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NASA Contractor Report 187180

ASTROP3 User's Guide

(NASA-CR-187180) ASTROP3 USER'S GUIDE Final Report (Sverdrup Technology) 34 p CSCL 20K

N91-30562

Unclas

G3/39 0037371

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August 1991

Prepared for
Lewis Research Center
Under Contract NAS3-25266

National Aeronautics and
Space Administration

ASTROP3 USER'S GUIDE

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ASTROP3 USER'S GUIDE

This document is being provided as an aid in the preparation of the input data files necessary for the execution of the ASTROP3 computer code. It has been prepared under the guidelines provided by NASA's Computer Software Management and Information Center (COSMIC). This document is meant to serve as a guide in the use of the ASTROP3 code. Detailed explanations of the aerodynamic theory, aeroelastic analysis, or numerical algorithms are beyond the scope of this document, and may be found in the references. ASTROP3 has been developed by the NASA Lewis Structural Dynamics Branch in cooperation with Professor Marc Williams at Purdue University.

Please note that the ASTROP3 code is being made available strictly as a research tool. Neither NASA Lewis Research Center, nor any Contractors nor Grantees that have contributed to the code development, assume liability for application of the code beyond research needs.

1.0 PROBLEM/FUNCTION DEFINITION

ASTROP3 (**A**eroelastic **ST**ability and **R**esponse **O**f **P**ropulsion Systems) is a Fortran computer code developed for calculating the performance and dynamic stability, i.e., classical flutter, of single rotation, propfan rotors. Three-dimensional, subsonic aerodynamics with constant pressure panel descretization, and MSC/NASTRAN finite element analysis of the blade are used to calculate the steady and unsteady aerodynamic forces. The perfomance analysis can incorporate the blade's deflection under centrifugal and steady airloads to obtain the "hot" shape performance. The flutter analysis is a modal based technique utilizing motion dependent aerodynamic forces based on in-vacuum frequencies and normal modes of the individual propfan blades.

2.0 METHOD OF SOLUTION

Detailed explanations of the theory and method of solution are given in Williams (1990) and Kaza (1989). Williams (1990) provides the development of the aerodynamic theory, calculation of the air velocity normal to the blade surface, blade pressure distributions, calculation of net forces and moments on the blade, and efficiency of the propfan. Kaza (1989) describes the aeroelastic equation of motion of the blade, linearization of the equations of motion, steady-state configuration and vibration analysis, and gives an explanation of flutter analysis by the modal method. A somewhat more extensive explanation of just the programming details regarding the aerodynamic analysis is given in Williams (1985).

ASTROP3 has been developed with the flexibility of having structural modeling and aerodynamic panel descretization done independently. Interface subroutines interpolate structural geometry, deflection, and mode shapes into the format required for the aerodynamic formulation. Although this version of the code uses MSC/NASTRAN output format to transfer the structural information, it is not restricted to only that format. Other structural analyses, or even experimental displacement or modal data, may be imported with relatively minor programming revisions to the input subroutine.

The complete subroutine hierarchy for the program is given in Figure 1. The version of ASTROP3 described herein has three main sets of subroutines used for blade geometry input (CNNET), flutter (FLUTTER), and performance (PERF) analysis. Subroutines READFL and MESG are utility subroutintes used to read input data and output error messages, respectively. Also, there are calls to Version 1.0 IMSL subroutines throughout the code.

The first grouping consists of just the subroutine CNNET, the structural data input subroutine. CNNET reads MSC/NASTRAN output files containing the propfan blades' grid geometry, nodal steady-state displacements, blade in-vacuum natural frequencies, and mode shape information.
Information from CNNET is then processed by the subroutine NASTY, which is called by both FLUTTER and PERF. NASTY computes the blade planform in cylindrical coordinates and the interpolation coefficients to calculate the normal velocity on the aerodynamic panels. FLUTTER and PERF also call the subroutine PRPAN and its support subroutines which perform the aerodynamic analysis. The subroutine PRPAN calculates the steady-state blade normal velocities for performance analysis, blade pressure distribution, radial force distribution, and the performance parameters, i.e., thrust coefficient, power coefficient, and efficiency. PRPAN also calculates the generalized, unsteady forces for use in the flutter analysis.

