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FLEXAN (Version 2.0) User's Guide

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Preface

This document describes the FLEXAN computer program, version 2.0. FLEXAN is an acronym for "Flexible Animation". FLEXAN animates three dimensional wireframe structural dynamics on the Evans & Sutherland PS300 graphics workstation with a VAX/VMS host computer. FLEXAN runs under VMS 4.5 or later and PS300 firmware version A3.V01 or later. The FLEXAN program does not model structures or calculate the dynamics of structures; it only animates data from other computer programs.

FLEXAN is based on the MODAN program developed by the Aerospace Corporation. MODAN animates unconstrained structural vibrational modes. FLEXAN animates unconstrained vibrational modes, mode time histories (multiple modes), delta time histories (modal and/or nonmodal deformations), color time histories (elements of the structure change colors through time), and rotational time histories (parts of the structure rotate through time). Concurrent color, mode, delta, and rotation time history animations are supported by FLEXAN.

FLEXAN was developed for the Spacecraft Analysis Branch, NASA Langley Research Center to aid in the study of the structural dynamics of spacecraft. A typical application of FLEXAN is the animation of a spacecraft undergoing structural stresses caused by thermal and vibrational effects. The animation displays the spacecraft shape distortions while the changing element colors represent temperature variations.

FLEXAN was written in VAX FORTRAN and is specific to the Evans and Sutherland PS300 family of graphics workstations. VAX FORTRAN and PS300 dependencies are reasonably well separated, but the program would require extensive changes if ported to another environment. FLEXAN was written specifically for the PS390 but there are no PS390 dependencies in the code.

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1.0 Introduction

FLEXAN is a computer program that animates structural dynamics on an Evans & Sutherland PS300 graphics workstation with a VAX/VMS host. FLEXAN can display single natural modes of vibration, a mode time-history (multiple modes), or any general deformations of a flexible structure. Elements of a structure can be animated through color changes to reflect thermal information, stresses, etc. Selected parts of a structure can also be rotated through time. FLEXAN does not generate structural geometries or calculate any influences on structures; it only displays data generated from other computer programs.

A structure is represented on the PS300 as a three-dimensional wireframe object. Solid objects or raster representations are not supported. The VAX/VMS computer calculates the animation frames and sends them to the PS300. The PS300 displays these frames in real time with rotation, scaling, and translation provided by the dials of the PS300. The PS300 is not a true real time machine, but it does provide a very close approximation. The animation can be displayed forward or backward at one to fifty frames per second or stepped one frame at a time. The animation speed is controlled by a dial and two function keys. Other function keys toggle on and off various parts of the display or enable different views of the structure.

FLEXAN is capable of animating two independent sets of data in separate windows on the PS300. An optional third window displays a superposition of the two datasets. This capability is useful for displaying the differences between design iterations, or analytical versus experimental datasets.

2.0 Mathematical Model

This section explains the mathematical model used by FLEXAN. Animations are described as a sequence of matrix operations. A basic understanding of matrix algebra is assumed.

2.1 Geometry

Structural geometry information is input through a *geometry file* as a matrix of nodes **A** and a matrix of elements **E.**

$$\mathbf{A} = \begin{bmatrix} a_{x1} & a_{y1} & a_{z1} \\ a_{x2} & a_{y2} & a_{z2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ a_{xp} & a_{yp} & a_{zp} \end{bmatrix} \qquad \mathbf{E} = \begin{bmatrix} e_{m1} & e_{d1} \\ e_{m2} & e_{d2} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ e_{mq} & e_{dq} \end{bmatrix}$$

Where: p = the number of nodes
q = the number of elements.

Each row of **A** represents the undeformed location of a node point in three-dimensional space. Each row of **E** contains two integer row indices into **A** specifying the endpoints of an element (move and draw).

2.2 Animation

An animation consists of a sequence of frames; each frame f_i is displayed in rapid succession from frame f_1 to the last frame f_n.

$$f_1,\ f_2,\ f_3,\ \ldots f_n = \{f_i\}_{i=1,n}$$

Each frame contains the color values for each element and the absolute coordinates of each node point. The deformed node point data and color values are input through data files. The program processes the matrices in the frame generation function $\mathcal{F}$.

$$f_i = \mathcal{F}(\mathbf{H}_i, \mathbf{E}, \mathbf{C}_i)$$

Where **E** is the matrix of elements, and **H** and **C** are described below. For an animation involving the geometry elements, color values are supplied in a *color history file.* This file contains a sequence of **C** matrices from frame f_1 to the last frame f_n.

$$\mathbf{C} = \begin{bmatrix} c_1 \\ c_2 \\ \cdot \\ \cdot \\ \cdot \\ c_q \end{bmatrix} \qquad \{\mathbf{C}_i\}_{i=1,n}$$

Matrix **C** contains the color information (real number values) corresponding to each element (row) in matrix **E**. FLEXAN maps the values into a range of continuous colors from blue through green, yellow, and red. A labeled color bar is also generated and displayed.

If no color history file is supplied, then the elements of the first dataset default to red for a single dataset animation or for dataset one of a two dataset animation. The elements of dataset two of a two dataset animation will be green.

For an animation involving deformed node points, four options are available: *mode animation*, *mode history animation*, *delta history animation*, and *rotation history animation*. The details of each option are explained later, but the result is a sequence of **H** matrices which contain the absolute node points for each frame f_1 to the last frame f_n.

$$\mathbf{H} = \begin{bmatrix} h_{x1} & h_{y1} & h_{z1} \\ h_{x2} & h_{y2} & h_{z2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ h_{xp} & h_{yp} & h_{zp} \end{bmatrix} \qquad \{\mathbf{H}_i\}_{i=1,n}$$

Concurrent combinations of the animation options are possible. All concurrent combinations of mode history, delta history, color history, and rotation history animations are supported by FLEXAN. Mode animations cannot be animated concurrently with any other animation option.

2.3 Delta History Animation

The simplest and most general node point deformation animation is a delta history animation. A *delta history file* is supplied which contains a sequence of **D** matrices for frame f_1 to frame f_n. Each $\mathbf{D}_i$ contains the relative translations or "Deltas" for each node point in the geometry.

$$\mathbf{D} = \begin{bmatrix} d_{x1} & d_{y1} & d_{z1} \\ d_{x2} & d_{y2} & d_{z2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ d_{xp} & d_{yp} & d_{zp} \end{bmatrix} \qquad \{\mathbf{D}_i\}_{i=1,n}$$

$$\{\mathbf{H}_i = \mathbf{A} + \mathbf{D}_i \alpha\}_{i=1,n}$$

α = Amplitude scale factor (input on command line)

2.4 Mode Animation

A single, unconstrained vibrational mode can be animated using a sine wave function to drive the animation. A *mode shape file* is supplied which contains a sequence of matrices, where each matrix **M** contains the relative translation of each node point. The sequence of matrices represents mode 1 to the number of modes w. A frequency ω_k in hertz is supplied in the file for each mode. The frequency is displayed and the number of frames per second *s* is calculated and displayed.

$$\mathbf{M} = \begin{bmatrix} m_{x1} & m_{y1} & m_{z1} \\ m_{x2} & m_{y2} & m_{z2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ m_{xp} & m_{yp} & m_{zp} \end{bmatrix} \qquad \{\mathbf{M}_k\}_{k=1,w}$$

$$\left\{\mathbf{H}_i = \mathbf{A} + \mathbf{M}_k \sin\left(\frac{(i-1)2p}{z}\right)\alpha\right\}_{i=1,z} \qquad s = (z)(\omega_k)$$

α = Amplitude scale factor (input on command line)
k = Selected mode to animate (input on command line)
z = Number of frames per cycle (input on command line)

2.5 Mode History Animation

An animation displaying the contribution of all modes in the mode shape file is generated by supplying a *mode history file* which contains a single matrix **X.** This matrix contains the relative contribution of each mode across the rows from mode 1 to mode w. The contribution (damping) factors typically range from 0.0 to 1.0. Each column represents a single frame in the animation from f_1 to f_n.

$$\mathbf{X} = \begin{bmatrix} x_{11} & x_{21} & \cdots & x_{n1} \\ x_{12} & x_{22} & \cdots & x_{n2} \\ \vdots & \vdots & & \vdots \\ x_{1w} & x_{2w} & \cdots & x_{nw} \end{bmatrix}$$

$$\left\{ \mathbf{H}_i = \mathbf{A} + \left(\sum_{k=1}^{w} \mathbf{M}_k \, x_{ik} \right) \alpha \right\}_{i=1,n}$$

α = Amplitude scale factor (input on command line)

2.6 Rotation History Animation

Rotation history animations involve the rotation of selected parts of a structure through time. The rotating parts of a structure are identified in the structural geometry input file. A rotation history file supplies the absolute rotation of each part relative to the undeformed geometry for each frame in the animation. The rotation matrix operations are well known and will not be discussed here[1].

