
92		32
93		33
94	Force in Spring Number	1
95		2
96		3
97		4
98		5
100		7
101		8
103		10
104		11
105		12
106		13
107		14
108		15
109		16
110		17
111		18
112		19
113		20
114		21
115		22

TABLE III. Continued		
CODE		
116		5
117		7
118	Movement in Torsional Spring Number	8
119		10
120		27
121		28
122		29
123	Force in Far-Coupled Spring Number	30
124		31
125		32
126		33
127		21
128	Vertical Displacement of Coordinate	22
129		23

OUTPUT FROM SUBROUTINE "OPT2": This subroutine first provides a detailed digital tabulation of output parameters. The format titles each of the arrays according to the generalized model (Figures 1 through 5) and lists the results at each of the requested plot-times. This output feature is not a user's option.

If any plots have been requested, the user is supplied with a combination digital and printer-scaled-plot display of the plot code parameters. An example is provided in Figure 10. The plot will be titled according to the generalized model and a digital listing on the left side of the paper. The first column is the time and the following columns are the digital values of the requested plot parameters in E format. Notice that the title identifies the curve and digital listing by assigning a plot symbol. There is no limit to the number of plots that can be requested.



EXAMPLE PROBLEM

The computer simulator just discussed was used to investigate the effects of vertical impacts on a UH-1D/H helicopter. This aircraft, shown in Figure 11, is in widespread use by the Army, Air Force, and Marine Corps as a tactical transport.

Two major categories of input data were required: (1) weight data to apply to the lumped mass simulation and (2) spring constant data to apply to the various springs connecting the masses.

Information supplied by the helicopter manufacturer was used to distribute the weight in the lumped mass model. This weight distribution is shown in Table IV for the empty aircraft and for the aircraft configured as a troop carrier.

The helicopter airframe structure was mathematically represented by the system of lumped masses (Figure 12) superimposed on a general side view of the fuselage. Comparison with Figure 1 will illustrate the application of the generalized model to the UH-1D/H helicopter.

Of the 14 masses available in the model, only 10 were used to represent this aircraft. Mass (M1) was not used, since in this aircraft the engine, gearbox, and rotor are located in close proximity. Mass (M2) was used to represent the main rotor assembly, while the engine and gearbox were simulated by mass (M3). Mass (M4) depicts the tail rotor and 90-degree gearbox. The upper portion of the cockpit section was simulated by mass (M5), while mass (M6) represents the upper portion of the passenger compartment and the aft fuel cells. Mass (M7) simulates the tail-boom structure. The floor loads and the structure below the floor including the forward fuel cells were represented by masses (M8) and (M9), which were located to either side of a possible break point in the fuselage. Mass (M10) was not used, although the possibility of using it in combination with mass (M7) to simulate crushing of the tail boom was considered. However, since the tail-boom weight is small, and since in severe crashes peak floor accelerations will occur before tail-boom crushing, the effect of this mass would be negligible. Masses (M11) and (M13) were chosen to represent the landing skids. Those masses not used were assigned a weight of 1 pound.

Analysis of accident case histories involving the UH-1D/H aircraft revealed that two possible locations existed for the formation of a plastic hinge: one just forward of the main rotor and another at the juncture of the tail boom and fuselage.

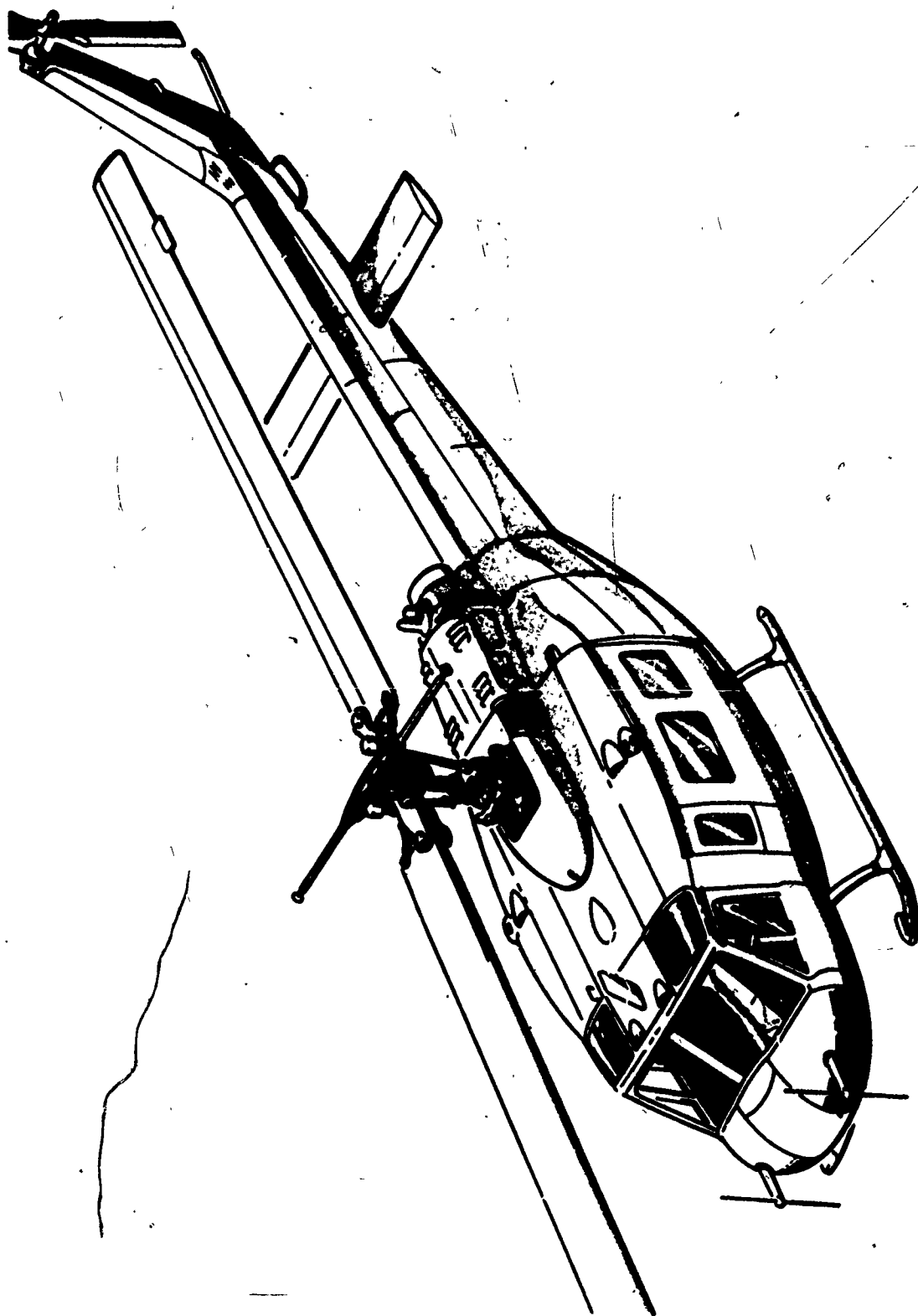


Figure 11. Helicopter Model UH-1D/H.