The flutter analysis is performed by the ROOTS subroutine sub-grouping, which incorporates the generalized, unsteady forces into the aeroelastic equations of motion given in Williams (1990). The equations are formulated into an eigenvalue problem, with flutter occuring when the real part of the eigenvalue becomes positive.

3.0 USER INSTRUCTIONS FOR INPUT DATA

ASTROP3 is executed in a batch mode, and requires at least three user supplied data files. Necessary data files for the performance analysis option are: SRPARAMS dimensioning parameter file, program input file, and MSC/NASTRAN SOL64 output file containing grid coordinates, element connectivity and steady-state displacements. The flutter analysis option requires the same three files, plus an MSC/NASTRAN SOL63 output file containing frequencies and mode shapes. Descriptions of the required data files are given in the following sections.

3.1 SRPARAMS FILE

The SRPARAMS file is comprised of parameter definitions that are used to dimension arrays in the code. This flexibility of dimensioning arrays allows control of memory size requirements. The file contains Fortran PARAMETER statements which define a total of nine required parameter values. For ASTROP3 application purposes, the SRPARAMS file cannot contain any Fortran executable statements. An example SRPARAMS file is given in Figure 2.

The format of the PARAMETER statement is:

PARAMETER ($name_1 = xx_1$, ..., $name_n = xx_n$)

where: 1. the string "PARAMETER" starts no earlier than column 7
2. required integer variable definitions for ASTROP3 are:

name		description
nrpbm	=	maximum number of radial panels per blade
nxpm	=	maximum number of chordwise panels
nphmx	=	maximum number of intergroup phase angles
nbpgm	=	maximum number of blades per group
nmdmx	=	maximum number of assumed modes
nommx	=	maximum number of assumed interpolation frequencies
nnodmc	=	maximum number of finite element grid points
nxmxc	=	maximum number of finite element grid rows
nelemx	=	maximum number of elements in model

3.2 PROGRAM INPUT FILE

The program input file contains information on the type of analysis to perform; system data specifying blade, rotor, aerodynamic, aeroelastic, and structural input parameters; and analysis results to be output. It is comprised of three parts; main input, analysis input data, and end of data card. The main input data are the general propfan rotor information. It is always required, regardless of the analysis specified. Analysis input data are based on the type of analysis requested, performance or flutter. An end of data card is required to designate the stop-point of the input file.

The input format is semi-structured. A uniquely defined input word-string is used to locate the start of a data record. However, the data itself is entered as free-format. The combination word-string card and data records can occur in any order in the input file, but the data records must immediately follow the appropriate word-string card. Word-string cards are always designated by the "#" character in the first column. This way, the input deck can be commented as liberally, or as sparsely, as required. A sample input file is shown in Figure 3.

Descriptions of all the data records are given in the following sections. It should be noted again that the format of the word-string cards is unalterable; they <u>must</u> be entered exactly as shown, <u>must</u> start in column 1, and <u>must</u> be lower-case.

3.2.1 MAIN INPUT CARDS

word-string: # main : job type
input data : text string
description: text string = "perform" for performance analysis
text string = "flutter" for flutter analysis
note: separate data files need not be created for different analyses. Both types of cards maybe present in the job execution data file, but only the ones necessary for the specified analysis will be read.

word-string: # main : title
input data : text string
description: text string = job title card in A70 format

word-string: # main : rtip reference radius
input data : *rtip*
description: *rtip* = blade tip radius, inches

word-string: # main : s or rpm
input data : *s, rpm*
description: *s* = blade tip speed to axial Mach number ratio
rpm = rotor speed in revolutions per minute
note: only one variable to be defined, the other must be zero valued

word-string: # main : p0 ,a0
input data : *p0, a0*
description: *p0* = atmospheric pressure, psi
a0 = speed of sound at *p0*, inches/second

word-string: # main : axial Mach no.
input data : *mx*
description: *mx* = axial Mach number

word-string: # main : inmode
input data : *inmode*
description: *inmode* = 2 call CNNET to read structural data
note: for this version of ASTROP3, *inmode* must be set equal to 2

word-string: # main : no. of panels on chord
input data : *nxp*
description: *nxp* = number of chordwise panels
nxp cannot be greater than *nxpm* specified in the SRPARAMS file

