NASA-TM-84897 19860018604

A Reproduced Copy

OF

N86-28076

Reproduced for NASA

by the

NASA **Scientific and Technical Information Facility**

FFNo 672 Aug 65

21 pages

00002
Copy___of 25

NASA Technical Memorandum 84897

N86-28076

(NASA-TM-84897) NASTRAN/FLEXSTAB PROCEDURE
FOR STATIC AEROELASTIC ANALYSIS (NASA) 21 p
HC A02/MF A01 CSCL 01C

Unclas
G3/05 43220

ds NC 473657

NASTRAN/FLEXSTAB Procedure for Static Aeroelastic Analysis

Lawrence S. Schuster

September 1984

National Aeronautics and
Space Administration

Review for general release June 30, 1986

N86-28076#

NASA Technical Memorandum 84897

NASTRAN/FLEXSTAB Procedure for Static Aeroelastic Analysis

Lawrence S. Schuster
NASA Ames Research Center, Dryden Flight Research Facility, Edwards, California 93523

1984

National Aeronautics and
Space Administration
Ames Research Center
Dryden Flight Research Facility
Edwards, California 93523

SUMMARY

Presented is a procedure for using the FLEXSTAB External Structural Influence Coefficients (ESIC) computer program to produce the structural data necessary for the FLEXSTAB Stability Derivatives and Static Stability (SD&SS) program. The SD&SS program computes trim state, stability derivatives, and pressure and deflection data for a flexible airplane having a plane of symmetry. The procedure uses a NASTRAN finite-element structural model as the source of structural data in the form of flexibility matrices. Selection of a set of degrees of freedom, definition of structural nodes and panels, reordering and reformatting of the flexibility matrix, and redistribution of existing point mass data are among the topics discussed. Also discussed are boundary conditions and the NASTRAN substructuring technique.

INTRODUCTION

Large modern aircraft structures are frequently quite flexible and produce large flexibility effects on aircraft stability derivatives and aerodynamic loads. This situation makes the design of such aircraft difficult because the techniques used for the analysis of these structures must be able to accommodate the effects of flexibility on the analytically derived loads and stability derivatives.

Definitions

Some of the concepts used in the NASTRAN/FLEXSTAB procedure are aerodynamic and structural models, structural nodes and GRID points, slender and thin bodies, and flexibility matrices. Aerodynamic and structural models are mathematical descriptions of the airplane. Aerodynamic models are used by the FLEXSTAB program to compute the aerodynamic pressures on each part of the airplane at a given set of flight conditions. Structural models are used by the NASTRAN program to compute the deformations of the airplane that result from an applied load distribution (such as the aerodynamic pressures computed by FLEXSTAB). Structural nodes (used in FLEXSTAB) and GRID points (used in NASTRAN) are geometrical points located on the structural model of the airplane. When loads are applied to these points, the structure will deform in a predictable and calculatable way. Structural nodes will allow translational deformation of the structure in three orthogonal directions, whereas GRID points will allow these translational deformations and will also allow rotational deformations about these three directions. Slender bodies are used in the aerodynamic model to describe parts of the airplane that resemble a body of revolution, such as fuselages, nacelles, and external stores. Thin bodies are used to describe the relatively flat parts of an airplane, such as wings, fins, and tails. The flexibility matrix is a square matrix that contains the structural deformations of all structural nodes that result from unit loads applied individually at each structural node of the airplane.

Assumptions and Recommendations

This procedure requires that the reader has some familiarity with the FLEXSTAB and NASTRAN computer programs and that FLEXSTAB aerodynamic models and NASTRAN structural models of an aircraft are available for use. These models can be quite independent of each other, but there should be structural elements in NASTRAN for all aerodynamic bodies in the FLEXSTAB model and the same coordinate systems should be used for both. A source of distributed mass data should be available. It is recommended that all bodies with significant mass or structural properties be present in the models, even if they are not usually necessary for the type of analysis performed. For example, the vertical tail should be included, even in a symmetric-only analysis, to properly account for the inertial forces caused by its mass.

The FLEXSTAB system of aeroelastic analysis programs permits the analysis of flexible aircraft structures. This system has a structural modeling capability of its own; but because it is relatively simple, FLEXSTAB also allows use of an alternate structural modeling technique using matrices to describe the structural properties of an aircraft. Any structural analysis method may be adopted to generate the structural matrices. This report explains how to use NASTRAN structural models to produce the necessary matrices and how to incorporate this structural information into the FLEXSTAB system.

COMPUTER PROGRAM DESCRIPTIONS

FLEXSTAB is a system of computer programs used for modeling aircraft aerodynamics and structure and for analyzing aircraft stability and loads (ref. 1). Aerodynamic modeling is accomplished by defining geometry and then deriving aerodynamic influence coefficients by using the FLEXSTAB Geometry Definition (GD) program and the FLEXSTAB Aerodynamic Influence Coefficients (AIC) program. Structural modeling is accomplished by generating flexibility and mass distribution information by using NASTRAN and other non-FLEXSTAB programs; and then defining structure and deriving structural influence coefficients by using the FLEXSTAB External Structural Influence Coefficients (ESIC) program. Aircraft stability derivatives, surface pressures, and structural deformations are obtained by using the FLEXSTAB Stability Derivatives and Static Stability (SD&SS) program.

NASTRAN is a general-purpose, finite-element computer program for structural analysis (ref. 2). It is especially suitable for analyzing complex aircraft structures because it is designed to handle very large structural models. The user-oriented modeling system is an important characteristic of the program. NASTRAN can produce flexibility matrices for both symmetric and antisymmetric boundary conditions, and if the structural model is accurately sized, NASTRAN can produce most of the mass-distribution data required by FLEXSTAB.