TABLE IV. UH-1D/H WEIGHT DISTRIBUTION			
MASS NO.	A/C EMPTY (lb)	TROOP CARRIER (lb)	TOTAL (lb)
M1	0	-	0
M2	980	-	980
M3	1047	25	1072
M4	60	-	60
M5	250	-	250
M6	847	1300	2147
M7	230	-	230
M8	1306	1645	2951
M9	270	1100	1370
M10	0	-	0
M11	60	-	60
M12	0	-	0
M13	60	-	60
M14	0	-	0
TOTALS	5110	4070	9180

The lumped mass model was therefore arranged so that these hinges were simulated between the masses at stations 110.00 and 243.89 as shown in Figure 12.

The load-deflection characteristics of the UH-1D/H airframe structure were simulated by the combinations of springs shown in Figure 13. Comparison with Figure 2 shows the application of the generalized model to this specific case.

Spring-constant data for the system were estimated by analysis of accident case histories obtained from the helicopter manufacturer and the U. S. Army Board for Aviation Accident Research (USABAAR), and by inspection of wrecked airframe structures at the U. S. Army Aeronautical Depot Maintenance Center (ARADMAC).

The main rotor and transmission in the UH-1D/H are supported by a sturdy box structure which ties directly to the floor. To simulate this structure, spring (K2) was omitted from the

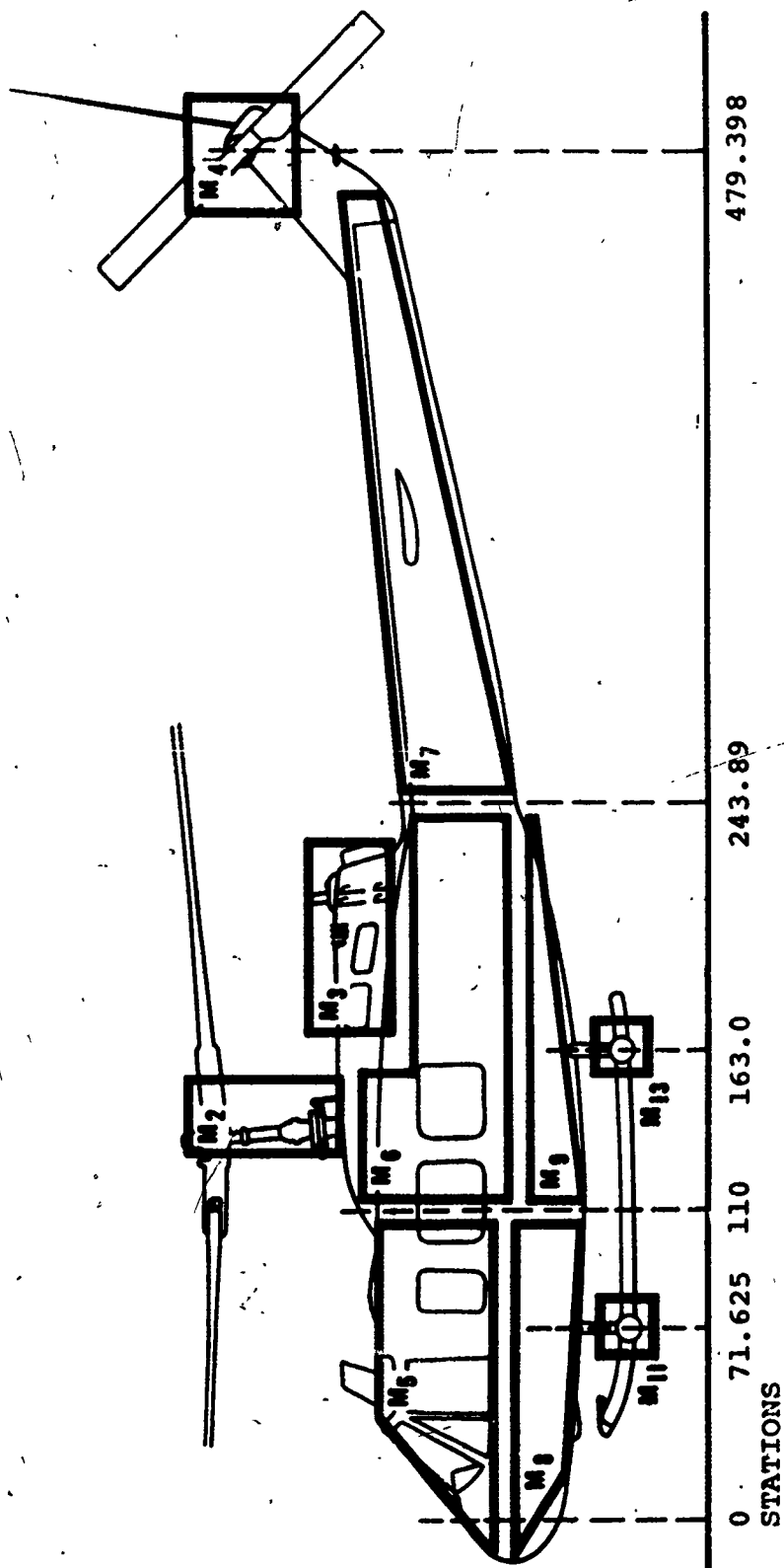
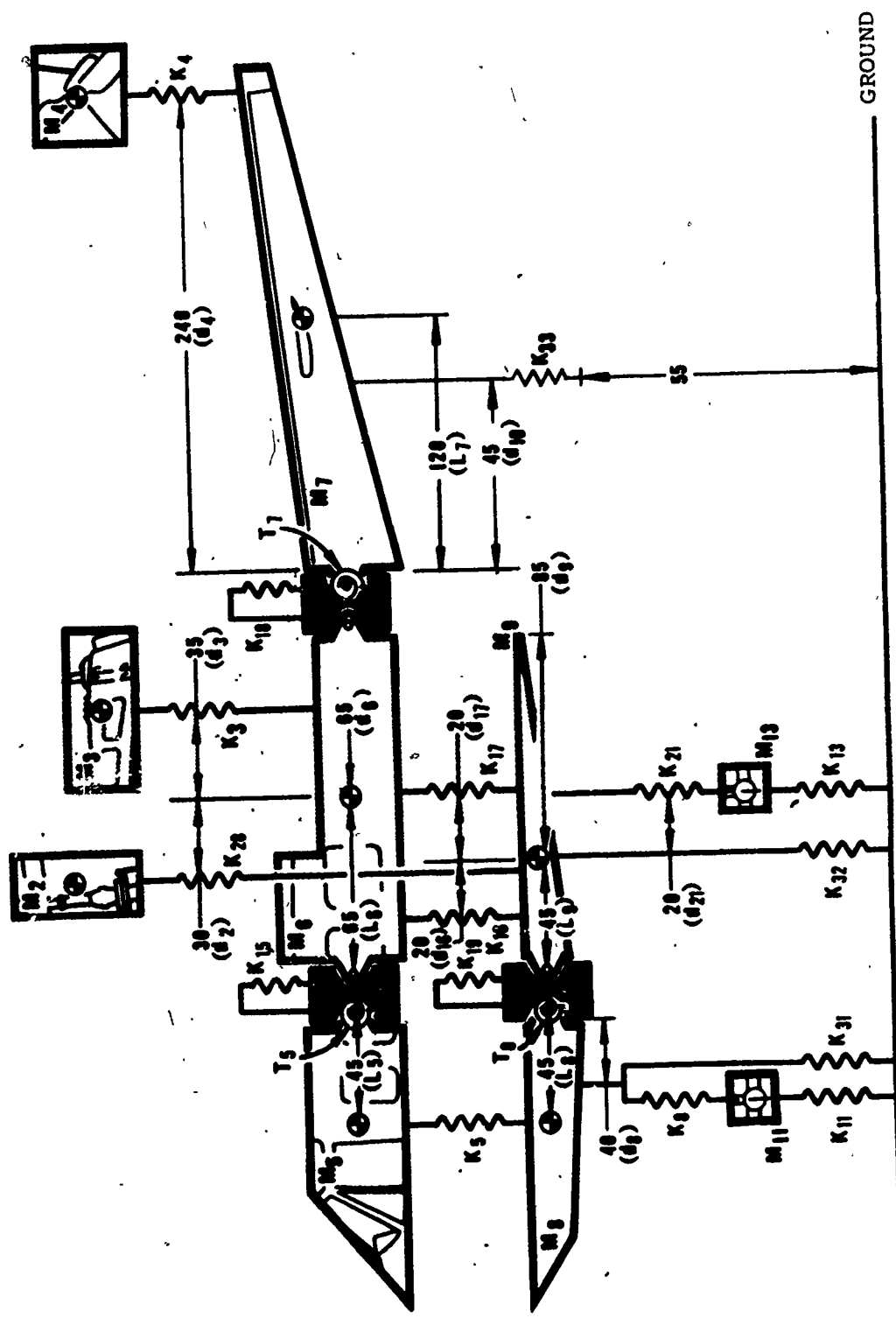