word-string: # main : tse : partition of chord
input data : *tse(1), ..., tse(nxp)*
description: *tse* = panel partitioning of unit chord
If *tse*(1) = 0., uniform chord partitioning is used

word-string: # main : no. of blade groups
input data : *nb*
description: *nb* = number of identical blade groups or packets
for tuned analysis, *nb* = actual number of blades, and each group consists of one blade

word-string: # main : no. of blades per group
input data : *nbpg*
description: *nbpg* = number of identical blades per blade group
nbpg = 1 for tuned analysis
nbpg must be less than *nbpgm* in the SRPARAMS file

The following "# main :" data cards must be repeated *nbpg* times. These cards represent individual blade group parameters, and are only repeated for mistuned rotor analysis. The word-string card must include the string "for blade*xx*", where xx is a two digit, right justified, integer specifying the blade within the blade group.

word-string: # main : bet3q,dxt,dtht for blade*xx*
input data : bet3q, dxt, dtht
description: *bet3q* = 3/4 blade span setting angle, degrees
dxt = blade axial shift, inches
dtht = circumferential shift, degrees
note: dxt and dtht are used for aerodynamic de-tuning

word-string: # main : no. of radial panels for blade*xx*
input data : *nrp*
description: *nrp* = number of radial panels for blade*xx*
nrp cannot be greater than *nrpbm* specified in the SRPARAMS file

word-string: # main : panel radii for blade*xx*
input data : *ri(1), ..., ri(nrp+1)*
description: radial partitioning of blade, non-dimensionalized by blade tip radius
nrp+1 values required for *nrp* panels

word-string: # main,inmode=1 or 2 : file name for blade*xx*
input data : filename
description: name of scratch file to be used if inmode=1 or 2
note: filename format must be compatible with host machine

word-string: # main ,inmode=2 : cnnet job flag for blade*xx*
input data : *ijob*
description: *ijob* = 1; use blade cold shape, no deflections
ijob = 2; use blade hot shape, include deflections

The following cards are part of the main input, and are required for the CNNET subroutine.

word-string: # cnnet : number of grid points
input data : *ngpts*
description: *ngpts* = number of NASTRAN grid points in blade's structural model, must not exceed *nnodmc*

word-string: # cnnet : straddle grid points
input data : *le1, te1, le2, te2*
description: *le1* = leading edge grid point immediately below 3/4 span
te1 = trailing edge grid point immediately below 3/4 span
le2 = leading edge grid point immediately above 3/4 span
te2 = trailing edge grid point immediately above 3/4 span
note: these points are used to calculate the blade setting angle

3.2.2 ANALYSIS INPUT CARDS

The main input job type card is used to specify the analysis to be performed, either performance or flutter. Both types of analysis input cards may be present in the job execution data file, but only the ones necessary for the specified analysis will be read. Descriptions of the two types of analysis input cards are given in the following sections.

3.2.2.1 Performance Input Cards

word-string: # perform : nsol
input data : *nsol*
description: *nsol* = number of cases to analyze

word-string: # perform : iprnt : for isol = 1
input data : *iprnt(1), iprnt(2), iprnt(3), iprnt(4), iprnt(5)*
description: following print flag values will output defined results, any other value will suppress that output:
iprnt(1) = 1, list components of normal velocity
iprnt(2) = 1, list pressure distributions
iprnt(3) = 1, list distributed blade forces and moments
iprnt(3) = 2, list above and performance parameters
iprnt(4) = 1, list generalized forces
iprnt(4) = 2, generate NASTRAN PLOAD cards
iprnt(5) = 0, echo input and execute
iprnt(5) = 1, echo input only, no program execution
iprnt(5) = 2, no input echo, but execute program

The following "# perform :" data cards must be repeated *nsol-1* times (original performance analysis parameters were set with the main input cards). The word-string card must include "for isol=xx", where xx is a two digit, right justified, integer specifying the case number. If nsol=1, the above two cards are sufficient to run just the one performance case.