ESIC INPUT REQUIREMENTS

A comparison of the FLEXSTAB aerodynamic model geometry with the NASTRAN structural model geometry is necessary to select a set of structural nodes for ESIC. ESIC structural bodies are defined in the same order as their corresponding aerodynamic bodies in the FLEXSTAB GD program. A set of GRID points extending approximately from the nose to the tail of the NASTRAN fuselage should be selected as ESIC structural nodes for the fuselage slender body. For some models, it may prove convenient to define a set of extra GRID points along the fuselage mean centerline, and connect these points to the fuselage structure using multi-point constraint (MPC) cards. Multi-point constraints cause a specified point to deform in a particular direction based on the deformations of several other points.

The ESIC structural representation for thin bodies consists of structural nodes and a method of connecting these nodes to form either triangular or quadrilateral panels. GRID points along leading and trailing edges and along main spars should be selected as ESIC structural nodes for thin bodies, using about the same number of structural nodes as there are aerodynamic panels.

The choice of triangular or quadrilateral structural panels is dictated by structural rather than aerodynamic considerations; i.e., the shape of structural panels is completely independent of the shape of aerodynamic panels. Unusually large structural panels should be split into a number of smaller panels by the addition of a few more structural nodes wherever possible, and panels that are considerably larger in one dimension than in another should be avoided.

Each body has its own local coordinate system in which the geometry of the body is defined. Slender-body axes are all parallel to the FLEXSTAB basic coordinate system. The x-axis is a horizontal vector pointing from the nose toward the tail. The y-axis is a horizontal vector perpendicular to the x-axis and pointing from the plane of symmetry toward the right wing tip. The z-axis is perpendicular to both x- and y-axes and points up (right-hand rule). The x-coordinates of the slender-body nodes are input from the smallest to the largest value; the y- and z-coordinates of the slender body are the same for all nodes on the body.

For thin bodies, the x-axis is a horizontal vector in the lifting plane of the thin body that is parallel to the plane of symmetry and points from the leading edge toward the trailing edge. The y-axis is a vector in the lifting plane perpendicular to the x-axis and pointing toward the tip of the thin body. The z-axis is perpendicular to both the x- and y-axes and is therefore normal to the lifting plane. Its positive direction is found by use of the right-hand rule. The nodes on thin bodies can be in any order; their x- and y-coordinates are input in pairs; the z-coordinate is zero.

Selection of Degrees of Freedom

The geometry of the body and the translational degrees of freedom are defined in the local-axis system for each body, but rotational degrees of freedom must be excluded. Each structural node can have up to three degrees of freedom, but all nodes on a body must have the same number and type of degrees of freedom.

For bodies on the plane of symmetry, the flexibility matrix should include only those degrees of freedom for the desired type of motion: symmetric or antisymmetric. The degrees of freedom for slender and thin bodies must be ordered d_x, d_y, d_z for each node, in the same order as the structural node locations. All degrees of freedom required for both types of symmetry should be included in the ESIC degrees of freedom set; the ESIC program automatically eliminates invalid degrees of freedom for all nodes on the plane of symmetry for each of the symmetry conditions.

The degrees of freedom used in the analysis are as follows:

1. On the plane of symmetry: For the symmetric flexibility matrix, the FLEXSTAB d_z degrees of freedom are used for slender bodies and d_y degrees of freedom are used for thin bodies, whereas for the antisymmetric flexibility matrix, d_y degrees of freedom are used for slender bodies and d_z degrees of freedom are used for thin bodies.

2. Not on the plane of symmetry: For both symmetric and antisymmetric flexibility matrices, d_y and d_z degrees of freedom are used for slender bodies and d_z degrees of freedom are used for thin bodies.

The degrees of freedom used in ESIC are those which appear in either or both of the flexibility matrices. The degrees of freedom used for each body in ESIC are specified in the $DEGREES OF FREEDOM card set for each ESIC body. The degrees of freedom that become part of the flexibility matrix are controlled by NASTRAN ASET cards.

Constraints

For clamped flexibility matrices, ESIC requires NASTRAN constraints that resist rigid-body motions of the aircraft. The clamp point is the GRID point that has all six degrees of freedom set equal to zero by a single-point constraint (SPC) card. Single-point constraints cause a specified point to deform a known amount in a particular direction. It is generally advisable to clamp the model at a single GRID point near the center of gravity on a relatively stiff part of the structure. However, a GRID point can instead be located exactly at the center of gravity, and its deformation can be defined by using MPC cards. This extra point can then be used as the clamp point.

Boundary conditions for symmetric or antisymmetric motion require two different sets of SPC cards for GRID points on the plane of symmetry. For symmetric motion all out-of-plane degrees of freedom of GRID points on the plane of symmetry are set equal to zero, whereas for antisymmetric motion all in-plane degrees of freedom of GRID points on the plane of symmetry are set equal to zero. Thus, two separate executions of NASTRAN are required to produce both symmetric and antisymmetric flexibility matrices.

Flexibility Matrices

ESIC always requires a clamped flexibility matrix representing the reactions of the aircraft structure to symmetric loads, a separate flexibility matrix is often necessary for representing reactions to antisymmetric loads. The FORTRAN program, NASTY, converts flexibility matrices from the internal degree-of-freedom ordering of NASTRAN to the order required by ESIC.