Figure 12. Lump Mass Representation of the UH-1D/H.



system and far-coupled spring (K28) was used to support mass (M2) at the floor, so the rotor and transmission loads would bypass the upper fuselage structure. The load-deflection characteristics of the transmission and rotor support system (Figure 14) allow approximately 1/2 inch of elastic deflection at a load of 8,000 pounds before the transmission supports fail.

The engine mass (M3) is supported by the upper fuselage section mass (M6) through spring (K3) whose load-deflection characteristics are similar to those of spring (K28), as shown in Figure 14. The sudden decrease in the load-carrying ability of springs (K3) and (K28) represents local buckling of structural members.

The displacement of the tail-boom mass (M7) is controlled by three springs: torsional spring (T7), far-coupled spring (K33), and shear spring (K18). The load-deflection characteristics of spring (T7), shown in Figure 15, permit a 2-degree rotation before a plastic hinge forms. This plastic hinge can then rotate up to 15 degrees before failure occurs, and the tail boom becomes incapable of resisting further rotation. This unlimited rotation is controlled by spring (K33), whose characteristics simulate the tail boom striking the ground after a predetermined displacement of the center of gravity of mass (M7). Shear spring (K18) is essentially rigid so that no shear deformation occurs at the hinge point.

Rotation of the forward portion of fuselage masses (M5) and (M8) about the potential plastic hinge at Station 110 (Figure 12) is controlled by torsional springs (T5) and (T8). The load-deflection characteristics of these springs are shown in Figure 15. Shear springs (K15) and (K19) control shear deformation at the hinge point. As with spring (K18), these shear springs allow no shear deformation.

The load-deflection characteristics of the landing skids are represented by two sets of springs: one for the forward portion of the skids and one for the rear portion. Each set consists of three springs: one far-coupled and two direct-coupled with springs (K8), (K11), and (K31) representing the front portion of the skids, and springs (K13), (K21), and (K32) representing the rear portion. Each of these sets allows simulation of elastic deformation, plastic deformation, skid failure, and ground contact of the fuselage. The load-deflection characteristics of these springs are presented in Figure 16.

Consider the set formed by springs (K8), (K11), and (K31). Spring (K11) allows elastic deformation up to 2 inches, with an applied load of 18,000 pounds, at which point the spring

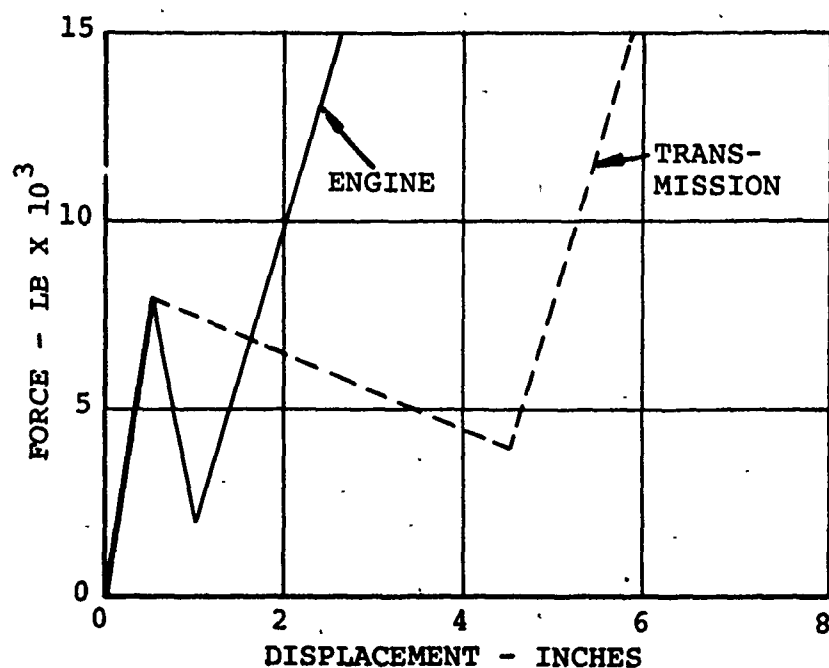


Figure 14. Load-Deflection Curve (Engine and Transmission) for UH-1D/H.