word-string: # perform : s,rpm,bet3q(1,nbpg) : for isol=xx
input data : *s, rpm, bet3q(1,1), ..., bet3q(1,nbpg)*
description: *s* = blade tip speed to axial Mach number ratio
rpm = rotor speed in revolutions per minute
note: only one variable to be defined, the other must be zero-valued
bet3q(1,i) = blade setting angle for each blade in group

word-string: # perform : iprnt : for isol =xx
input data : *iprnt(1), iprnt(2), iprnt(3), iprnt(4), iprnt(5)*
description: performance analysis output flags, see description above

3.2.2.2 Flutter Input Cards

The following four "# flut :" data cards must be repeated *nbpg* times. These cards represent individual blade group parameters, and are only repeated for mistuned rotor analysis. The word-string card must include "for blade*xx*", where *xx* is a two digit, right justified, integer specifying the blade within the blade group.

word-string: # flut : nmodeb : for blade*xx*
input data : *nmodeb*
description: *nmodeb* = number of blade modes used in analysis

word-string: # flut : jdist(nmodeb) : for blade*xx*
input data : *jdist(1), ..., jdist(nmodeb)*
description: *jdist* = 1, calculate upwash based on modal displacements and rotations
jdist = 2, calculate upwash based on modal displacements only

word-string: # flut : nsol
input data : *nsol*
description: *nsol* = number of flutter cases to analyze

The following "# flut :" data cards must be repeated *nsol* times. The word-string card must include "for sol*xx*", where *xx* is a two digit, right justified, integer specifying the case number.

word-string: # flut : nphase : for sol*xx*
input data : *nphase*
description: *nphase* = number of intergroup phase angles to analyze,
nphase cannot not be greater than *nphmx* specified in SRPARAMS file

word-string: # flut : iph(i),i=1,nphase : for sol*xx*
input data : *iph(1), ..., iph(nphase)*
description: intergroup phase angle indices to analyze

word-string: # flut : nom : for sol*xx*
input data : *nom*
description: number of interpolation frequencies
nom cannot be greater than *nommx* specified in the SRPARAMS file

word-string: # flut : om(i),i=1,nom : for sol*xx*
input data : *om(1), ..., om(nom)*
description: interpolation frequencies, hz, to evaluate for flutter

word-string: # flut : jcat : for sol*xx*
input data : *jcat*
description: *jcat* = 0, no print out of aeroelastic eigenvectors
jcat = 1, print out aeroelastic eigenvectors

word-string: # flut = iprnt(*) : for sol*xx*
input data : *iprnt(1), iprnt(2), iprnt(3), iprnt(4), iprnt(5)*
description: see description in Section 3.2.2

3.2.3 END OF DATA CARD

word-string: #end
description: required card that designates end of input data

3.3 NASTRAN OUTPUT FILES

For this version of ASTROP3, the propfan blade structural information is supplied through MSC/NASTRAN output files. The information is read into the program through the CNNET subroutine. The CNNET reads the MSC/NASTRAN output files directly, eliminating the need for any NASTRAN post-processing, or extra NASTRAN-ASTROP3 translators. Currently, the finite element models must be constructed of either CTRIA3 or CQUAD4 shell elements. The CNNET subroutine does require that the blade finite element model be defined in a right-handed cartesian coordinate system; with the axial air flow along the positive x-axis, and the pitch change axis, i.e., blade span, along the z-axis. Also, grid points must be numbered leading edge to trailing edge, root to tip. For each node row, the x-coordinate must be increasing in value for blade leading edge to trailing edge. It is assumed the blade's rotation vector is also along the positive x-axis.

The performance analysis option requires an MSC/NASTRAN output file containing grid geometry, element connectivity, and grid point displacements. The grid displacements are required only if IJOB=2. The keywords which CNNET scans to input data; and therefore must be present in the NASTRAN output file, are: "CTRIA" or "CQUAD" starting in column 30 for element connectivity, "GRID" starting in column 30 for grid point coordinates, "D I S P L A C E M E N T" starting in column 45 for grid point displacements, "R E A L E I G E N V A L U E" starting in column 46 for natural frequencies, and the eigenvector number starting in column 88.

If grid displacements are required, the CNNET subroutine will read only the first set of displacements it locates. Therefore, the output file should be stripped of all unnecessary displacement subcases before it is used within ASTROP3. To further save user file space, only the NASTRAN grid geometry, element connectivity, and required displacement output data cards need be saved.