NASTRAN STRUCTURAL DATA

Two important types of structural data can be obtained from NASTRAN: the flexibility matrix and the mass matrix. Both of the matrices are available from Rigid Format #1, commonly called STATICS, a program that produces static reactions of a structure to applied loads. STATICS is requested in the NASTRAN executive control deck. Generally, the NASTRAN order of the degrees of freedom for the flexibility matrix is from the smallest GRID point number to the largest, with the degrees of freedom for each GRID point in the following order: T1, T2, T3, R1, R2, and R3 (or 123456). A listing showing the NASTRAN order of the degrees of freedom can be obtained with the DIAG card in the executive control deck. Two NASTRAN executions are required to produce the symmetric and the antisymmetric flexibility matrices, whereas the mass matrix (if present) can be produced during either execution. The diagonal of the flexibility matrix should be examined for unusually large values (greater than about

0.10 for relatively flexible aircraft; greater than about 0.010 for stiffer aircraft). The mass matrix can only be obtained if the NASTRAN model is dimensionally detailed and if mass densities have been specified for all elements. The diagonal of the mass matrix is the data of interest for input to ESIC.

NASTRAN SUBSTRUCTURING NOTES

When an airplane structure is too large to put into the computer as a single structural model, the structure may be divided into smaller parts (substructures) and entered into the computer separately. The substructure technique requires two types of executions. The Phase 1 executions enter the data from each substructure. The Phase 2 execution then combines this data from all substructures to form the entire airplane structure. In Phase 1 executions, the ASET cards must include all FLEXSTAB degrees of freedom desired for the flexibility matrix and all unconstrained boundary (or substructure connection) degrees of freedom. All degrees of freedom in the Phase 2 analysis set are in the NASTRAN basic coordinate system, which is a parallel system to the FLEXSTAB basic coordinate system. For thin bodies with considerable dihedral (+ or -), a transformation of the Phase 2 matrices may be required to provide degrees of freedom in the FLEXSTAB local-axis system. The flexibility matrix is output from the Phase 2 NASTRAN execution.

ESIC DATA PREPARATION

The data needed for ESIC are a set of point masses for the vehicle, a NASTRAN structural model, and a FLEXSTAB aerodynamic model. The FLEXSTAB aerodynamic model is composed of one or more slender (shell) bodies, and one or more thin (lifting surface) bodies. These bodies are numbered differently in the GD and the ESIC decks (figs. 1 and 2):

Body Name	Body Number	
	GD	ESIC
Fuselage	1	1
Interference body	2	-
Lower vertical tail	3	2
Upper vertical tail	4	3
Inner wing	5	4
Outer wing	6	5
Horizontal tail	7	6

In ESIC, the interference body is ignored. The following sections present a step-by-step procedure for generating the necessary input to the ESIC module. A simplified ESIC model (fig. 3) is used to generate the entries in tables 1 through 3.

ESIC Node Identification

For ESIC node identification, it is necessary to generate a plan view of the NASTRAN model with numbered GRID points, such as in figure 4, and select a set of GRID points for each ESIC body. The selected set should have about the same density as the aerodynamic paneling used in the FLEXSTAB GD model (see fig. 1). For some cases, where the structural model is somewhat simpler than the aerodynamic model, extra GRID points and structures must be added to the NASTRAN model to achieve a reasonable density of structural nodes. On thin bodies the selected points must be connected to form structural panels. All panels on each body should be of about the same size. Output coordinate-system axes for NASTRAN GRID points should be oriented parallel to the ESIC local-coordinate-system axes for each body. A list should be made of the selected GRID points (table 1) specifying:

1. FLEXSTAB body number: Monotonically increasing, starting from one with one number for each slender or thin body.

2. Component node number: Monotonically increasing, starting from one, for each body. Nodes on the boundary between two bodies must be included with the lower-numbered body.

3. ESIC degree-of-freedom number: Monotonically increasing, starting from one, including all bodies in their FLEXSTAB order. Degrees of freedom for each node are listed in d_x, d_y, d_z order.

4. NASTRAN GRID ID number: From NASTRAN model plot or listing.

5. NASTRAN degree-of-freedom: 1, 2, or 3 for x, y, or z, respectively.

6. NASTRAN order number: From NASTRAN DIAG 21 output.

7. x- and y-coordinates of the nodes in the local coordinate system of each body: These entries are entered on ESIC card sets 23 and 29 (see App. A).

ESIC Panel Identification

For ESIC panel identification, the component node numbers (table 1) should be marked on the NASTRAN plan-view plot and a list of ESIC panel corner numbers should be made (table 2). The ESIC panels may be quadrilateral or triangular, but no strange shapes (i.e., panels with angles greater than about 160° or less than 20°) should be generated. The component node numbers should be listed in either clockwise or counter-clockwise order around the perimeter of each panel in the four columns (table 2). If the panel is triangular the last column is left blank and if any of the nodes used to define a panel on a body are from an adjoining body, the number of the adjoining body should be noted in parenthesis behind the node number. The entries in table 2 are entered on the ESIC card set 31 (see App. A).

Flexibility Matrix Generation

To produce the flexibility matrix, NASTRAN ASET cards (table 3) should be generated by entering the NASTRAN GRID ID numbers and degrees of freedom on NASTRAN ASET cards. Insert the ASET cards in the NASTRAN bulk data deck and add the following DMAP ALTER cards to the NASTRAN executive control deck:

```
ALTER 73 $
SOLVE KLL, /ELL/ $
DIAGONAL ELL/EDIAG/ $
MATRPN ELL,EDIAG,,,// $
```

```
OUTPUT2 ELL,,,,//C,N,-1/C,N,11/C,N,FLEXMAT $
OUTPUT2 ,,,,//C,N,-9/C,N,11/ $
ENDALTER $
```

Finally, insert a DIAG 21 card in the NASTRAN executive control deck, and insert the following card in the system control cards before the NASTRAN execution card to create a disk file to contain the flexibility matrix to be generated:

```
DEFINE(UT1=FLEXMAT)
```

The flexibility matrix will be generated by NASTRAN and written on the disk file FLEXMAT. The matrix and its diagonal will be printed in the NASTRAN output for use in checking individual data of interest.