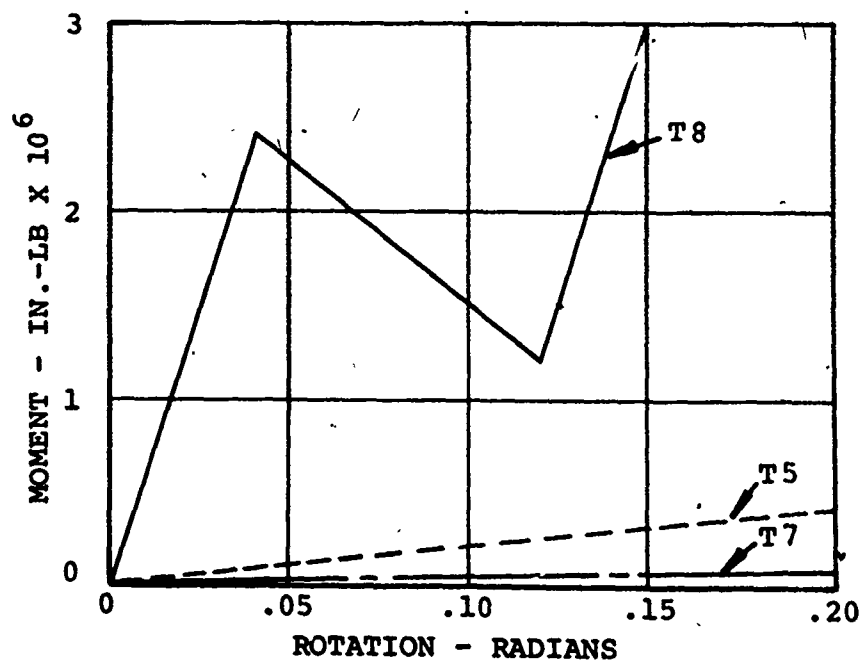


Figure 15. Load-Deflection Curves for Torsional Springs.

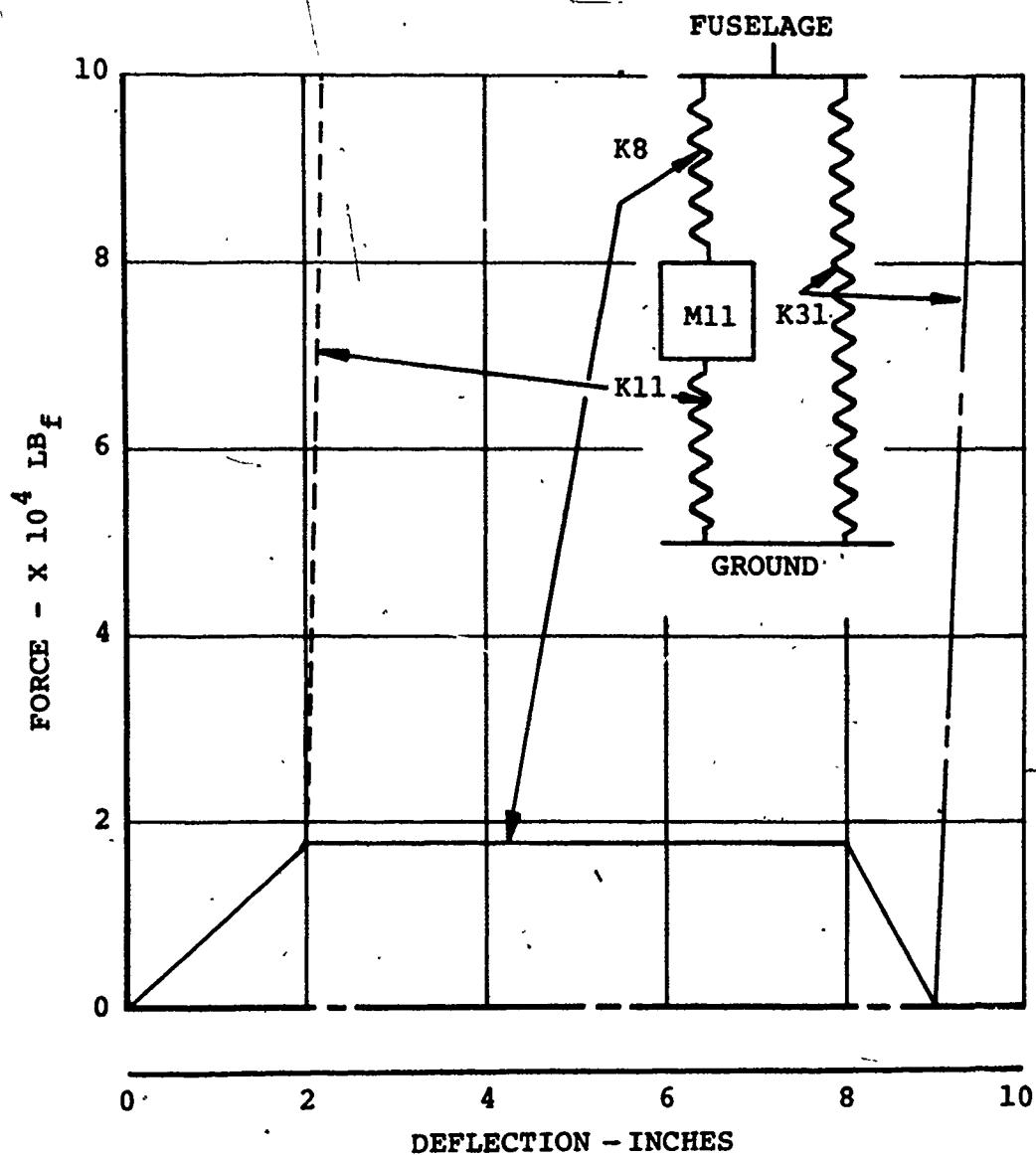


Figure 16. Load-Deflection Characteristics (Forward Landing Skid) for UH-1D/H.

becomes essentially rigid. Spring (K8) also allows elastic deformation of approximately 2 inches with an applied load of 18,000 pounds. This spring combination allows a deflection of 4 inches at a peak total load of about 36,000 pounds, or about 2G's on the 9,000-pound aircraft for each gear. Both skids then allow plastic deformation at the 36,000-pound load for an additional 7 inches. At this point the skids fail, the fuselage contacts the ground, and the influence of spring (K31) is felt. This spring represents the interaction of the fuselage and the impact surface and, therefore, carries no load until the total deflection exceeds 9 inches.