The flutter analysis option requires a second MSC/NASTRAN output file which contains the blade's natural frequencies, generalized masses, and mode shapes. Again, to save user file space, all records may be deleted; save for the eigenvalue table, and *nmodeb* eigenvectors.

Details on performing NASTRAN analysis for propfan blades are given in Lawrence, (1984,1987).

4. IMPLEMENTATION INSTRUCTIONS

At LeRC, ASTROP3 is run in batch mode on the Cray-XMP, with UNICOS operating system. Figure 4 illustrates a sample job execution file to compile, load, and execute ASTROP3. The propfan being analyzed is comprised of eight SR7L blades. This job execution file is submitted to the Cray from a VM front-end machine. The files being accessed via the "fetch" command are:

fn	ft	
srparams	fortran	SRPARAMS file containing parameter definitions
astrop3	input	program input file
sr7l189c	mscdefl1	SR7L NASTRAN output file with blade geometry and deflections
sr7l	modes	SR7L NASTRAN output file with frequencies and mode shapes (required only for flutter analysis)
astrop3	fortran	source code
sr_aero	output	output file sent to the VM RDRLIST

The IMSL library subroutines are loaded through the segldr.inp file. This file is comprised of the following two lines:

```
lib = /tpsw/imsl/imslib.a
dupentry = ignore
```

For further explanation of the UNICOS commands used in the jobstream, see the Cray Research Inc., UNICOS User Commands Reference Manual.

5. SAMPLE PROBLEM

The sample job input data file shown in Fig. 3 was used in conjunction with the job execution file described above to perform a performance and a flutter analysis. The blade analyzed is the SR7L large-scale propfan. The MSC/NASTRAN output files were previously generated and stored. Explanations of the program output are provided in the following sections.

5.1 PERFORMANCE OPTION

The performance option calculates three performance parameters: thrust coefficient, power coefficient, and efficiency. The performance analysis output is given in Fig. 5. The first page of output is an echo of the structural grid coordinate information. The planform data is then echoed in cylindrical coordinates, and represents the blade's panel descritization based on the input number of radial and chordwise panels.

The normal velocity distribution calculated in the UPWASH subroutine is printed in complex format under "displacements & slopes," *(iprnt(1)=1)*. For the steady case, normal velocity is based strictly on the rotor rotational speed with the oscillatory component, or the imaginary part, of the normal velocity being zero. The normal velocities are printed out for the root to tip radial panels, from leading edge panel to trailing edge.

The steady pressure difference across the blade due to the normal velocity is printed out next *(iprnt(2)=1)*. The real and imaginary parts of the pressure are printed out for each non-dimensional, panel mid-span radius, from leading edge to trailing edge. Since this is a steady case, only the real part of the pressure has a non-zero value.

The net forces and moments acting on the blade are printed out next *(iprnt(3)>0)*. These are calculated by integrating the pressure distribution over the blade. Note again, that for the steady case, there is no imaginary component to the forces and moments.

The performance parameters; advance ratio, thrust and power coefficients *(iprnt(3)=2)* are then listed. Since these are steady-state parameters, the data output is only meaningful in terms of the performance option. A second case *(nsol=2)* is also listed in this output.

5.2 FLUTTER OPTION

The flutter option calculates the stability of the blade at a specified Mach number and rotational speed. The program solves for the eigenvalues and eigenvectors of the system equations of motion, including the motion dependent aerodynamic forces. Flutter is predicted to occur when the real part of one of the system's eigenvalues, representative of the modal damping, becomes positive. The recommended print parameters are *iprnt = 0,0,0,0,0*. Setting *jcat* to 1 also will print out the complex aeroelastic eigenvectors at the operating point in terms of the structural modes.

The flutter analysis is actually an iterative procedure, requiring at least two runs to determine stability at a particular point. The first trial run should have *nom* set to at least three, and *om* set to a wide band frequency range which would include lower, mid-range, and upper frequencies spanning *nmodeb* blade frequencies. These frequencies are used to interpolate generalized unsteady aerodynamic forces for each intergroup phase angle. Eigenvalues are then calculated for each modal component of each intergroup phase angle. For the case used in the input, six modes and eight intergroup phase angles result in 48 eigenvalues at the operating point (Fig. 6). The least damped eigenvalue, i.e., the largest valued real part of the 48 eigenvalues, is found to be the first interblade phase angle, third mode.