Matrix Reordering

To be compatible with ESIC, the flexibility matrix generated by the procedure in the previous section must be reordered as follows:

1. List the ASET order number (column A from the DIAG 21 printout) as the NASTRAN order number in the ESIC node identification list (table 1).

2. Punch a deck of monotonically increasing numbers, FORMAT (I3), one per card, for each ESIC degree-of-freedom number (table 1). Sort the deck of ESIC degree-of-freedom numbers, using the NASTRAN order numbers, and run the FORTRAN program NASTY (w/NASCON), using this deck as input (the deck setup is shown in appendix B).

ESIC Deck Setup

Follow the instructions of reference 1, pages 11-1 to 11-49. For static aeroelastic loads analysis, the following card sets are used:

```
$CASE
$GDTAPE
$OPTION
$DEGREES
$SLENDER
$SCALE
$THIN
$SCALE
$END
$EXIT
```

Mass Data Generation

Masses are located at structural nodes and are input in the same order as the structural nodes. Generally, the mass data available will not coincide with the ESIC node locations. FORTRAN programs FUMAS and REMAS are used to produce the appropriate mass cards for $SLENDER and $THIN data groups, respectively. To produce slender-body mass data cards for ESIC, an input deck is set up for FUMAS as follows (the deck setup is shown in appendix C):

1. Take the $SLENDER deck for ESIC.

2. Remove the $SLENDER card.

3. Add the number of input masses, FORMAT (F10.0), to columns 31-40 of ESIC card 22.

4. Add the input mass deck, FORMAT (2F10.0), with each mass magnitude and its x-coordinate paired on a single card, to the end of the input deck.

If the program is executed for each slender body, this will produce punched ESIC mass cards for each slender body, due to its own mass.

To produce thin-body mass data cards for ESIC, an input deck is set up for REMAS as follows (deck setups are shown in appendices D and E):

1. Punch the number of ESIC bodies for REMAS on the first card, FORMAT (I1).

2. Add the $SLENDER deck for ESIC (except for mass and $SCALE cards) and the $THIN deck for ESIC (except for mass and $SCALE cards).

3. Add a card with the number of input masses, FORMAT (I3).

4. Add the input mass deck, FORMAT (3F10.0), with each mass magnitude, and x- and y-coordinate on a single card, to the end of the input deck.

This will produce punched ESIC mass cards for both slender and thin bodies, due to thin-body masses.

The mass cards for the slender body, punched by both REMAS and FUMAS, are for the same set of slender-body nodes. The mass in each field of each card punched by REMAS must be added to the mass in the same field of the corresponding card punched by FUMAS. The resulting total mass for each node must be punched into the same field on the corresponding new cards for input to ESIC.

ESIC EXECUTION

To execute the program, insert the mass cards produced from the procedures described in the previous section into the $SLENDER and $THIN sections of the ESIC input deck and make an initial run using the RIGID option. The flexibility matrix file (NASTAP) is not required. This execution of ESIC will produce the total mass, center-of-gravity location, and total vehicle moments of inertia for the distributed masses input. If necessary, adjustments to the fuselage masses are made to adjust the x-location of the center of gravity, and, if desired, adjustments can be made to the z-reference location of the fuselage to correct to the z-location of the center of gravity. When the mass distribution produces an acceptable center-of-gravity location, execute ESIC using the STATIC-ELASTIC option to produce the necessary input to FLEXSTAB SD&SS for the aeroelastic analysis.

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX A

ESIC CARD SETS

ESIC card image
(••••• represents the point mass values)