A detailed listing of the input used to simulate the UH-1D/H helicopter is shown in Figures 7 and 9.

The initial conditions for this example are a vertical impact velocity of 240 in./sec with all masses having zero angular velocity. Output of the program is also included. Figures 7 and 9 are self-descriptive output of subroutine OPT1. The complete digital output of subroutine OPT2 is omitted due to its length. Three examples of the plotting format are provided. They represent the requested plots 1 (Figure 10), 4 (Figure 17), and 5 (Figure 8) as shown in the output of Figure 7. Notice that the example has imposed restrictions on springs 3 and 28 (Figure 7). Possible load-deflection characteristics which provide results within these restrictions are provided by output (see Figure 18).

The exact input required for this example is presented in Figure 19 using the master input coding sheets included in Appendix II.

REQUIRED LOAD-DEFLECTION CHARACTERISTICS
IMPOSED ON SPRING 28 IN UNDER NOT TO EXCEED
A DEFORMATION OF 3.00000 INCHES

FORCE(LB) DEFLECTION(IN)

0.191091 00 0.113271F-04
0.110532 02 0.490827E-03
0.430424 02 0.269140E-02
0.104716 03 0.479884E-02
0.225404 03 0.140800E-01
0.191444 03 0.247154E-01
0.620141 03 0.387590E-01
0.495397 01 0.561498E-01
0.170446 04 0.755010E-01
0.152877 04 0.855400E-01
0.183886 04 0.114931F CC
0.212784F 04 0.132903F CC
0.240234F 04 0.150167E 00
0.248044 04 0.167533E 00
0.256438 04 0.185284E 00
0.123579 04 0.202237E 00
0.164476 04 0.216546F 00
0.341134F 04 0.226959E 00
0.375248 04 0.274531E 00
0.345318 04 0.240824E 00
0.198546 04 0.249106E 00
0.446477 04 0.279173E 00
0.541210 04 0.338257E 00
0.498447 04 0.434453E 00
0.792022 04 0.549779E 00
0.778946 04 0.721047E 00
0.760786 04 0.952118E 00
0.742157 04 0.107847E 01
0.722167 04 0.127832E 01
0.692759 04 0.150725E 01
0.673740 04 0.176240E 01
0.642239 04 0.203774E 01
0.243514 05 0.233725E 01
0.530044 05 0.240447F 01
0.609451 05 0.280196E 01
0.636342 05 0.291028E 01
0.616643 05 0.291913F 01
0.622456 05 0.294810E 01
0.595369 05 0.271276E 01
0.554201 05 0.256692E 01
0.503277 05 0.222306E 01
0.442042 05 0.194432E 01
0.347941 05 0.137941E 01
0.287106 05 0.117132E 01
0.200397 05 0.737895E 00
0.110102 05 0.286430E 00
0.250135 04-0.155024E 00
-0.430402 04-0.530143E 00
-0.104429 05-0.910773E 00
-0.154943 05-0.174406E 01

REQUIRED LOAD-DEFLECTION CHARACTERISTICS
IMPOSED ON SPRING 3 IN UNDER NOT TO EXCEED
A DEFORMATION OF 2.50000 INCHES

FORCE(LB) DEFLECTION(IN)

0.222004E-03 0.130303F-07
0.644912E 03 0.405710E-04
0.707134E 01 0.441940E-03
0.315488 02 0.197180E-02
0.444911 02 0.593557E-02
0.225379E 03 0.140661F-01
0.455591E 03 0.283444E-01
0.407374F 03 0.504563E-01
0.130540F 04 0.514874E-01
0.195171E 04 0.121902F CC
0.273047 04 0.170444E 00
0.198076 04 0.224879E 00
0.445804 04 0.274474E 00
0.512789 04 0.324874E 00
0.575554 04 0.359723E 00
0.614779 04 0.384193E 00
0.642046 04 0.401468E 00
0.663823E 04 0.414889E 00
0.674444F 04 0.421653E 00
0.648333E 04 0.418551F 00
0.640317 04 0.404541E 00
0.634408F 04 0.394909E 00
0.534272 04 0.374521E 00
0.402302E 04 0.348535E 00
0.442237 04 0.428393E 00
0.747781E 04 0.510192E 00
0.623457E 04 0.645453E 00
0.392632E 04 0.834474E 00
0.343434E 04 0.104990E 01
0.796593E 04 0.137287E 01
0.125945 05 0.164178E 01
0.255941 05 0.194304E 01
0.176640E 05 0.217088E 01
0.459459E 05 0.237216E 01
0.491647F 05 0.247021E 01
0.483457E 05 0.247987E 01
0.469427E 05 0.240072E 01
0.434324E 05 0.223523E 01
0.187488 05 0.199003E 01
0.325190 05 0.147853E 01
0.253847E 05 0.123192E 01
0.178930E 05 0.647234E 00
0.108144E 05 0.593508E 00
0.444644 04 0.277409E 00
-0.442779 03-0.469502E-02
-0.510492 04-0.271679E 00
-0.910074E 04-0.516719E 00
-0.125134 05-0.733124E 00
-0.133242 05-0.983302E 00
-0.169228 05-0.180507E 01

Figure 18. Required Load-Deflection Characteristics Imposed on Springs 3 and 28.

MASTER INPUT CODING FORM: PROGRAM CHARGE																																																											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	4												

Figure 19. Input for Example Problem.