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1 Refer to reference 1 of this document for a complete discussion of matrix rotation transformations.

3.0 FLEXAN Execution

All program input is through data files and command line parameters and qualifiers. Prompts are not generated during the execution of FLEXAN. The parameters and qualifiers define the input file names and animation options. FLEXAN reads the input files then generates and sends the animation frames to the PS300. FLEXAN execution ends on the VAX/VMS host computer when all frames have been sent to the PS300. The animation is then completely controlled by the PS300 using the labeled dials and function keys. The FLEXAN command follows the VAX/VMS command conventions concerning parameters and qualifiers. Consult the VMS documentation for more information on the VMS commands and the Evans & Sutherland PS300 documentation on the operation of the PS300.

The frame calculation and download time can last several minutes. As frames are downloaded, a progress "Thermometer" is displayed on the PS300 screen. When all of the frames are downloaded the thermometer disappears and the animation begins.

Press the <shift> <line_local> keys of the PS300 to get into local mode. In local mode the animation can be controlled using the dials and function keys. Press <line_local> to get into the VAX/VMS terminal emulation mode.

3.1 FLEXAN Command

FLEXAN can be run from any terminal type but the graphics must be sent to a PS300 workstation. The /DEVICE qualifier described below may be used to choose a particular PS300 device. The default PS300 device is installation dependent. FLEXAN is executed by issuing the FLEXAN command :

$ FLEXAN ***geo1 geo2***

The two parameters *geo1* and *geo2* are the file-specifications for the geometry files. *Geo1* is required and *geo2* is optionally used for a two dataset animation. The default file extension is ".GEO".

3.2 Parameter Qualifiers

Qualifiers on each parameter specify the animation options for the respective datasets. If no parameter qualifiers are present, then the undeformed geometry is sent to the PS300 with no animation frames.

/MS = ***Mode-shape-file-spec***

Specifies a mode shape file to be used for a mode animation or a mode history animation. The default file extension is ".MOD". The presence of this qualifier requires the presence of the **/AMP** and either **/MODE** or **/MH** qualifiers. If no file-spec is supplied with this qualifier, then the geometry file name with ".MOD" extension is implied.

/MH = ***Mode-history-file-spec***

Specifies a mode history animation. The default file extension is ".MHY". If no file-spec is supplied with this qualifier, then the geometry file name with ".MHY" extension is implied.

/DH = ***Delta-history-file-spec***

Specifies a delta history animation. The default file extension is ".DHY". The presence of this qualifier requires the presence of the **/AMP** qualifier. If no file-spec is supplied with this qualifier, then the geometry file name with ".DHY" extension is implied.

/CH = ***Color-history-file-spec***

Specifies a color history animation. The default file extension is ".CHY". If no file-spec is supplied with this qualifier, then the geometry file name with ".CHY" extension is implied.

/RH = ***Rotation-history-file-spec***

Specifies a rotation history animation. The default file extension is ".RHY". If no file-spec is supplied with this qualifier, then the geometry file name with ".RHY" extension is implied.

/MODE = ***Mode-number***

Specifies a mode animation. *Mode-number* is the desired mode number (integer) from the mode shape file.

/AMP = ***Amplitude-scale-factor***

Specifies an amplitude scale factor (positive real number) for mode, mode history, and delta history animations.

/CMIN = ***Minimum-color***

Specifies a minimum color value (real number) for the color mapping of a color history animation. The presence of this qualifier requires the presence of the **/CH** qualifier. The minimum color value in the color history file is used if this qualifier is not present.

/CMAX = ***Maximum-color***

Specifies a maximum color value (real number) for the color mapping of a color history animation. The presence of this qualifier requires the presence of **/CH**. The maximum color value in the color history file is used if this qualifier is not present.

3.3 Command Qualifiers

Command qualifiers affect both datasets if two datasets are animated and they can appear anywhere on the command line.

/Frames = ***Number-of-frames***

Specifies the number of frames to animate for time history animations. If this qualifier is not present, then the number of frames is chosen to be the lowest number of frames specified in the time history file(s). For mode animations, this qualifier is required and refers to the *number of frames per cycle*. The maximum number of frames is 9999.

/Super

If two datasets are animated then this qualifier creates a third window which is a superposition of the two animations in the same window. If this qualifier is absent, then no superposition window is available (saves memory space).

/Device = ***Device-number***

Specifies a PS300 device to be used for the animation. *Device-number* is an integer. The range of devices and the default for this qualifier is installation dependent.

3.4 Dials and Function Keys

There are eight dials and twelve function keys available on the PS300. This section lists the functions of the dials and function keys used by FLEXAN.

dial 1	Translates the structure(s) horizontally.
dial 2	Translates the structure(s) vertically.
dial 3	Translates the structure(s) in the z direction (depth).
dial 4	Scales the structure(s) in all three directions.
dial 5	Rotates structure(s) about the x axis.
dial 6	Rotates structure(s) about the y axis.
dial 7	Rotates structure(s) about the z axis.
dial 8	Controls the animation rate. (1...50 FPS)

fkey 1	Toggles start and stop of an animation.
fkey 2	Steps through frames one at a time.
fkey 3	Toggles the undeformed geometry (white).
fkey 4	Toggles the animation in the forward/backward directions.
fkey 5	Toggles the animation frames.
fkey 6	Toggles the information (amp, FPS, title, etc.).
fkey 7	Toggles the color bar (for color animations only).
fkey 8	Toggles the node numbers.
fkey 9	Toggles the element numbers.
fkey 10	Toggles the frame number.
fkey 11	Toggles the orientation axis.
fkey 12	Toggles through windows (for two dataset animations only).

4.0 File Formats

This section describes the text formats for the FLEXAN input files. The file formats were designed to integrate well with other programs at NASA Langley Research Center, but every effort was made to make them as easy to create and read as possible. All real or integer values are read by "list directed" read statements.

Each file type is described; then FORTRAN code fragments to read the file are presented. The code fragments represent the method used by FLEXAN to read each file (error checking code has been stripped out). Section 5.7 of this document contains a complete set of example files.

The first two lines of each file type have the same format. The first line is an 80-character title. The title is ignored in all file types except the geometry file type. The title of the geometry file is displayed at the top of the animation window(s). The first three columns of the second line must contain the default file extension for the respective file types. For example, geometry files must have "GEO" in the first three columns of line two.

4.1 Geometry Files

Example files are presented on pages 5-9 and 5-14. The first line is an 80-character title that is displayed across the top of the window for each dataset. The second line must contain the file type "GEO" in the first three columns. The third line must contain the integer number of nodes followed by the integer number of elements. The fourth line contains the number of rotating parts, the number of rotating part types, the starting element index number and the ending element index number for the main body of the structure.

Rotating part types are consecutive integers starting at one. Each rotating part in the structure has one or more rotating part types associated with it. Rotating part types are specified later in this file by supplying a point of rotation and an axis of rotation. Rotation history files (discussed in section 4.6) supply an angle or rotation for each rotation part type in each animation frame.

The next lines contain the node points (one node point per line). The first number on each line must be an integer node index starting at 1 increasing to the number of nodes (specified on line three). The next three numbers on each line are the X, Y, and Z coordinates (real numbers) of the node point. The node indexes must be consecutive; otherwise an error is generated. The node coordinates may be in any consistent cartesian system. FLEXAN will scale and translate the geometry to fit into the display window.

The next lines contain the element or connectivity information (one element per line). The first number on each line must be an integer element index starting at 1 increasing to the number of elements (specified on line three). The next two numbers on each line are the integer indexes of the node points which form the endpoints of an element. The element indexes must be consecutive; otherwise an error is generated.