The second run is restricted to a narrow band, two frequency range which brackets (104 to 106 hz) the least damped eigenvalue. The eigensolution table in Fig. 7 shows a large negative damping value i.e., -1.1683, for the 105 hz eigenvalue, implying this to be a very stable point at the subsonic operating point.

Since this is a modal based approach, and the modes and frequency are affected by changes in RPM, only the axial Mach number may be changed without re-running the structural analysis. Therefore, a flutter point at a fixed RPM can be found by increasing the Mach number until the damping becomes positive.

6. ENVIRONMENTAL CHARACTERISTICS

This program is currently operational on the NASA-Lewis Research Center's Cray XMP with the UNICOS operating system. The source code is written in standard FORTRAN77. Because the Cray uses 32-bit precision by default, the variables used are all Cray-single precision, as are all calls to the Version 1.0 IMSL library routines.

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Kaza, K.R.V., et. al., "Analytical Flutter Investigation of a Composite Propfan Model," Journal of Aircraft, Vol. 26, No. 8, August, 1989, pp. 772-780.

Williams, M.H., "User's Guide to UPROP3S," Purdue University Report, January, 1985.

Williams, M.H., "Unsteady Lifting Surface Method for Single Rotation Propellers," NASA CR 4302, July, 1990.

Cray Research, Inc., UNICOS User Commands Reference Manual, SR-2011, 1987.