PAGES _____
ARE
MISSING
IN
ORIGINAL
DOCUMENT

[illegible]

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22 FORMAT(10X,30HN) RELATIVE DEFORMATIONS ARE RESTRICTED;
330 FORMAT(10X,39HRELATIVE DEFORMATIONS IS RESTRICTED FOR/
110X,21HTIME FOLLOWING SPRINGS//,
@1X,10M SPIN,5X,10H RELATIVE,5X,10H DELTA /
@1X,10M NUM,5X,10H ALLOWABLE,5X,10H SLOPE /
@30X,10M DEF,38X,15K,10I(10),5X,10I(10),5X,10I(10))
40 FORMAT(15X,110 ,5X,F10.2,5X,F1C,2)
88 FORMAT(10X,39HITF FOLLOWING PLOTS HAVE BEEN REQUESTED/
18MPLOT NO.,5X,19MPLOTTING PARAMETERS
89 FORMAT (11,20X,43HFRAME CHARACTERISTICS STUDY, MODE

uuu

40 FORMAT(15X,110,*,5F10.2,5X,1C,2)
88 FORMATION,39M4E FOLLOWING PLOTS HAVE BEEN REQUESTED//15X,
18MPL0T NO.,2X,18MPL0TING PARAMETERS)
89 FORMATION,1M1,2X,43AIRFRAME CRASHWORTHINESS STUDY, MODEL NO.

89 FORMAT (1H1,20X,43H AIRFRAME CRASHWORTHINESS STUDY, MODEL NU. 1 /


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0001      SIMPRTIME RUMGA
0002      DIMENSION RK(120),RK2(120),RK3(120),RK4(120),RK5(120),
0003      COMMON BLNK,PRN,STAR,EQ,PLUS,T,DT,PLT,TMAX,DPLT,NS,NP,IRUN,
0004      LA(33),C(10),CL(1),CH(14),CX(120),O(121),DF(33),DZF(33),F(40),
0005      IF(33),NM(33),PU(33),PS(33),RV(33),SD(33),SI(33),SK(20),X(23),Y(23),
0006      IX(23),XI(23),XJ(23),XT(23),YT(23),YI(23),YJ(23),Z(23),ZI(23),ZJ(23),
0007      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0008      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0009      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0010      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0011      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0012      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0013      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0014      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0015      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0016      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0017      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0018      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0019      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0020      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0021      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0022      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0023      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0024      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0025      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0026      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0027      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0028      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0029      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0030      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0031      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
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0033      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0034      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0035      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0036      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0037      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0038      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)
0039      IF(33),PT(100),NMU,CH(14),ISN(10),DFE(10),DSD(10),NIS,NEGOT(4)

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DOS	FORTRAN	IV	360M-FO-479	3-1	FUNCT	DATE	08/23/70	TIME	18.14.27	PAGE	0002
0037					F(10)=F(10)+CL(10)*VX(20)+VX(10)*S(20)-CL(10)*F(20)-CH(20)				FUNT0058		
0038					DO 40 I=21,40				FUNT0059		
0039					40 F(1)=F(1-20)				FUNT0060		
0040					DO 50 I=1,20				FUNT0061		
0041					50 F(1)=VX(1)				FUNT0062		
0042					RETURN				FUNT0063		
0043					40 FORMAT(1X,29HC(1)=0.0 IN SUBROUTINE FUNCT)				FUNT0064		
0044					70 FORMAT(1X,29HC(1)=0.0 IN SUBROUTINE FUNCT)				FUNT0065		
0045					END				FUNT0066		

56

12-15-42

TIME

DATE 30/23/70

REFURN

175 FURTRAN IV 36CN-FO-470 3-1

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7042  RV171=VH(71)-VH(131)+CL(171)+VH(171)+CH(171)-VH(121)+CH(1201)
7043  RV181=VH(81)-VH(111)+CL(181)+VH(181)+CH(181)-VH(121)+CH(1201)
7044  RV191=VH(91)-VH(111)+CL(191)+VH(191)+CH(191)-VH(121)+CH(1201)
7045  RV111=VH(11)-VH(111)+CL(111)+VH(111)+CH(111)-VH(121)+CH(1201)
7046  RV121=VH(12)-VH(111)+CL(121)+VH(121)+CH(121)-VH(121)+CH(1201)
7047  RV131=VH(13)-VH(111)+CL(131)+VH(131)+CH(131)-VH(121)+CH(1201)
7048  RV141=VH(14)-VH(111)+CL(141)+VH(141)+CH(141)-VH(121)+CH(1201)
7049  RV151=VH(15)-VH(111)+CL(151)+VH(151)+CH(151)-VH(121)+CH(1201)
7050  RV161=VH(16)-VH(111)+CL(161)+VH(161)+CH(161)-VH(121)+CH(1201)
7051  RV171=VH(17)-VH(111)+CL(171)+VH(171)+CH(171)-VH(121)+CH(1201)
7052  RV181=VH(18)-VH(111)+CL(181)+VH(181)+CH(181)-VH(121)+CH(1201)
7053  RV191=VH(19)-VH(111)+CL(191)+VH(191)+CH(191)-VH(121)+CH(1201)
7054  RV121=VH(12)-VH(111)+CL(121)+VH(121)+CH(121)-VH(121)+CH(1201)
7055  RV131=VH(13)-VH(111)+CL(131)+VH(131)+CH(131)-VH(121)+CH(1201)
7056  RV141=VH(14)-VH(111)+CL(141)+VH(141)+CH(141)-VH(121)+CH(1201)
7057  RV151=VH(15)-VH(111)+CL(151)+VH(151)+CH(151)-VH(121)+CH(1201)
7058  RV161=VH(16)-VH(111)+CL(161)+VH(161)+CH(161)-VH(121)+CH(1201)
7059  RV171=VH(17)-VH(111)+CL(171)+VH(171)+CH(171)-VH(121)+CH(1201)
7060  RV181=VH(18)-VH(111)+CL(181)+VH(181)+CH(181)-VH(121)+CH(1201)
7061  RV191=VH(19)-VH(111)+CL(191)+VH(191)+CH(191)-VH(121)+CH(1201)
7062  RV121=VH(12)-VH(111)+CL(121)+VH(121)+CH(121)-VH(121)+CH(1201)
7063  RV131=VH(13)-VH(111)+CL(131)+VH(131)+CH(131)-VH(121)+CH(1201)
7064  RV141=VH(14)-VH(111)+CL(141)+VH(141)+CH(141)-VH(121)+CH(1201)
7065  RV151=VH(15)-VH(111)+CL(151)+VH(151)+CH(151)-VH(121)+CH(1201)
7066  RV161=VH(16)-VH(111)+CL(161)+VH(161)+CH(161)-VH(121)+CH(1201)
7067  RV171=VH(17)-VH(111)+CL(171)+VH(171)+CH(171)-VH(121)+CH(1201)
7068  RV181=VH(18)-VH(111)+CL(181)+VH(181)+CH(181)-VH(121)+CH(1201)
7069  RV191=VH(19)-VH(111)+CL(191)+VH(191)+CH(191)-VH(121)+CH(1201)
      RETURN
      END
  