The next lines contain the rotating part information. The first number must be an integer rotating part index starting at 1 increasing to the number of rotating parts (specified on line four). The number of rotating part types for the part is next, followed by the starting and then the ending element index numbers for the part. The next lines for each part contain the rotation part type number followed by "1", "2", or "3" for the axis of rotation "X", "Y", or "Z" respectively. The "XYZ" point of rotation ends the line.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80   TITLE              File title
      CHARACTER*3    FTYPE              File type
      INTEGER        NNODES             Number of nodes
      INTEGER        NELEM              Number of elements
      INTEGER        NFRAMS             Number of frames
      REAL           NODES(3,5000)      Nodes array
      INTEGER        ELEMS(2,5000)      Elements array
      INTEGER        NROT               Number of rotating parts
      INTEGER        NROTYPE            Number of rotating part types
      INTEGER        BODYS              Element index for start of main body
      INTEGER        BODYE              Element index for end of main body
      INTEGER        NRTYP(100)         Number of rotating part types array
      INTEGER        RINDS(100)         Element indexes for start of parts
      INTEGER        RINDE(100)         Elements indexes for end of parts
      INTEGER        RTYPE(100,100)     Rotation part type numbers
      INTEGER        RAXIS(100,100)     Rotation axis numbers
      REAL           RP(3,100,100)      Rotation points
       .
       .
       .
      READ(2,200) TITLE
      READ(2,201) FTYPE
200   FORMAT(A80)
201   FORMAT(A3)
      READ(2,*) NNODES, NELEM
      READ(2,*) NROT, NROTYPE, BODYS, BODYE
      DO 100 I = 1, NNODES
         READ(2,*) N, NODES(1,I), NODES(2,I), NODES(3,I)
100   CONTINUE
      DO 110 I = 1, NELEM
         READ(2,*) N, ELEMS(1,I), ELEMS(2,I)
110   CONTINUE
      DO 120 I=1, NROT
         READ(2,*) N, NRTYP(I), RINDS(I), RINDE(I)
         DO 130 J=1, RNTYP(I)
            READ(2,*) RTYPE(I,J), RAXIS(I,J),
     1                RP(1,I,J), RP(2,I,J), RP(3,I,J)
130      CONTINUE
120   CONTINUE
       .
       .
       .
```

4.2 Mode Shape Files

An example file is presented on page 5-10. The first line is an 80-character title which is ignored by the program. The second line must contain the file type "MOD" in the first three columns. The third line must contain the integer number of modes followed by the integer number of nodes.

The next lines contain the sequence of modes from mode 1 to the number of modes (specified on line three). The first line of each mode must contain the integer mode number followed by the real number frequency of the mode in Hertz. On each of the following lines of the mode there must be an integer node index starting at 1 increasing to the number of nodes (specified on line three). The next three numbers on each line of the mode are the X, Y, and Z translations (real numbers) of the node point. The node indexes must be consecutive; otherwise an error is generated. The node translations must be in the same coordinate system as used by the geometry file. An error is generated if the number of nodes in this file is not equal to the number of nodes in the geometry file.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80   TITLE                 File title
      CHARACTER*3    FTYPE                 File type
      INTEGER        NNODES                Number of nodes
      INTEGER        NMODES                Number of modes
      REAL           FREQS(1000)           Frequency array
      REAL           MDEL(3,5000)          Mode shape array
       .
       .
       .
      READ(2,200) TITLE
      READ(2,201) FTYPE
 200  FORMAT(A80)
 201  FORMAT(A3)
      READ(2,*) NMODES,NNODES
      K = 0
      DO 100 I = 1, NMODES
         READ(2,*) N, FREQS(I)
         DO 110 J = 1, NNODES
            K = K + 1
            READ(2,*) N, MDEL(1,K), MDEL(2,K), MDEL(3,K)
 110     CONTINUE
 100  CONTINUE
       .
       .
       .
```

4.3 Delta History Files

An example file is presented on page 5-13. The first line is an 80-character title which is ignored by the program. The second line must contain the file type "DHY" in the first three columns. The third line must contain the integer number of frames in the history followed by the integer number of nodes in the corresponding geometry file. The fourth line must contain the real number of frames per second (FPS) the history represents. The FPS is displayed as a label on the screen and serves only as a guide for determining the display real time ratio. This value should be 0.0 if the FPS is unknown or undefined.

A FORTRAN "implied do loop" is used to read the rest of the file so that the lines or records can be any length desired but the real number delta values must appear in the correct order. The following pseudo-code defines the order of the delta values:

```
do i = 1 to the number of frames
    do j = 1 to the number of nodes
        do k = 'x' to 'y'
            write the delta value for frame i , node j , coordinate k
        end do
    end do
end do
```

The delta values are the absolute translation of each node point relative to the undeformed geometry. The number of nodes in this file must be equal to the number of nodes in the geometry file and the node translations must be in the same coordinate system used by the geometry file.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80  TITLE              File title
      CHARACTER*3   FTYPE              File type
      INTEGER       NNODES             Number of nodes
      INTEGER       NFRAMS             Number of frames
      REAL          FPS                Number of frames per second
      REAL          DELTAS(3,500000)   Delta array
        .
        .
        .
      READ(2,200) TITLE
      READ(2,201) FTYPE
200   FORMAT(A80)
201   FORMAT(A3)
      READ(2,*) NFRAMS,NNODES
      READ(2,*) FPS
      INUM = NFRAMS * NNODES
      READ(2,*) ((DELTAS(K,J), K=1,3), J = 1, INUM)
        .
        .
        .
```

4.4 Color History Files

Example files are presented on pages 5-11 and 5-16. The first line is an 80-character title which is ignored by the program. The second line must contain the file type "CHY" in the first three columns. The third line must contain the integer number of frames in the history followed by the integer number of elements in the corresponding geometry file. The fourth line must contain the real number of frames per second (FPS) the history represents. The FPS is displayed as a label on the screen and serves only as a guide for determining the display real time ratio. This value should be 0.0 if the FPS is unknown or undefined. The fifth line must contain the left justified characters of the color value units (maximum of ten characters) starting in column one. The units are not used in any calculations, but is displayed at the bottom of the labeled color bar.

A FORTRAN "implied do loop" is used to read the rest of the file so that the lines or records can be any length desired but the real number color values must appear in the correct order. The following pseudo-code defines the required order of the color values:

```
do i = 1 to the number of frames
    do j = 1 to the number of elements
        write the color value for frame i , element j
    end do
end do
```

The color values may span any range of real numbers desired. FLEXAN determines the maximum and minimum color values and maps the range to the color system of the PS300. The number of geometry elements in this file must be equal to the number of geometry elements in the geometry file.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80   TITLE             File title
      CHARACTER*3    FTYPE             File type
      CHARACTER*10   UNITS             Color units
      INTEGER        NELEM             Number of elements
      INTEGER        NFRAMS            Number of frames
      REAL           FPS               Number of frames per second
      REAL           COLORS(500000)    Colors array
       .
       .
      READ(2,200) TITLE
      READ(2,201) FTYPE
  200 FORMAT(A80)
  201 FORMAT(A3)
      READ(2,*) NFRAMS,NELEM
      READ(2,*) FPS
      READ(2,202) UNITS
  202 FORMAT(A10)
      INUM = NFRAMS * NELEM
      READ(2,*) (COLORS(J), J = 1, INUM)
```

4.5 Mode History Files

An example file is presented on page 5-12. The first line is an 80-character title which is ignored by the program. The second line must contain the file type "MHY" in the first three columns. The third line must contain the integer number of frames in the history followed by the integer number of modes in the corresponding mode shape file. The fourth line must contain the real number of frames per second (FPS) the history represents. The FPS is displayed as a label on the screen and serves only as a guide for determining the display real time ratio. This value should be 0.0 if the FPS is unknown or undefined.