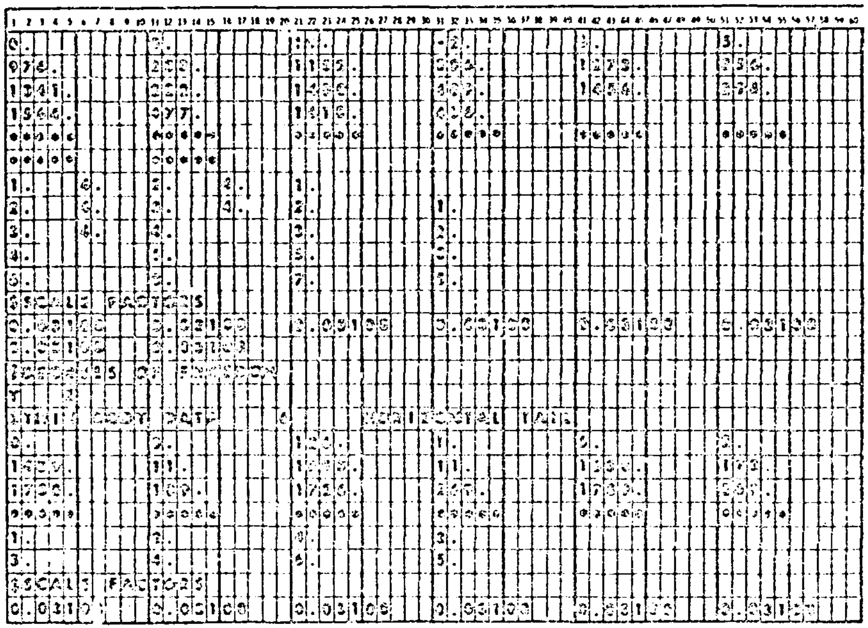
ESIC card set number

```
$CASE FOR ESIC                                                   1
NASTRAN-FLEXSTAB INTERFACE EXAMPLE                               2
L. S. SCHUSTER                                                   3
$GDTAPE DATA                                                     4
GD MODEL  1.                                                     5
$OPTIONS FOR ELASTIC FORMULATION                                 6
STATIC-ELASTIC                                                   7
$DEGREES OF FREEDOM                                              17
Y   Z                                                            18
$SLENDER BODY DATA  1      FUSELAGE                              21
0.        28.       7.                                           22
55.       200.      525.      845.      1250.     1500.          23
1595.                                                            23
*****     *****     *****     *****     *****     *****          24
*****                                                            24
$SCALE FACTORS FOR FORCES TO SLUGS CONVERSION                    25
0.03108   0.03108   0.03108   0.03108   0.03108   0.03108        26
0.03108                                                          26
$DEGREES OF FREEDOM                                              17
Y                                                                18
$THIN BODY DATA      2      LOWER VERTICAL TAIL                  27
0.        0.        0.        20.       0.        2.             28
1600.     183.      1632.     180.      1570.     180.           29
*****     *****     *****                                        30
0.   1.   1.   1.   2.        1.                                 31
```

```
7.   1.   3.        2.                                           31
$SCALE FACTORS                                                   32
0.03108   0.03108   0.03108                                      33
$THIN BODY DATA      3      UPPER VERTICAL TAIL                  27
0.        0.        0.        30.       5.        4.             28
1577.     225.      1654.     205.      1702.     207.           29
1647.     202.      1701.     202.      1727.     224.           29
*****     *****     *****     *****     *****     *****          30
1.   2.   2.   2.   2.        1.                                 31
2.   2.   3.   2.   3.        2.                                 31
1.        2.        5.        4.                                 31
2.        3.        6.        5.                                 31
$SCALE FACTORS                                                   32
0.03108   0.03108   0.03108   0.03108   0.03108   0.03108        33
$DEGREES OF FREEDOM                                              17
Z                                                                18
$THIN BODY DATA      4      INNER WING                           27
0.        0.        78.       -2.       3.        2.             28
625.      78.       960.      145.      1231.     149.           29
*****     *****     *****                                        30
3.   1.   4.   1.   2.        1.                                 31
4.   1.   5.   1.   3.        2.                                 31
$SCALE FACTORS                                                   32
0.03108   0.03108   0.03108                                      33
$THIN BODY DATA      5      OUTER WING                           27
```

APPENDIX A — Concluded.

ORIGINAL PAGE IS
OF POOR QUALITY



```
0.        3.        [illegible]  -2.      3.        3.                  28
976.      222.      1155.     264.      1273.     256.                29
1341.     222.      1456.     327.      1654.     278.                29
1566.     377.      1416.     626.                                    29
[illegible]                                                           30
[illegible]                                                           30
1.   6.   2.   2.   1.                                                31
2.   6.   3.   4.   2.        1.                                      31
3.   6.   4.        3.        2.                                      31
4.        5.        5.        3.                                      31
5.        5.        7.        5.                                      31
$SCALE FACTORS                                                        32
0.03100   0.03100   0.03100   0.03100   0.03100   0.03100             33
0.03100   0.03100                                                     33
$[illegible]S OF [illegible]                                          17
Y    2                                                                18
$TAIL BODY DATA    6    HORIZONTAL TAIL                               27
0.        2.        120.      1.        0.        3.                  28
1427.     11.       1455.     11.       1330.     172.                29
1700.     100.      1726.     240.      1733.     267.                29
[illegible]                                                           30
1.        2.        0.        3.                                      31
3.        4.        5.        5.                                      31
$SCALE FACTORS                                                        32
0.03100   0.03100   0.03100   0.03100   0.03100   0.03100             33
$END OF CASE                                                          40
$EXIT                                                                 41
```

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX B

NASTY INPUT DATA AND NASCON INPUT DATA

```
 26
 27
 24
 25
 22
 23
 21
 19
 20
 18
 36
 37
 38
 39
 32
 33
 34
 35
 30
 31
 28
 29
  1
  2
 17
```

```
  3
 16
 15
 14
 13
 12
 11
 10
  9
  8
  7
  6
  5
  4
FLEXIBILITY MATRIX FOR 3N, SYMMETRIC                       0   32   39    0    0
7/8/9 ← End-of-record
       1.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0
```

APPENDIX C

FUMAS INPUT DATA DECK

ORIGINAL PAGE IS
OF POOR QUALITY

FUMAS card images

ESIC card set number

```
3.        36.       7.        33.                                          23 modified
58.       144.      529.      909.      1293.     1400.                    23
1599.                                                                      23
   1641.36    958.85                                                      }
    700.39    273.02                                                      } FUMAS
   1279.19    773.19                                                      } input
---------08 additional mass data cards--------                            } masses
```

APPENDIX D

REMAS INPUT DATA DECK; VERTICAL TAIL MASSES

REMAS card image						ESIC card set number
3						Number of bodies
$SLENDER BODY	DATA 1	FUSELAGE				21
0.	15.	7.				22
55.	469.	724.	997.	1290.	1452.	23
1575.						23
3THIN BODY	DATA 2	LOWER	VERTICAL	TAIL		37
0.	5.	5.	20.	5.	3.	28
1459.	136.	1562.	156.	1670.	156.	29
6. 1.	7. 1.	2.	1.			31
7. 1.	3.	2.				31
3THIN BODY	DATA 3	UPPER	VERTICAL	TAIL		37
0.	5.	3.	20.	3.	3.	28
1577.	225.	1684.	234.	1722.	237.	29
1667.	222.	1721.	222.	1727.	225.	29
1. 2.	3. 2.	2.	1.			31
2. 2.	3. 3.	3.	2.			31
1.	3.	3.	3.			31
2.	3.	3.	3.			31
58						Number of masses
38.72	1310.88	64.58				REMAS input masses
24.35	1564.92	30.21				
127.52	1512.58	38.38				
———— 55	additional	mass data	cards ————			