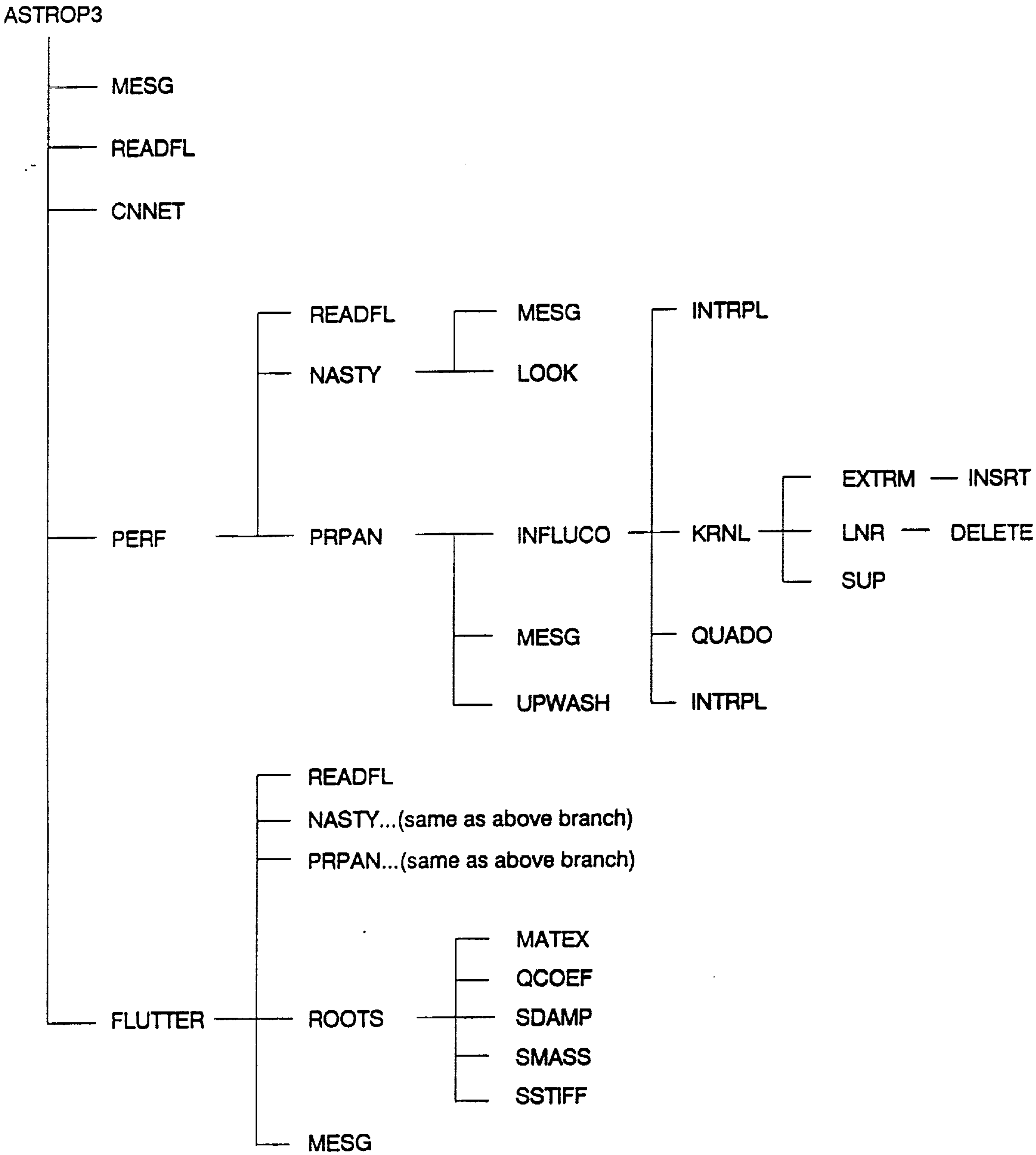

Fig. 1 ASTROP3 Subroutine Hierarchy

```
c     SRPARAMS FILE FOR SINGLE ROTATION 3D AEROELASTIC CODE
      parameter (nrpbm=17,nxpm=8,nphmx=8,nbpgm=2)
      parameter (nmdmx=6)
      parameter (nommx=10)
      parameter (nnodmc=360,nxmxc=50)
      parameter (nelemx=800)
c
c         nrpbm  =  max. no. of radial panels per blade
c         nxpm   =  max. no. of chordwise panels
c         nphmx  =  max. no. of inter-group phase angles
c         nbpgm  =  max. no. of blade per group
c         nmdmx  =  max. no. of assumed modes
c         nommx  =  max. no. of assumed interpolation frequencies
c         nnodmc =  max. no. of finite element grid points
c         nxmxc  =  max. no. of finite element grid rows
c         nelemx =  max. no. of elements in model
c
```

Fig. 2 SRPARAMS File

```
                input format for ASTROP3

..   This file can be read by the ASTROP3.
..   The lines starting with "#" are flags indicating that the immediately
     following line is to be read.
..   All numeric format is free.
..   All #lines must be exact and unique.
..   Character string data is in A70 format
..   The file must end with '#end'.

          MAIN INPUT
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
..   just move the desired job up to top of stack
# main : job type
flutter
perform

# main : title
ASTROP3/SR7L FLUTTER ANALYSIS, WIDE BAND FREQUENCY INTERPOLATION

# main : rtip reference radius
  53.90

# main : s or rpm
0.   1420.0

# main :  p0 ,a0
13.6  13380.

# main :  axial mach no.
.685

..  inmode is 0, 1 or 2
# main :  inmode
2

# main :  no. of panels on chord
8

..  tse(1) = 0 means default uniform spacing
# main :  tse : partition of chord
0  0  0  0  0  0  0  0

# main :  no. of blade groups
8

# main :  no. of blades per group
1
```

Fig. 3 ASTROP3 Sample Input File

```
..  repeat the rest of the data nbpg times
..  flags must read "..bladeXX", XX is 2 digit, right justified, integer

..  bet3q = desired blade setting angle in deg.
..  dxt = desired axial shift
..  dtht = circumferential shift (deg)
# main :  bet3q,dxt,dtht for blade 1
56.7     0.   0.

# main :  no. of radial panels for blade 1
12


# main :  panel radii for blade 1
.35 .45 .54 .62 .69 .75 .80 .85 .89 .93 .96 .98 1.

# main,inmode=1 or 2 : file name for blade 1
DAT31

..  cnnet flag:  1=cold shape;  2=hot shape
# main ,inmode=2 : cnnet job flag for blade 1
1

.....     end of main section

# cnnet : number of grid points
     244                     $ number of grid points
# cnnet : straddle grid points
     127  140  141  154      $ LE1, TE1;  LE2, TE2

..  end of cnnet data

               PERFORMANCE INPUT
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
# perform : nsol
2

# perform : iprnt : for isol= 1
1 1 2 0 0

..  the following block of data should be repeated nsol-1 times
# perform : s,rpm,bet3q(1,nbpg) : for isol= 2
0. 1500.0  56.7

# perform : iprnt : for isol= 2
0 0 2 0 2

          end of performance input
```