A FORTRAN "implied do loop" is used to read the rest of the file so that the lines or records can be any length desired but the real number mode contribution values must appear in the correct order. The following pseudo-code defines the order of the values:

```
do i = 1 to the number of frames
    do j = 1 to the number of modes
        write the mode contribution value for frame i , mode j
    end do
end do
```

The values are the contribution of each mode for each frame. Typically the values range from 0.0 to 1.0. The number of modes in this file must be equal to the number of modes in the mode shape file.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80  TITLE           File title
      CHARACTER*3   FTYPE           File type
      INTEGER       NMODES          Number of modes
      INTEGER       NFRAMS          Number of frames
      REAL          FPS             Number of frames per second
      REAL          DAMPS(500000)   Mode history damping array
       .
       .
       .
      READ(2,200) TITLE
      READ(2,201) FTYPE
 200  FORMAT(A80)
 201  FORMAT(A3)
      READ(2,*) NFRAMS,NMODES
      READ(2,*) FPS
      INUM = NFRAMS * NMODES
      READ(2,*) (DAMPS(J), J = 1, INUM)
       .
       .
       .
```

4.6 Rotation History Files

An example file is presented on page 5-15. The first line is an 80-character title which is ignored by the program. The second line must contain the file type "RHY" in the first three columns. The third line must contain the integer number of frames in the history followed by the integer number of rotating part types in the corresponding geometry file. The fourth line must contain the real number of frames per second (FPS) the history represents. The FPS is displayed as a label on the screen and serves only as a guide for determining the display real time ratio. This value should be 0.0 if the FPS is unknown or undefined.

A FORTRAN "implied do loop" is used to read the rest of the file so that the lines or records can be any length desired but the real number rotation values must appear in the correct order. The following pseudo-code defines the order of the values:

```
do i = 1 to the number of frames
    do j = 1 to the number of rotating part types
        write the angle for frame i , rotating part type j
    end do
end do
```

The values are the absolute rotation angle in degrees of each rotating part type relative to the undeformed geometry.

The FORTRAN code fragment to read this file is:

```
      CHARACTER*80  TITLE            File title
      CHARACTER*3   FTYPE            File type
      INTEGER       NRTYPS           Number of rotating part types
      INTEGER       NFRAMS           Number of frames
      REAL          FPS              Number of frames per second
      REAL          ROTS(500000)     Rotations array
       .
       .
       .
      READ(2,200) TITLE
      READ(2,201) FTYPE
 200  FORMAT(A80)
 201  FORMAT(A3)
      READ(2,*) NFRAMS,NRTYPS
      READ(2,*) FPS
      INUM = NFRAMS * NRTYPS
      READ(2,*) (ROTS(J), J = 1, INUM)
       .
       .
       .
```

5.0 Examples

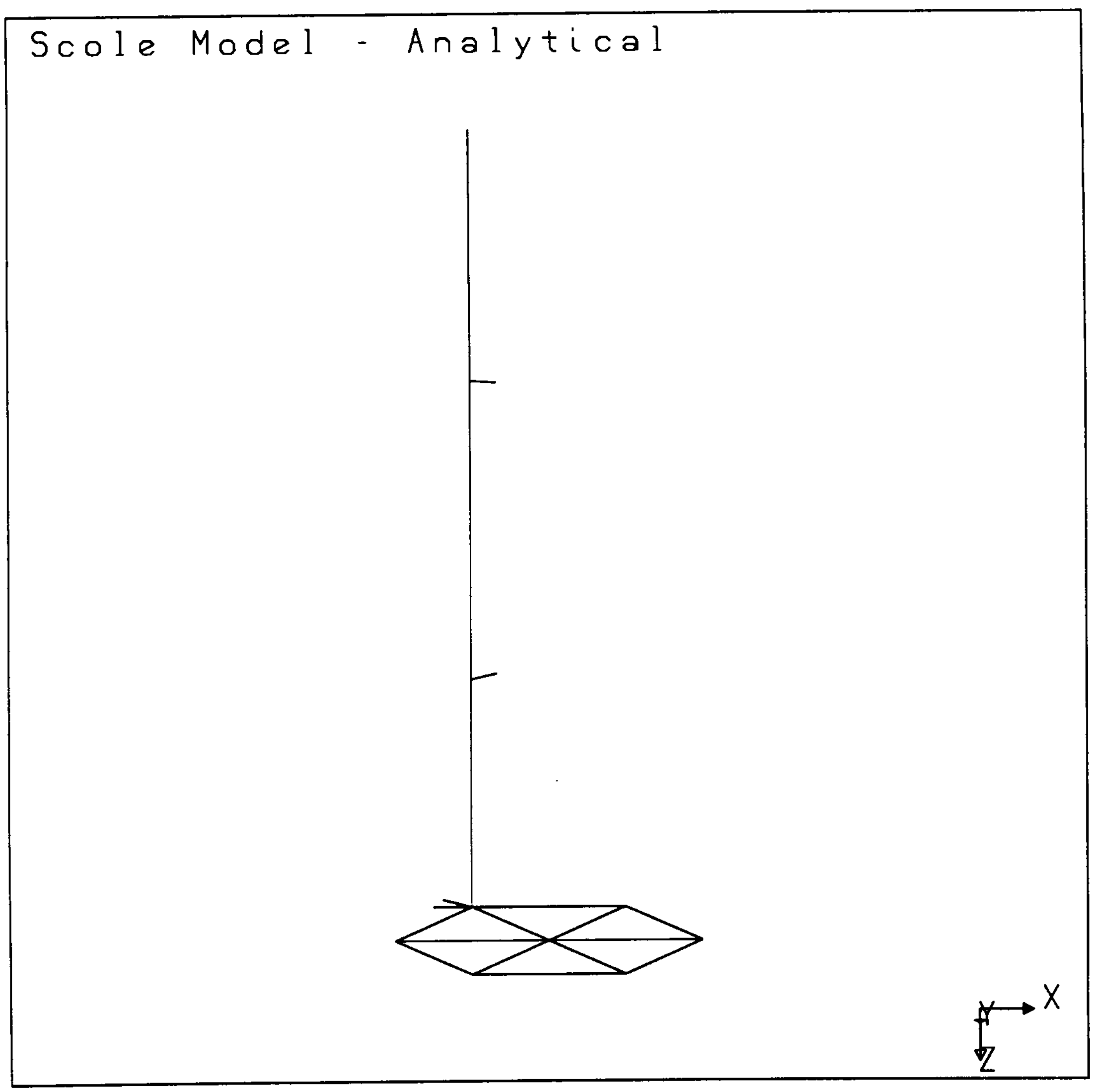
This section presents six example FLEXAN runs. The examples use the sample data files provided on the FLEXAN distribution tape. Fragments of these files are presented in section 5.7. Five of the examples use a simplified antenna structure under study at NASA Langley Research Center. The last example is a simplified "generic" satellite model with rotating solar arrays. Unfortunately the PS300 screen pictures in this document are black and white. The undeformed geometries are displayed in black (white on the PS300). The animation frame geometries are also shown here in black (red or green on the PS300). Color history animations are shown here with all black elements and a solid black color bar. The PS300 uses "depth cueing"; objects grow dimmer as the object's distance increases from the eye. Depth cueing is not preserved in these pictures.

Each of the following example runs contains a description followed by the corresponding command line and then a PS300 screen picture. Each animation window shown here displays the frame number of the "still" picture from the animation. The "Frames/sec" section shows the FPS of the dataset and the current display FPS selected by dial number 8 on the PS300.

5.1 Example 1 - Geometry

The screen picture below shows FLEXAN's ability to display a simple undeformed geometry with no animation. The geometry file is "TEST.GEO" in the current default directory.