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX E

REMAS INPUT DATA DECK; WING AND HORIZONTAL TAIL MASSES

REMAS card image — ESIC card set number

```
6.                                                             Number of bodies
$SLENDER BODY DATA 1     FUSELAGE                              21
0.        26.       7.                                         22
55.       348.      535.      969.      1250.     1400.        23
1595.                                                          23
$THIN BODY DATA    2     FAKE LOWER VERTICAL TAIL              27
0.        0.        3.        90.       3.        1.           28
2000.     0.        2001.     0.        2001.     1.           29
1.        2.        2.                                         31
$THIN BODY DATA    3     FAKE UPPER VERTICAL TAIL              27
0.        0.        0.        90.       3.        1.           28
2000.     0.        2001.     0.        2001.     1.           29
1.        2.        2.                                         31
$THIN BODY DATA    4     INNER WING                            27
0.        0.        18.       -2.       3.        2.           28
425.      78.       [illegible] 146.    1231.     149.         29
3.  1.    4.   1.   2.        1.                               31
4.  1.    5.   1.   3.        2.                               31
$THIN BODY DATA    5     OUTER WING                            27
0.        3.        17.       -3.       2.        3.           28
976.      233.      1152.     304.      1273.     232.         29
1361.     223.      1600.     400.      1436.     266.         29
1560.     377.      1616.     456.                             29
1.  3.    2.   4.   1.                                         31
2.  3.    3.   4.   2.        1.                               31
```

```
3.  4.    5.        2.        2.                               31
4.        6.        5.        3.                               31
6.        5.        7.        5.                               31
$THIN BODY DATA    6     HORIZONTAL TAIL                       27
0.        0.        126.      1.        5.        2.           28
1499.     11.       1693.     11.       1633.     173.         29
1730.     109.      1726.     269.      1709.     269.         29
1.        2.        4.        3.                               31
3.        4.        6.        5.                               31
311                                                            Number of masses
   1293.55     536.40     53.16                                } REMAS
    537.35     738.72     54.83                                } input
    627.34     545.05     67.44                                } masses
       309 additional mass data cards
```

TABLE 1. — ESIC NODE IDENTIFICATION LIST

FLEXSTAB body number	Component node number	ESIC degree-of-freedom number	NASTRAN GRID ID number	NASTRAN degree-of freedom	NASTRAN order number	x-coor-dinate	y-coor-dinate
1	1	1	3000	3	23	55.0	
	2	2	3053	3	24	348.0	
	3	3	3113	3	26	625.0	
	4	4	5293	3	39	969.0	
	5	5	5173	3	38	1250.0	
	6	6	5133	3	37	1400.0	
	7	7	5000	3	36	1595.0	
2	1	8	4270	3	35	1469.0	136.0
	2	9	4250	3	34	1562.0	136.0
	3	10	4180	3	33	1679.0	136.0
3	1	11	4150	3	32	1577.0	225.0
	2	12	4130	3	31	1654.0	206.0
	3	13	4100	3	30	1702.0	207.0
	4	14	4060	3	29	1647.0	282.0
	5	15	4020	3	28	1701.0	282.0
	6	16	4010	3	27	1727.0	282.0
4	1	17	3110	3	25	625.0	78.0
	2	18	1490	3	10	969.0	145.0
	3	19	1320	3	8	1231.0	149.0
5	1	20	1450	3	9	976.0	233.0
	2	21	1290	3	7	1152.0	305.0
	3	22	1210	3	5	1273.0	356.0
	4	23	1240	3	6	1341.0	222.0
	5	24	1130	3	3	1400.0	409.0
	6	25	1160	3	4	1456.0	298.0
	7	26	1010	3	1	1564.0	477.0
	8	27	1040	3	2	1618.0	406.0
6	1	28	2270	2	21	1489.0	11.0
	1	29	2270	3	22		
	2	30	2200	2	19	1693.0	11.0
	2	31	2200	3	20		
	3	32	2090	2	15	1638.0	173.0
	3	33	2090	3	16		
	4	34	2120	2	17	1730.0	109.0
	4	35	2120	3	18		
	5	36	2010	2	11	1726.0	269.0
	5	37	2010	3	12		
	6	38	2040	2	13	1789.0	269.0
	6	39	2040	3	14		

TABLE 2. — ESIC PANEL IDENTIFICATION LIST

Body number	Component node numbers (adjoining body numbers)			
	Node A	Node B	Node C	Node D
2	6(1)	7(1)	2	1
	7(1)	3	2	—
3	1(2)	2(2)	2	1
	2(2)	3(2)	3	2
	1	2	5	4
	2	3	6	5
4	3(1)	4(1)	2	1
	4(1)	5(1)	3	2
5	1(4)	2(4)	1	—
	2(4)	3(4)	2	1
	3(4)	4	3	2
	4	6	5	3
	6	8	7	5
6	1	2	4	3
	3	4	6	5

TABLE 3. — ASET CARDS FOR THE NASTRAN DECK

ASET	3000	3	3053	3	3113	3	529[illegible]	3
ASET	5173	3	5133	3	5000	3	4270	3
ASET	4250	3	4180	3	4150	3	4130	3
ASET	4100	3	4060	3	4020	3	4010	3
ASET	3110	3	1490	3	1320	3	1450	3
ASET	1290	3	1210	3	1240	3	1130	3
ASET	1160	3	1010	3	1040	3	2270	23
ASET	2200	23	2090	23	2120	23	2010	23
ASET	2040	23						