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STOR0001
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STOR0028
STOR0029

SUMROUTINE STORE
COMMON SLWC,PRD,STAR,ED,PLUS,T,DT,PLT,TMAX,DPLT,MS,MP,IRUN,
IA(33),CI(10),CL(10),CH(14),CX(20),DI(22),DF(33),ZFI(33),FI(40),
IF(33),MM(33),POF(33),PFS(33),RV(33),SD(33),SI(8),SH(20),VX(23),VGR,
IX(23),XDI(23),XI(23),XT(23),ZT(22),P(129),ZP(120),31,MPA,
IPDI(33),PTI(100),MPUM,CH(14),ISV(10),JDFE(10),DSD(10),MIS,ME,GDI(3,4)

C ALL ACCELERATIONS, VELOCITIES, DISPLACEMENTS,
C RELATIVE DEFORMATIONS, AND SPRING FORCES ARE STORED
C

MP=NP+1
PT(NP)=T
DO 10 I=1,20
J=I+20
K=I+40
P(I,MP)=X(I)
P(J,MP)=VX(I)
10 P(K,MP)=F(I+20)
DO 20 I=1,33
J=I+60
K=I+93
P(K,MP)=FS(I)
20 P(J,MP)=DT(I)
K=I+124
J=I+20
30 P(K,MP)=P(J)
RETURN
END

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0001 SUBROUTINE LIMIT
0002 DIMENSION PX(100),PVX(100),PRV(20),NF(33),PDS(10)
0003 COMMON BLNK,PRD,STAR,EQ,PLUS,T,DT,PLT,IMAX,DPLT,MS,MP,IRUM,
      LA(33),CL(10),CL(10),CM(14),CX(20),DI(22),DF(33),DZF(33),FI(40),
      IPS(33),MH(33),PF(33),PFI(33),SV(33),SOL(33),SI(20),VX(23),VGR,
      IX(23),XI(23),XI(23),XI(23),XI(23),XI(23),XI(23),XI(23),XI(23),XI(23),
      IFN(33),PT(100),NRUN,CW(14),ISN(10),DFF(10),JSD(10),NIS,NE,GO(3,4)
      LIMT0001
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      LIMT0055
      LIMT0056
      LIMT0057