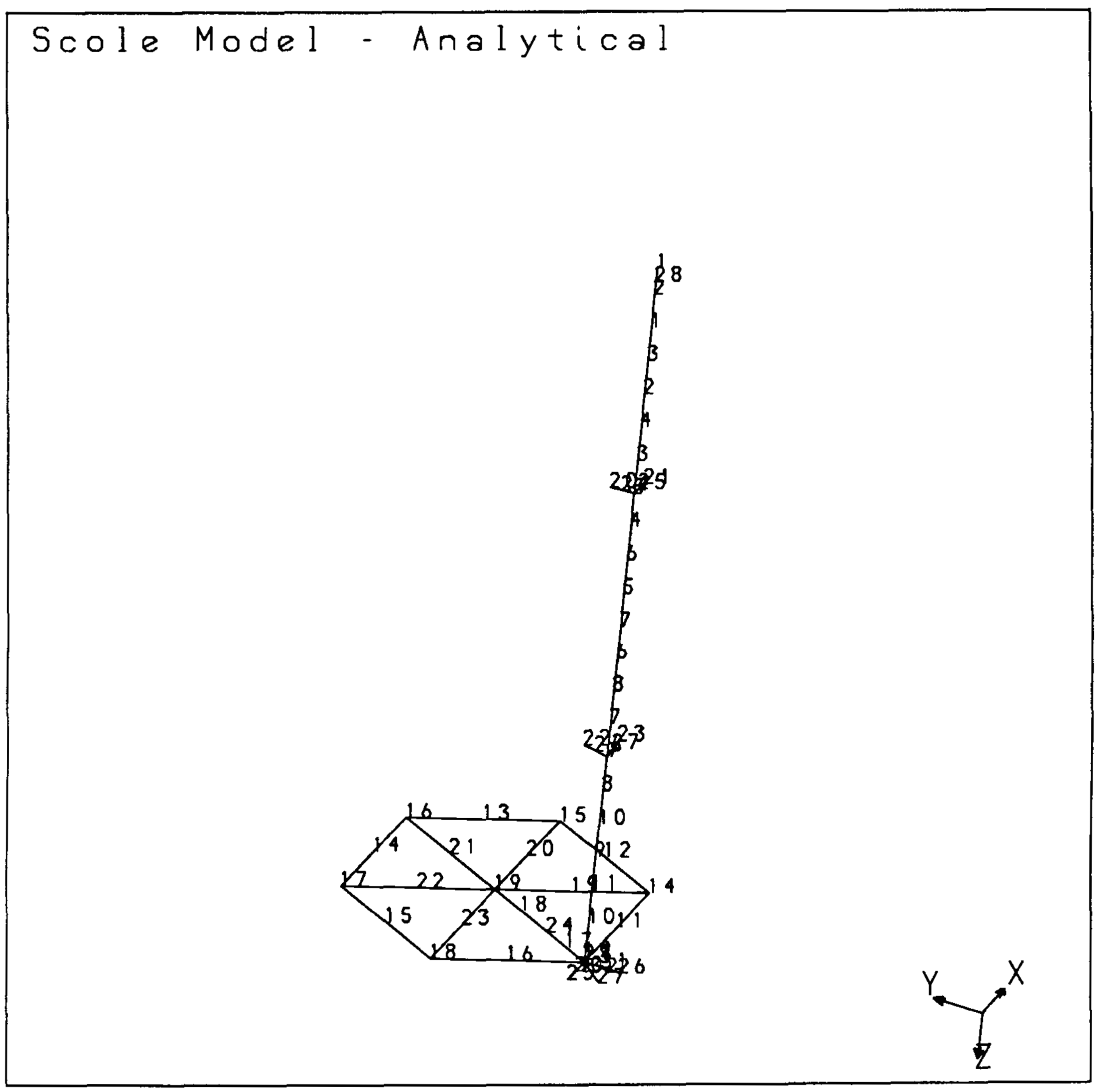
$ FLEXAN TEST



5.2 Example 2 - Node & Element Numbers

The screen picture below displays FLEXAN's ability to display node numbers and element numbers. The FLEXAN command is the same as example 1. The function keys for node and element numbers were toggled to make this picture.

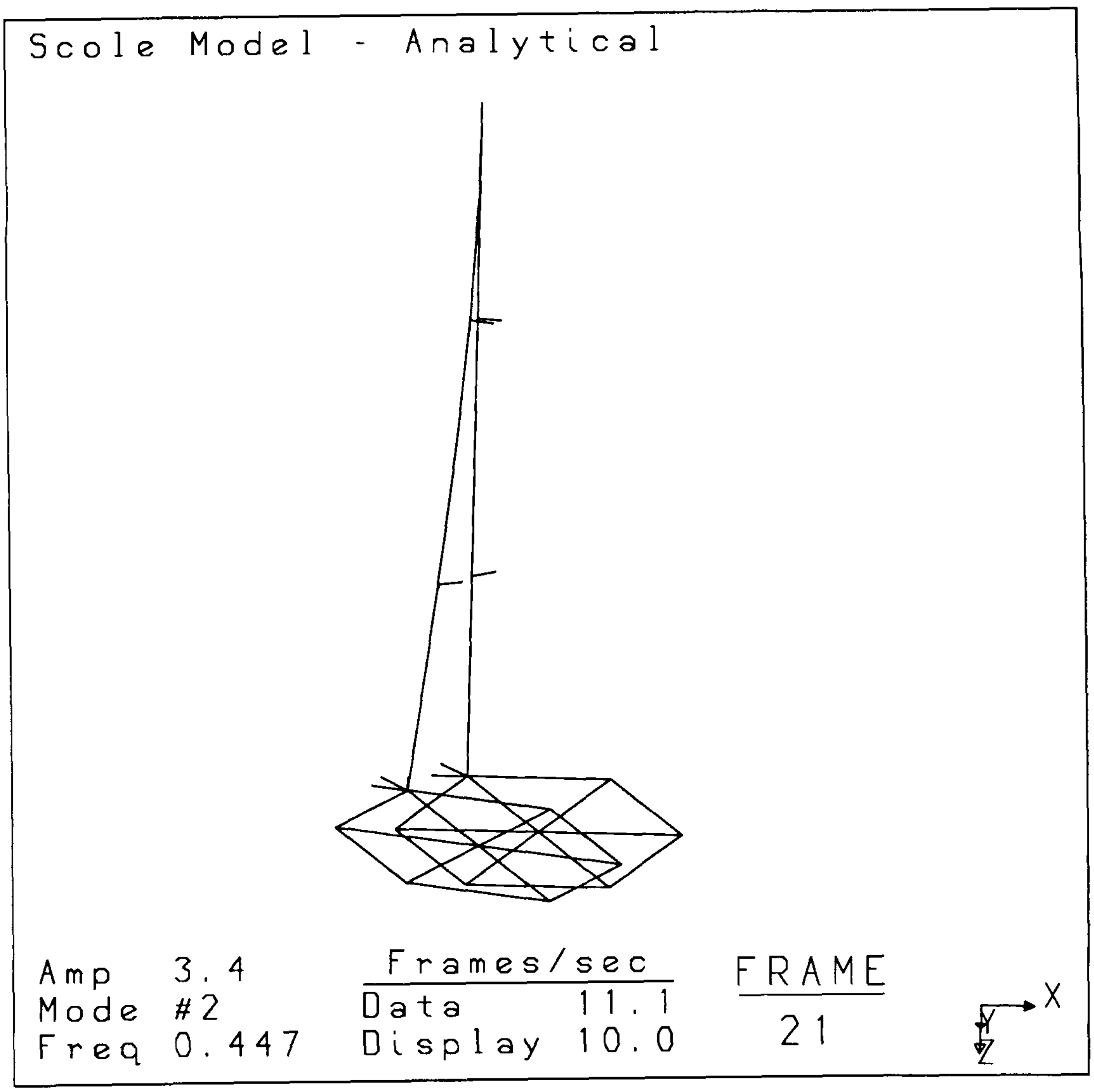
$ FLEXAN TEST



5.3 Example 3 - Mode Animation

The screen picture below displays frame 21 of a mode animation of mode #2 with an amplitude scale factor of 3.4. The undeformed geometry is also shown. The number of frames per cycle is 25.

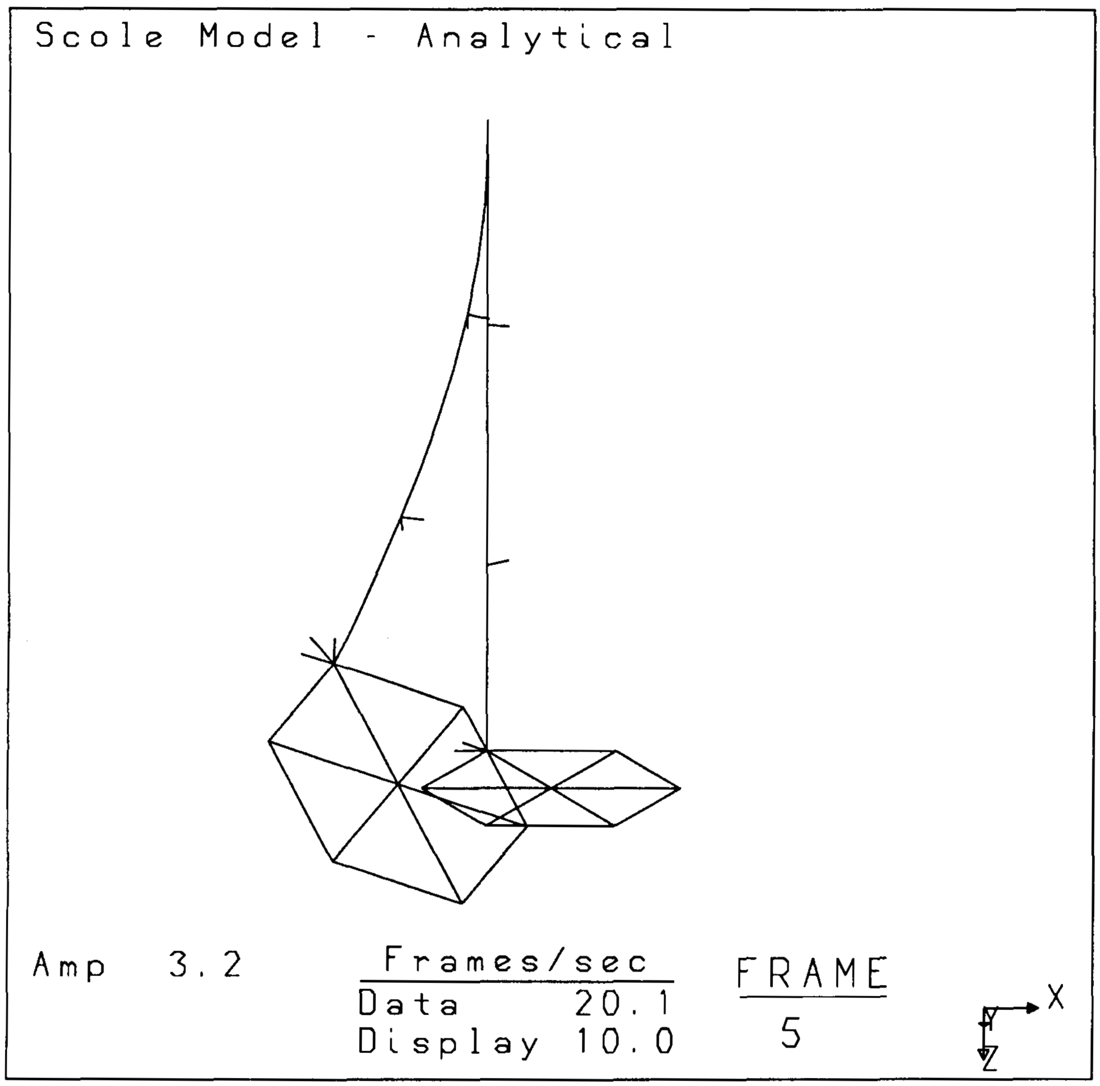
```
$ FLEXAN/FRAMES=25 -
        TEST/MS=TEST.MOD/MODE=2/AMP=3.4
```



5.4 Example 4 - Mode History Animation

The screen picture below displays frame 5 of a mode history animation with an amplitude scale factor of 3.2. The undeformed geometry is also shown. The number of frames defaults to the number of frames in the mode history file; 600.

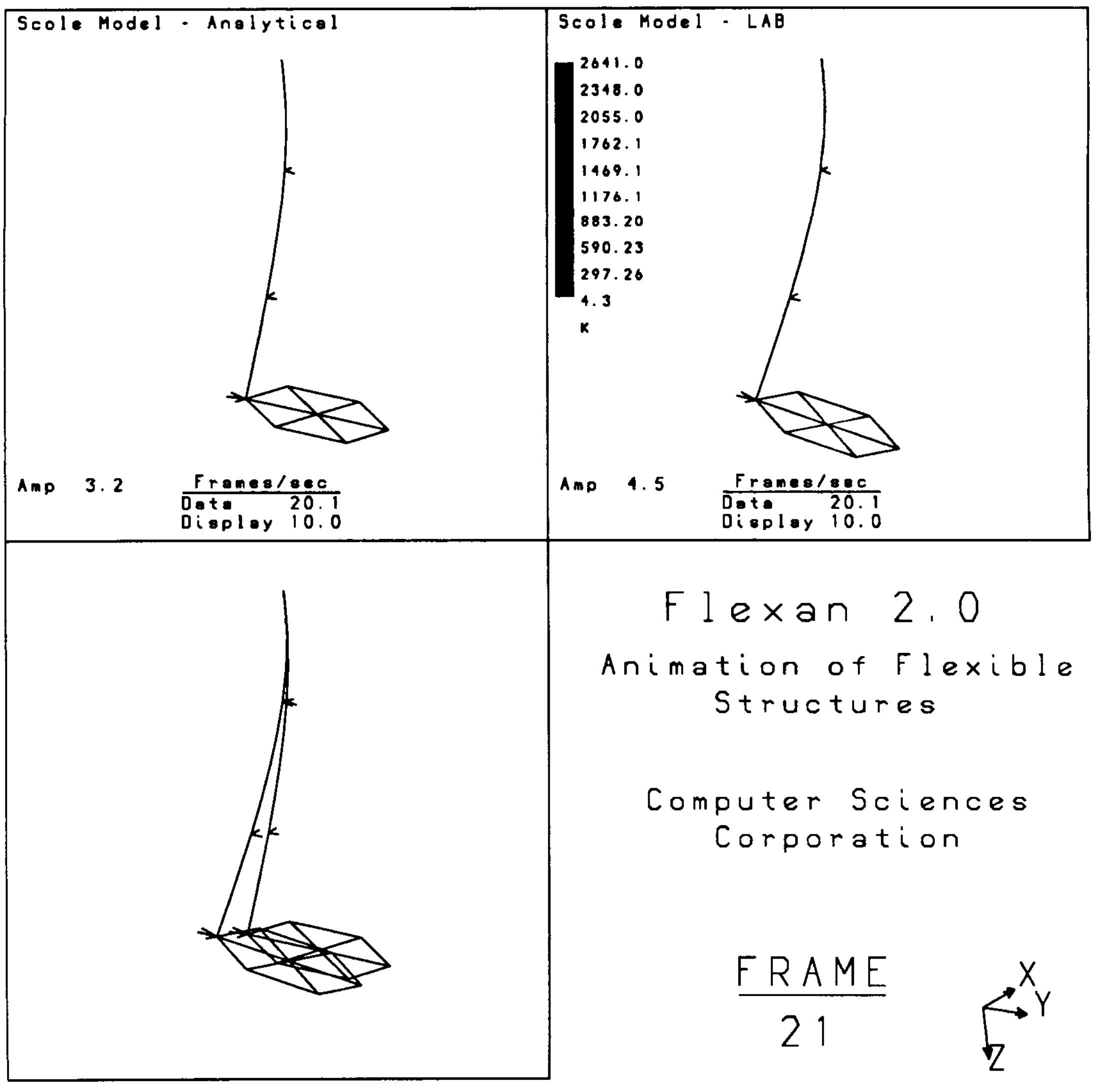
$ FLEXAN TEST/MS=TEST/MH=TEST/AMP=3.2



5.5 Example 5 - Delta / Color History Animation

The screen picture below displays frame 21 of a two dataset animation with a superposition window. The number of frames is chosen to be 400. Dataset one is a delta history animation with an amplitude scale factor of 3.2. Dataset two is a color history and a delta history animation with a scale factor of 4.5.

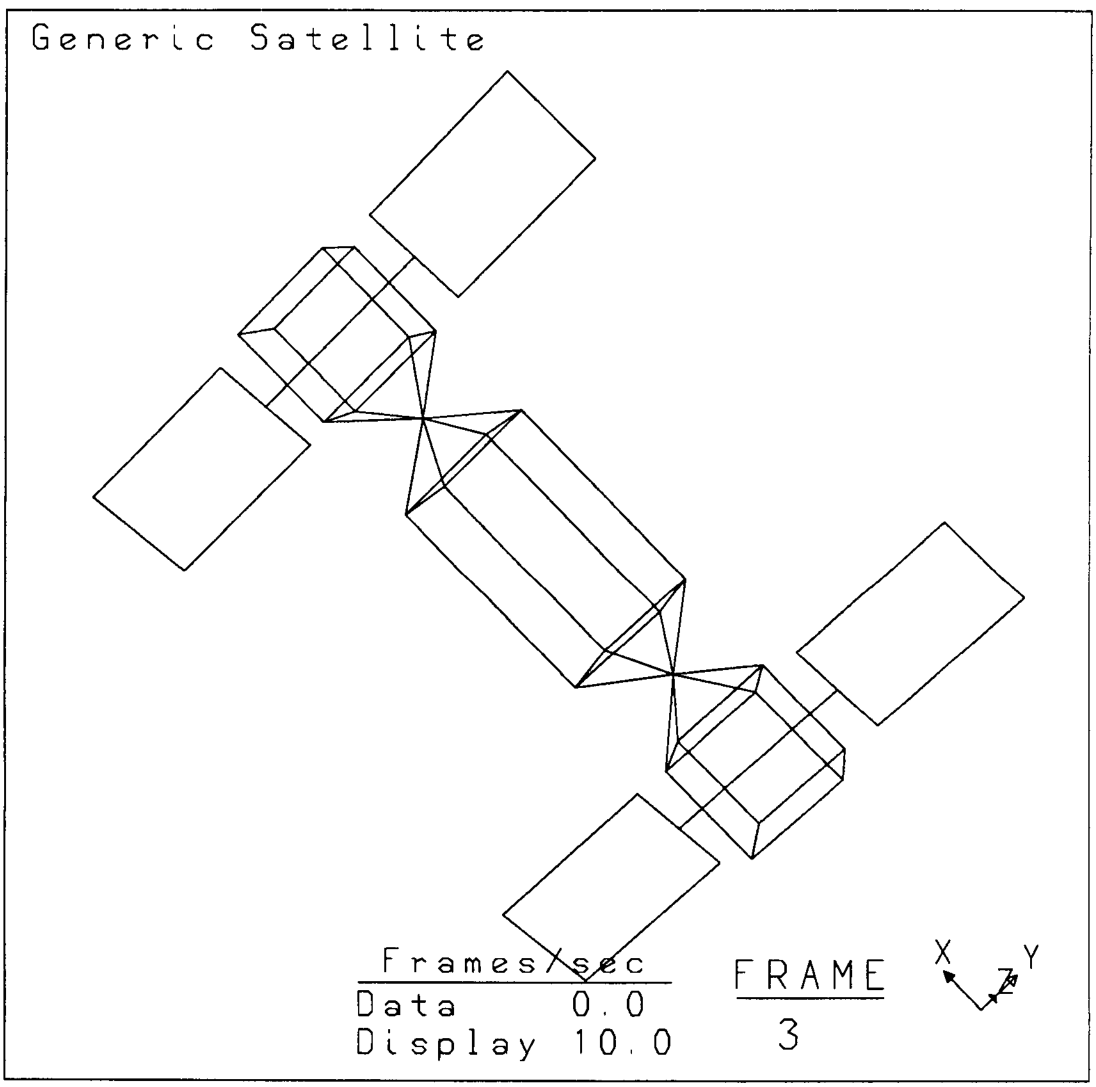
```
$ FLEXAN/FRAMES=400/SUPER  -
        TEST/DH=TEST/AMP=3.2  -
        TEST/DH=TEST/CH=TEST/AMP=4.5
```



5.6 Example 6 - Rotation / Color History Animation

The screen picture below displays frame 3 of a rotation and color history animation. Note the inheritance of file names from the geometry file name. The files read are GEN.GEO, GEN.RHY, and GEN.CHY.

$ FLEXAN GEN/RH/CH



5.7 Example Input Files

Fragments from each of the input files for the previous examples are listed below. The size of these files prevents complete file listings, but the distribution tape does contain the actual files.

TEST.GEO