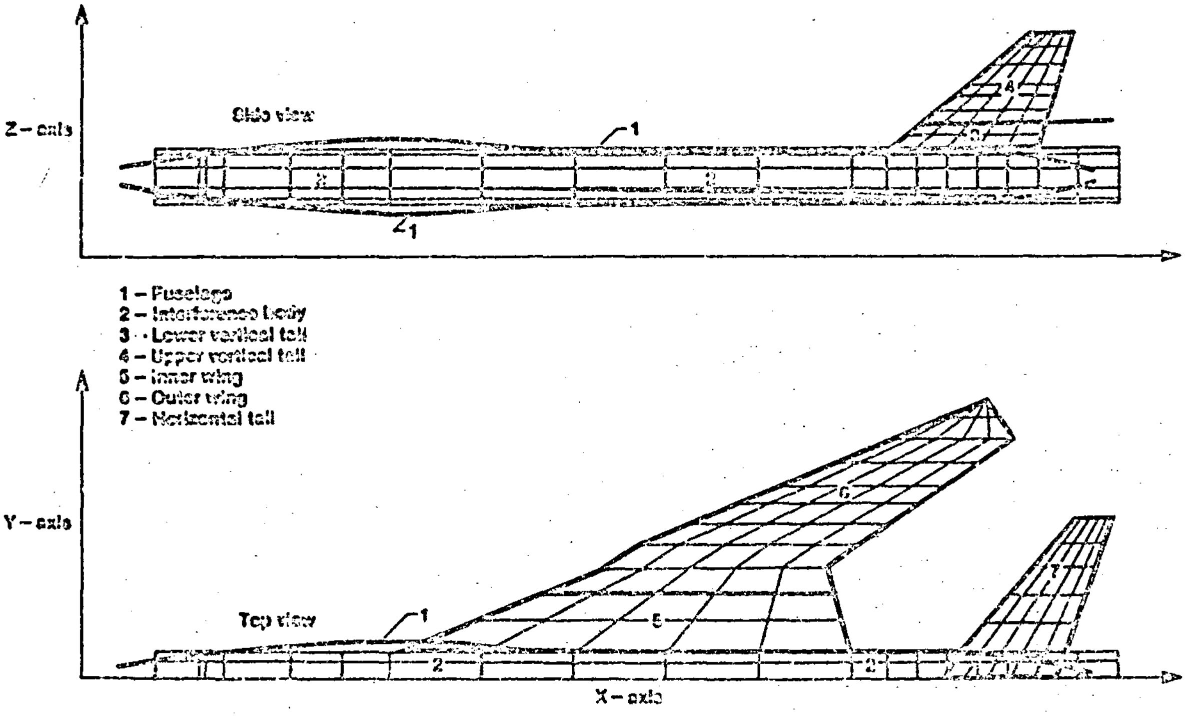


Figure 1. FLEXSTAB GD model.

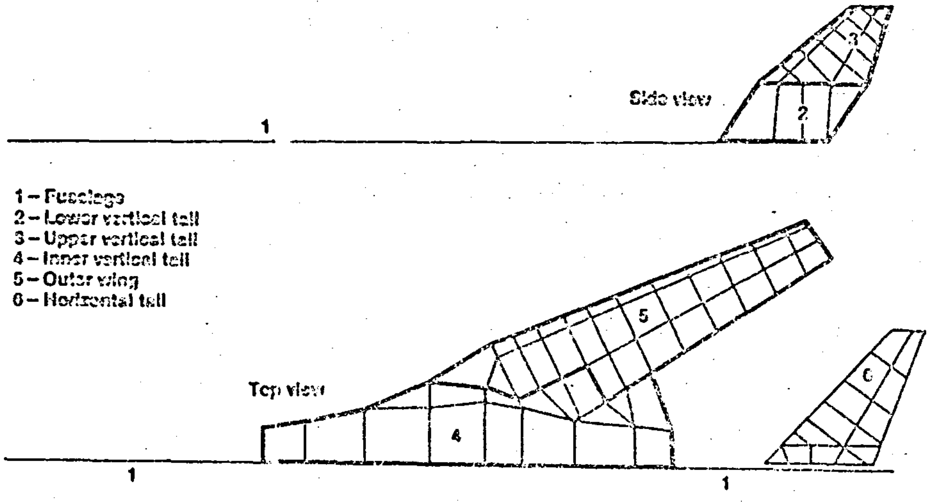


Figure 2. FLEXSTAB ESIC model.