C
C THIS SUBROUTINE USES THE CURRENT AND UPDATED VALUES
C OF VELOCITY TO LOOK AHEAD 50 TIME INCREMENTS
C TO CHECK THE RELATIVE DEFLECTIONS OF THE REQUESTED
C SPRINGS. IF THESE RESTRICTIONS ARE EXCEEDED ADJUSTMENTS
C IN THE LOAD DEFLECTION CURVES ARE MADE THIS SUBROUTINE
C RECYCLES THE PROGRAM UNTIL THE RESTRICTED
C DEFLECTIONS ARE OBTAINED
C
      MSW=0
      DO 110 I=1,NIS
      JJ=ISN(I)
      IF(DFF(I))=ABS(OF(JJ)+50.*DT*RV(JJ)) 10,10,105
      10 MSW=1
      IF(NF(JJ)-1) 20,20,30
      20 NF(JJ)=2
      PRV(JJ)=RV(JJ)
      MSW=-1
      GO TO 110
      30 IF(NF(JJ)-50) 40,40,140
      40 NF(JJ)=NF(JJ)+1
      FAC=(51.-NF(JJ))*(RV(JJ)-PRV(JJ))+RV(JJ)
      IF(RV(JJ)*FAC) 105,105,50
      50 IF(OF(JJ)-SD(JJ,2)) 60,60,70
      60 SD(JJ,1)=SD(JJ,1)+NF(JJ)*DSD(I)
      GO TO 110
      70 IF(OF(JJ)-SD(JJ,4)) 80,80,85
      80 SD(JJ,3)=SD(JJ,3)+NF(JJ)*DSD(I)
      GO TO 110
      85 SD(JJ,5)=SD(JJ,5)+NF(JJ)*DSD(I)
      GO TO 110
      105 NF(JJ)=1
      110 CONTINUE
      115 IF(MSW) 115,170,130
      DO 116 I=1,NIS
      JJ=ISN(I)
      IF(NF(JJ)-2) 116,116,170
      116 CONTINUE
      117 STOP
      DO 120 I=1,20
      PX(I)=XI(I)
      120 PVX(I)=VX(I)
      DO 125 I=1,NIS
      DO 125 PDS(I)=DSD(I)
      125 PDS(I)=DSD(I)
      130 RETURN
      140 DSD(I)=2.*PDS(I)
      DO 150 I=1,20
      XI(I)=PX(I)
      150 VX(I)=PVX(I)
      DO 160 I=1,33

```

	DO5 FORTRAN IV 3400-FO-479 3-1	LIMIT	DATE 08/23/70	TIME	10.16.52	PAGE 0002
0045	100 MF111=1				LINT0058	
0046	PRINT 800,T,ST				LINT0059	
0047	800 FORMAT(5X,30HALL TEST HAVE FAILED AT TIME -,F13.7,				LINT0060	
	125MI HAVE RETURNED TO TIME -,F13.7)				LINT0061	
0048	T=ST-DT				LINT0062	
0049	170 RETURN				LINT0063	
0050	END				LINT0064	

61

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0005      OPTZ 00059
0006      OPTZ 00060
0007      OPTZ 00061
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0017      OPTZ 00071
0018      OPTZ 00072
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0020      OPTZ 00074
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0040      OPTZ 00094
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0042      OPTZ 00096
0043      OPTZ 00097
0044      OPTZ 00098
0045      OPTZ 00099
0046      OPTZ 00100
0047      OPTZ 00101
0048      OPTZ 00102
0049      OPTZ 00103
0050      OPTZ 00104
0051      OPTZ 00105
0052      OPTZ 00106
0053      OPTZ 00107
0054      OPTZ 00108
0055      OPTZ 00109
0056      OPTZ 00110
0057      OPTZ 00111
0058      OPTZ 00112
0059      OPTZ 00113
0060      OPTZ 00114
0061      OPTZ 00115
0062      OPTZ 00116

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005 FORTRAN IV 360N-FO-379 3-1

OPTZ

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PAGE 0002

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C      DIGITAL OUTPUT
C
      PRINT 908
      NN=9
      K=401+4
      K1=K-3
      PRINT 907,(PNA4(J),J=K1,K)
      PRINT 905,(P(I,J),J=1,NP)
      IF(I=NN) 906,904,904
904 PRINT 908
      NN=NN+9
906 CONTINUE
C
      PLOTTING SEQUENCE
C
      DO 100 I=1,NPR
      N1=KP(I,1)
      N2=KP(I,2)
      N3=KP(I,3)
      IF(N2=N3) 60,2C,60
20 NC=1
      DO 30 J=1,NP
      Y1(J)=P(N1,J)
      N2=J
      N3=0
      GO TO 90
40 NC=2
      DO 50 J=1,NP
      Y1(J)=P(N1,J)
      Y2(J)=P(N2,J)
      N3=0
      GO TO 80
60 NC=3
      DO 70 J=1,NP
      Y1(J)=P(N1,J)
      Y2(J)=P(N2,J)
      Y3(J)=P(N3,J)
      N3=0
      GO TO 114
80 N1=4+NP1+4
      N2=4+NP2+4

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0040      N3=40N3+4
0041      N11=N1-3
0042      N22=N2-3
0043      N33=N3-3
0044      PRINT 800,(PNAM(JJ),JJ=N11,N1),(PNAM(JJ),JJ=N22,N2),
          1(PNAM(JJ),JJ=N33,N3)
0045      CALL PLOTTING(NP,PT,V1,V2,V3,PP,PM)
0046
100 CONTINUE
C
C      REQUIRED LOAD-DEFLECTION INFORMATION DETERMINED
C      BY SUBROUTINE LIMIT
C
110      IF(NIS) 140,140,110
          DO 120 I=1,NIS
              JJ=ISM(I),93
              KK=ISM(I),40
              V1(I)=P(JJ,II)
              V2(I)=P(KK,II)
              PRINT 91C,ISM(I),DEF(I)
              PRINT 909,(V1(J),V2(J),J=1,NP)
120 CONTINUE
140 CONTINUE
900 FORMAT(1H1,2X,34HDESCRIPTION OF PLOTTING PARAMETERS/21Y,
          121H( ) REPRESENTS THE ,44/21X,21H( ) REPRESENTS THE
          144/21X,21H( ) REPRESENTS THE ,444)
905 FORMAT(1X,1CE13.6)
907 FORMAT(5X,44)
908 FORMAT(11H)
910 FORMAT(1H1,5X,40HREQUIRED LOAD-DEFLECTION CHARACTERISTICS,/5X,
          118HIMPOSED ON SPRING ,15,2X,22HIN ORDER NOT TO EXCEED,/5X,
          117HA DEFORMATION OF ,1C,5,2X,6HNCMF5,//10X,25HFORCE(LB) ,DEFLCT
          110H(IN)/7)
909 FORMAT(5X,2E13.6)
          RETURN
          END
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18.17.25
OPT2C117
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TIME

DATE 08/23/70

OPT2

JJS FORTRAN IV 360N-F0-479 3-1

[illegible]

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0036      K=0.0
0037      K=0.0
0038      DO 10 I=1,3
0039      IF (P(I)-X(I)) 93,94,94
0040      94 K=PP(I)
0041      93 IF (P(I)-X(I)) 95,95,96
0042      95 K=PP(I)
0043      96 CONTINUE
0044      S(2)=PP(2)
0045      S(3)=PP(3)
0046      P(2)=PP(2)
0047      P(3)=PP(3)
0048      P(1)=S(1)
0049      P(2)=S(2)
0050      P(3)=S(3)
0051      N=100-(N-1)*10
0052      K=PP(I)
0053      SF=K-X(I)/RA
0054      SF=10.0-SF
0055      Z=K*(1-X(I)/RA)
0056      105 REF=ABS(Z)*1.5
0057      GO TO 107
0058      106 REF=ABS(Z)*1.5
0059      107 NR=REF
0060      GO TO (37C,37D,36C,1,4
0061      37C PRINT 375,SF
0062      GO TO 4
0063      37D PRINT 375,SF
0064      GO TO 4
0065      37E PRINT 375,SF
0066      4 PRINT 370
0067      DO 290 I=1,NP
0068      PLUT(M)=PP(I)
0069      L=V(I)/SF*REF
0070      PLUT(L)=STAP
0071      GO TO (114C,110,110),M
0072      11C K=V(2)/SF*REF
0073      PLUT(K)=EQ
0074      IF (4-2) 150,150,120
0075      120 J=V(1)/SF*REF
0076      PLUT(J)=PLUS
0077      GO TO 160
0078      140 PRINT 7,X(I),Y(1),Y(2),Y(3),(PLUT(J),J=1,10)
0079      PLUT(L)=RLNK
0080      GO TO 290
0081      150 PRINT 8,X(I),Y(1),Y(2),Y(3),(PLUT(J),J=1,10)
0082      PLUT(L)=RLNK
0083      PLUT(K)=RLNK
0084      GO TO 290
0085      160 PRINT 9,X(I),Y(1),Y(2),Y(3),(PLUT(J),J=1,90)
0086      C
0087      C
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0089      C
0090      C
0091      C
0092      C
0093      C
0094      C
0095      C
0096      C
0097      C
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0100      C
0101      C
0102      C
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MASTER INPUT CODING FORM: PROGRAM CRASH

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SD(25,1)	SD(25,2)	SD(25,3)	SD(25,4)	SD(25,5)	SD(25,6)	SD(25,7)	SD(25,8)	SD(25,9)	SD(25,10)
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SD(27,1)	SD(27,2)	SD(27,3)	SD(27,4)	SD(27,5)	SD(27,6)	SD(27,7)	SD(27,8)	SD(27,9)	SD(27,10)
SD(28,1)	SD(28,2)	SD(28,3)	SD(28,4)	SD(28,5)	SD(28,6)	SD(28,7)	SD(28,8)	SD(28,9)	SD(28,10)
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UNCLASSIFIED

Security Classification

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		2b. GROUP
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4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report		
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13. ABSTRACT A mathematical model which may be used to determine the dynamic response of a helicopter airframe subjected to vertical crash loading has been developed. This report is, in effect, a manual which will facilitate the use of the computer program "CRASH". The program was written to solve the equations and to handle the nonlinearities and constraints which result from use of the mathematical model. The program was used to evaluate the response of the UH-1D/H helicopter to vertical impact loadings. Recommendations have been made which, when implemented, will reduce the forces transmitted to the floor and trans- mission of the aircraft.		

DD FORM 1473

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REPLACES DD FORM 1473, 1 JAN 66, WHICH IS
OBSOLETE FOR ARMY USE.

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Security Classification

Security Classification

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		ROLE	WT	ROLE	WT	ROLE	WT
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Security Classification