```
Scole Model - Analytical
GEO
            27              32
 0 0 1 32
               1             .000        .000 -150.000
               2             .000        .000 -154.750
               3             .000        .000 -166.750
               4             .000        .000 -178.750
               5             .000        .000 -190.750
               6             .000        .000 -202.750
               7             .000        .000 -214.750
               8             .000        .000 -226.750
               9             .000        .000 -238.750
              10             .000        .000 -250.750
              11             .000        .000 -262.750
              12             .000        .000 -274.750
              13             .000        .000 -275.800
              14           24.000       -.005 -275.800
              15           36.000      20.780 -275.800
              16           24.000      41.565 -275.800
              17             .000      41.565 -275.800
              18          -12.000      20.780 -275.800
              19           12.000      20.780 -275.800
              20             .000       4.000 -191.000
              21            4.000        .000 -191.000
              22             .000       4.000 -237.800
              23            4.000        .000 -237.800
              24            5.000       8.656 -275.800
              25           -6.000        .000 -275.800
              26             .000      -6.000 -275.800
              27           -4.500      -4.500 -275.800
        1         2         3
        2         3         4
        3         4         5
                  .
                  .
                  .
       30        25        13
       31        26        13
       32        27        13
```

TEST.MOD

```
DATA FROM SPARKS DATABASE
MOD
          10              27
     1        .443
     1       .00000E+00       .00000E+00       .00000E+00
     2      -.25004E-05      -.41963E-05      -.14811E-08
     3      -.29074E-01      -.48794E-01      -.47036E-06
     4      -.10986E+00      -.18437E+00      -.93924E-06
     5      -.23389E+00      -.39251E+00      -.14081E-05
     6      -.39390E+00      -.66104E+00      -.18620E-05
     7      -.58347E+00      -.97916E+00      -.23159E-05
     8      -.79690E+00      -.13373E+01      -.27697E-05
     9      -.10291E+01      -.17270E+01      -.32236E-05
    10      -.12754E+01      -.21403E+01      -.36523E-05
    11      -.15315E+01      -.25701E+01      -.40811E-05
    12      -.17934E+01      -.30097E+01      -.45098E-05
    13      -.18165E+01      -.30484E+01      -.45101E-05
    14      -.18165E+01      -.30477E+01      -.52864E+00
    15      -.18171E+01      -.30473E+01      -.15647E+01
    16      -.18177E+01      -.30477E+01      -.20708E+01
    17      -.18177E+01      -.30484E+01      -.15401E+01
    18      -.18171E+01      -.30487E+01      -.50406E+00
    19      -.18171E+01      -.30480E+01      -.10341E+01
    20      -.23724E+00      -.39752E+00      -.80074E-01
    21      -.23687E+00      -.39715E+00      -.47715E-01
    22      -.10104E+01      -.16951E+01      -.13424E+00
    23      -.10101E+01      -.16947E+01      -.79998E-01
    24      -.18168E+01      -.30482E+01      -.42993E+00
    25      -.18165E+01      -.30485E+01       .13176E+00
    26      -.18163E+01      -.30484E+01       .22112E+00
    27      -.18164E+01      -.30485E+01       .26466E+00
     2        .447
     1       .00000E+00       .00000E+00       .00000E+00
     2       .42773E-05      -.25489E-05      -.16861E-09
     3       .49685E-01      -.29608E-01      -.53548E-07
                                .
                                .
                                .
```

TEST.CHY

```
TEST COLORS
CHY
500  32
20.1
K
  4.300000     7.600000     10.90000     14.20000     17.50000
  20.80000     24.10000     27.40000     30.70000     34.00000
  37.30000     40.59999     43.89999     47.19999     50.49999
  53.79999     57.09999     60.39999     63.69999     66.99999
  70.30000     73.60000     76.90000     80.20000     83.50001
  86.80001     90.10001     93.40002     96.70002     100.0000
  103.3000     106.6000     109.9000     113.2000     116.5000
  119.8000     123.1000     126.4000     129.7000     133.0000
  136.3000     139.6001     142.9001     146.2001     149.5001
  152.8001     156.1001     159.4001     162.7001     166.0001
  169.3001     172.6001     175.9001     179.2001     182.5001
  185.8001     189.1001     192.4001     195.7001     199.0001
  202.3001     205.6001     208.9001     212.2001     215.5001
  218.8001     222.1001     225.4001     228.7001     232.0001
  235.3001     238.6001     241.9001     245.2001     248.5002
  251.8002     255.1002     258.4001     261.7001     265.0001
  268.3001     271.6001     274.9001     278.2001     281.5001
  284.8000     288.1000     291.4000     294.7000     298.0000
  301.3000     304.6000     307.9000     311.2000     314.4999
  317.7999     321.0999     324.3999     327.6999     330.9999
  334.2999     337.5999     340.8998     344.1998     347.4998
  350.7998     354.0998     357.3998     360.6998     363.9998
                                .
                                .
                                .
```

TEST.MHY

```
TEST mode history
MHY
600 10
20.1
 5.00000  0.00000  0.00000
 0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000
 0.00000
 4.99227  0.00000  0.00000
 0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000
 0.00000
 4.96941 -0.00008 -0.00021
-0.00011 -0.00002 -0.00006
 0.00004 -0.00005  0.00000
-0.00009
 4.93181 -0.00033 -0.00078
-0.00041 -0.00009 -0.00020
 0.00010 -0.00008  0.00000
-0.00011
 4.87961 -0.00073 -0.00152
-0.00087 -0.00017 -0.00032
 0.00011 -0.00004  0.00002
-0.00002
 4.81295 -0.00130 -0.00227
-0.00142 -0.00024 -0.00035
 0.00006 -0.00002  0.00002
-0.00007
 4.73206 -0.00202 -0.00306
-0.00200 -0.00029 -0.00026
 0.00002 -0.00006  0.00000
-0.00011
 4.63717 -0.00290 -0.00407
-0.00252 -0.00029 -0.00011
 0.00004 -0.00006 -0.00001
-0.00004
 4.52859 -0.00394 -0.00540
-0.00292 -0.00026 -0.00001
 0.00008 -0.00003  0.00000
-0.00005
 4.40666 -0.00513 -0.00700
-0.00314 -0.00021 -0.00002
 0.00008 -0.00004  0.00000
-0.00010
 4.27175 -0.00646 -0.00882
-0.00316 -0.00014 -0.00014
 0.00005 -0.00006  0.00000
-0.00006
              .
              .
              .
```

TEST.DHY