ORIGINAL PAGE IS
OF POOR QUALITY

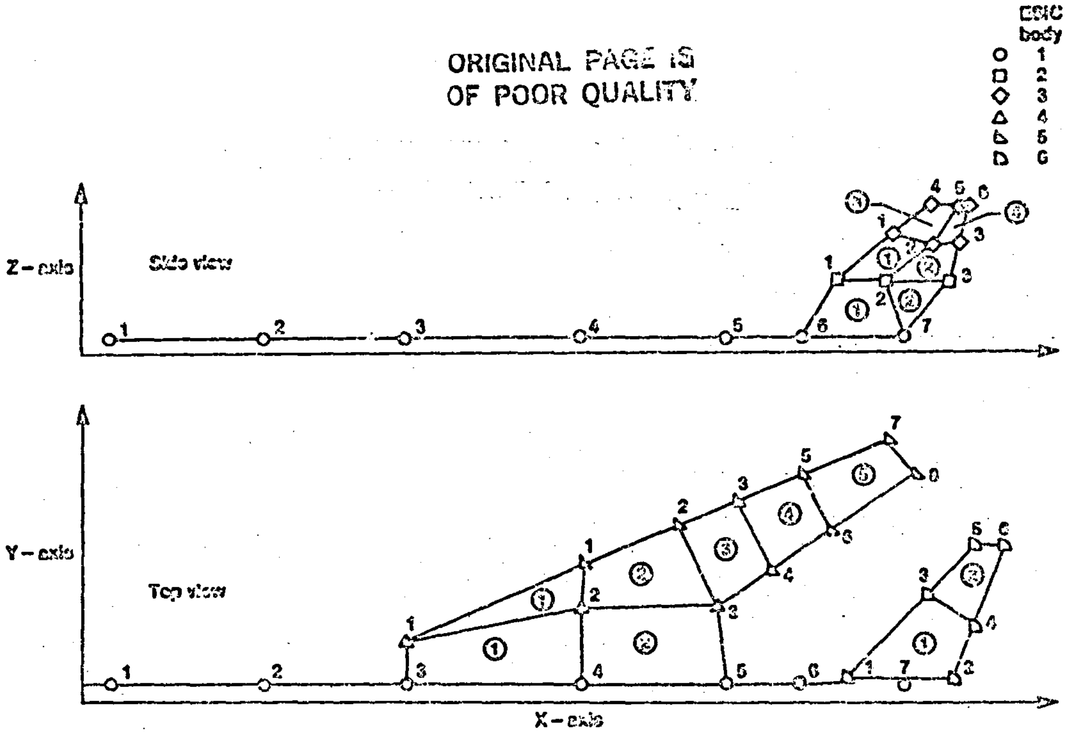


Figure 3. Simplified ESIC model. Circled numbers are ESIC panel numbers; other numbers are ESIC node numbers.

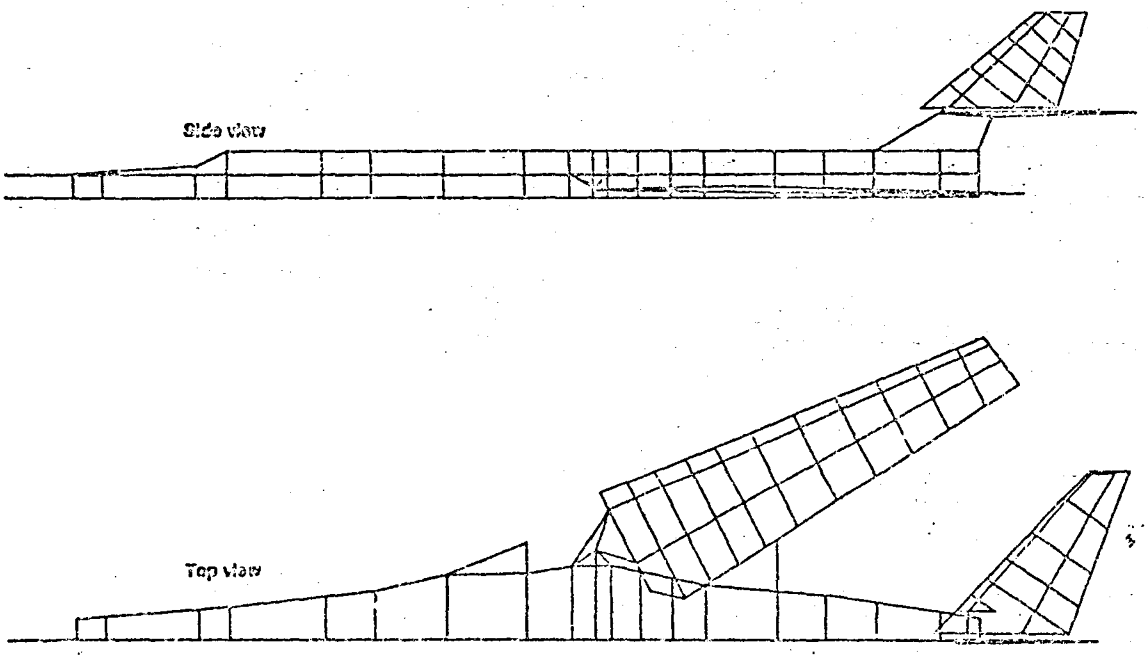


Figure 4. NASTRAN beam network model.

1. Report No.
NASA TM-84897

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
NASTRAN/FLEXSTAB Procedure for Static Aeroelastic Analysis

5. Report Date
September 1984

6. Performing Organization Code

7. Author(s)
Lawrence S. Schuster

8. Performing Organization Report No.
H-1223/A-9203

9. Performing Organization Name and Address
NASA Ames Research Center
Dryden Flight Research Facility
P.O. Box 273
Edwards, California 93523

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code
RTOP 505-33-61

15. Supplementary Notes

16. Abstract

Presented is a procedure for using the FLEXSTAB External Structural Influence Coefficients (ESIC) computer program to produce the structural data necessary for the FLEXSTAB Stability Derivatives and Static Stability (SD&SS) program. The SD&SS program computes trim state, stability derivatives, and pressure and deflection data for a flexible airplane having a plane of symmetry. The procedure uses a NASTRAN finite-element structural model as the source of structural data in the form of flexibility matrices. Selection of a set of degrees of freedom, definition of structural nodes and panels, reordering and reformatting of the flexibility matrix, and redistribution of existing point mass data are among the topics discussed. Also discussed are boundary conditions and the NASTRAN substructuring technique.

17. Key Words (Suggested by Author(s))
Flexibility matrix
Structural modeling
Boundary conditions
Symmetry and antisymmetry
Degrees of freedom
ESIC

18. Distribution Statement
[redacted]
[redacted]

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
19

22. Price*
A02

[redacted]

END

DATE

FILMED

SEP 9 1986