```
SCOLE DELTA HISTORY FILE NUMBER 1
DHY
100 27
20.1
  -4.3500   -6.4500   22.8100
  -4.3500   -6.4500   21.0800
  -4.3500   -6.4500   16.7300
  -4.3500   -6.4500   12.3800
  -4.3500   -6.4500    8.0300
  -4.3500   -6.4500    3.6800
  -4.3500   -6.4500   -0.6700
  -4.3500   -6.4500   -5.0200
  -4.3500   -6.4500   -9.3700
  -4.3500   -6.4500  -13.7200
  -4.3500   -6.4500  -18.0700
  -4.3500   -6.4500  -22.4300
  -4.3500   -6.4500  -22.8100
   4.3500   -6.4500  -22.8100
   8.7000    1.0900  -22.8100
   4.3500    8.6200  -22.8100
  -4.3500    8.6200  -22.8100
  -8.7000    1.0900  -22.8100
   0.0000    1.0900  -22.8100
  -4.3500   -5.0000    7.9400
  -2.9000   -6.4500    7.9400
  -4.3500   -5.0000   -9.0300
  -2.9000   -6.4500   -9.0300
  -2.5400   -3.3100  -22.8100
  -6.5300   -6.4500  -22.8100
  -4.3500   -8.6200  -22.8100
  -5.9800   -8.0800  -22.8100
  -4.3500   -6.4500   22.8100
  -4.3500   -6.4500   21.0800
  -4.3500   -6.4500   16.7300
  -4.3600   -6.4600   12.3800
  -4.3700   -6.4800    8.0300
  -4.3800   -6.5000    3.6800
  -4.3900   -6.5200   -0.6700
  -4.4100   -6.5500   -5.0200
  -4.4300   -6.5700   -9.3700
  -4.4400   -6.6000  -13.7200
  -4.4600   -6.6300  -18.0700
  -2.9200   -6.4800    7.9400
  -4.4200   -5.1200   -9.0400
  -2.9700   -6.5700   -9.0300
  -2.6700   -3.5300  -22.8400
  -6.6600   -6.6700  -22.8000
  -4.4800   -8.8500  -22.7900
  -6.1100   -8.3000  -22.7900
  -4.3500   -6.4500   22.8100
                .
                .
                .
```

GEN.GEO

```
Generic Satellite
GEO
46      70
4       2       1       20

1       -5      5       0
2       -5      5       -5
3       -5      0       0
4       -5      0       -5
          .
          .
          .
44      -15     -10     -2.5
45      -12.5 -2        -2.5
46      -12.5 7         -2.5

1       1       5
2       2       6
3       5       7
         .
         .
         .
68      43      44
69      44      41
70      45      46

1       1       21      36
1       1       7.5     2.5     -2.5

2       1       37      52
1       1       -7.5    2.5     -2.5

3         2         53        61
2         2         12.5      2.5       -2.5
1         1         7.5       2.5       -2.5

4         2         62        70
2         2         -12.5     2.5       -2.5
1         1         -7.5      2.5       -2.5
```

GEN.RHY

```
Generic satellite rotation history
RHY
80 2
.001
 -7.820000        -22.53000
 -8.450000        -20.62000
 -9.070000        -18.70000
 -9.670000        -16.78000
 -10.25000        -14.84000
 -10.81000        -12.90000
 -11.36000        -10.95000
 -11.89000        -8.990000
 -12.40000        -7.020000
              .
              .
              .
 -5.850000         331.7900
 -6.520000         333.6700
 -7.180000         335.5700
```

GEN.CHY

```
Generic Satellite Temperature Data   1 orbit
CHY
180  70
0.001
K
0.25860E+03 0.17010E+03 0.25860E+03 0.17010E+03 0.25800E+03
0.25800E+03 0.25800E+03 0.25800E+03 0.23780E+03 0.25830E+03
0.22650E+03 0.25830E+03 0.22650E+03 0.25860E+03 0.17010E+03
0.25860E+03 0.17010E+03 0.25800E+03 0.25800E+03 0.25800E+03
0.25800E+03 0.23780E+03 0.25830E+03 0.22650E+03 0.25830E+03
0.22650E+03 0.25860E+03 0.17010E+03 0.25860E+03 0.17010E+03
0.25800E+03 0.25800E+03 0.25800E+03 0.25800E+03 0.23780E+03
0.25830E+03 0.22650E+03 0.25830E+03 0.22650E+03 0.25860E+03
0.17010E+03 0.25860E+03 0.17010E+03 0.25800E+03 0.25800E+03
0.25800E+03 0.25800E+03 0.23780E+03 0.25830E+03 0.22650E+03
0.25830E+03 0.22650E+03 0.25860E+03 0.17010E+03 0.25860E+03
0.17010E+03 0.25800E+03 0.25800E+03 0.25800E+03 0.25800E+03
0.23780E+03 0.25830E+03 0.22650E+03 0.25830E+03 0.22650E+03
0.17010E+03 0.25860E+03 0.17010E+03 0.25800E+03 0.25800E+03
0.23780E+03 0.22650E+03 0.25830E+03 0.22650E+03 0.17010E+03
0.25860E+03 0.17010E+03 0.25800E+03 0.25800E+03 0.25800E+03
0.25800E+03 0.23780E+03 0.25830E+03 0.22650E+03 0.25830E+03
0.22650E+03 0.25860E+03 0.17010E+03 0.25860E+03 0.17010E+03
0.23780E+03 0.23780E+03 0.23780E+03 0.23780E+03 0.25280E+03
0.25280E+03 0.25800E+03 0.25800E+03 0.17010E+03 0.25860E+03
0.17010E+03 0.25860E+03 0.25830E+03 0.22770E+03 0.25510E+03
0.22770E+03 0.25280E+03 0.25280E+03 0.25800E+03 0.25800E+03
0.17010E+03 0.25860E+03 0.17010E+03 0.25860E+03 0.24190E+03
0.24190E+03 0.25810E+03 0.25390E+03 0.25280E+03 0.25280E+03
0.25800E+03 0.25800E+03 0.17010E+03 0.25860E+03 0.17010E+03
                          .
                          .
                          .
```

6.0 Hints and Final Comments

FLEXAN is a design tool to be used in conjunction with analytical computer programs and/or experimental data produced from physical devices such as laboratory instruments. In many applications, very large amounts of data may need to be animated. FLEXAN's FORTRAN array sizes are installation dependent but geometries on the order of 500 nodes and elements are acceptable.

PS300 workstations are configured with varying amounts of main memory and the systems will usually crash if memory is exhausted. The examples presented in this document were run on a four megabyte PS390. The following suggestions may help prevent memory problems:

In general, geometries should be as simple as possible. Try to keep the number elements less than 200.

The maximum number of animation frames is 9999. Two dataset mode or delta history animations of 1200 frames have been performed on a PS390 with four megabytes of memory.

Color history animations require large amounts of memory. Try to keep the number of animation frames below 100 for most color history animations.

Avoid two dataset animations with very large geometries or color history animations.

The superposition window in two dataset animations uses additional memory; avoid using it for large dataset animations.

References

1. Foley, J. D. ; Van Dam, A. : Fundamentals of Interactive Computer Graphics, Addison Wesley, 1982.

2. "Guide to Programming on VAX/VMS (FORTRAN Edition)", Order No. AA-Y503A-TE, Version 4.0, Digital Equipment Corp., September 1984.

3. "PS390 Document Set (E&S #901194-400)" , Version A3.V01, Evans & Sutherland Computer Corp. P. O. Box 8700, 580 Arapeen Dr. Salt Lake City, Utah 84108.

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15. Supplementary Notes

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16. Abstract

This document describes the FLEXAN (Flexible Animation) computer program, Version 2.0. FLEXAN animates three-dimensional wireframe structural dynamics on the Evans & Sutherland PS300 graphics workstation with a VAX/VMS host computer. Animation options include: unconstrained vibrational modes, mode time histories (multiple modes), delta time histories (modal and/or nonmodal deformations), color time histories (elements of the structure change colors through time), and rotational time histories (parts of the structure rotate through time). Concurrent color, mode, delta, and rotation, time history animations are supported. FLEXAN does not model structures or calculate the dynamics of structures; it only animates data from other computer programs. FLEXAN was developed by Computer Sciences Corporation for the Spacecraft Analysis Branch, NASA Langley Research Center to aid in the study of the structural dynamics of spacecraft.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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