Fig. 3 ASTROP3 Sample Input File (cont.)

```
                 FLUTTER INPUT
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

 input for each blade ib=1,nbpg ,repeat as needed:

..  nmodeb=no. of blade modes
# flut : nmodeb : for blade 1
 6

# flut : jdist(nmodeb) : for blade 1
 2 2 2 2 2 2

 end of individual blade input

# flut : nsol
1

..  the next block of 6 read lines should be repeated nsol times
# flut : nphase : for sol 1
8

# flut : iph(i),i=1,nphase : for sol 1
0  1  2  3  4  5  6  7

# flut : nom : for sol 1
3

# flut : om(i),i=1,nom : for sol 1
 30.  130.  230.

..  to print out eigenvectors, set jcat = 1
# flut : jcat : for sol 1
 0

# flut : iprnt(*) : for sol 1
0 0 0 0 0

..  END OF NSOL BLOCK

..  END OF FLUTTER INPUT

#end
```

Fig. 3 ASTROP3 Sample Input File (cont.)

```
# USER=        PW=
# QSUB-r sr3djcl
# QSUB-lT 60
# QSUB-lM 1.6Mw
set -kx
#cd
fetch srparams -t'fn=srparams,ft=fortran,addr=192'
fetch sr_in    -t'fn=astrop3, ft=input'
fetch mscdisp  -t'fn=sr71189c,ft=mscdefll,addr=192'
fetch mscmode  -t'fn=sr71,ft=modes,addr=192'
fetch sr_3d.f  -t'fn=astrop3 ,ft=fortran,addr=192'
#.....COMPILE, LOAD, AND RUN
cft77 -V  sr_3d.f
segldr -V -o sraero sr_3d.o $HOME/segldr.inp
#..DEFINE LOGICAL UNITS 20 & 30 FOR SUBROUTINE CNNET
ln mscdisp fort.20
ln mscmode fort.30
#
time sraero < sr_in > sr_out
dispose sr_out -nsr_aero -t'ft=output'
```

Fig. 4 ASTROP3 Job Execution File

```
1 DATE: 12/19/90       TIME: 15:27:24
 ASTROP3/SR7L PERFORMANCE ANALYSIS
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 +  pressure       = 13.6 psi
 +  speed of sound = 13380. inches/sec
 +  density        = 1.0635421763737E-7 lbm/(in**3)
 ++++++++++++++++++++++++++++
  data for bladel is writen to DAT31 by subroutine cnnet
  ..... STARTING SUBROUTINE CNNET
  ..... COMPLETED READING CNNET ELEMENT CONNECTIVITY
        CTRIA ELEMENTS READ: 449
 GRID        127          -7.3136 -2.9637 41.0000
 GRID        140           9.1913  8.1437 41.0000
 GRID        141          -5.4239 -1.6950 43.5000
 GRID        154           9.4272  8.8009 43.5000
  ..... COMPLETED READING CNNET GRID POINT GEOMETRY DATA
   NO. ELEMS, GRDPTS    = 449,  244
   LE1, TE1;  LE2,TE2   = 127,  140,  141,  154
   RPM                  = 1420.
      BETA1 = 0.9784384994579
      BETA2 = 0.955559672999
      RTIP, R2, R1 = 53.018,  43.5,  41.
      BETAG = 0.9897543670245
      BLADE SETTING ANGLE = 56.70874798515
      INPUT SETTING ANGLE = 56.7
      ... program currently can only handle 1 value for bet34
      DBET                 = 8.7479851486777E-3
 .....COMPLETED SUBROUTINE CNNET


 ********************************************************
       steady performance calculation
 *******************************************************
 *    operating conditions:
 *   ROTOR SPEED(RPM) = 1420.
 *   MACH NO.         = 0.685
 *   REF. TIP RADIUS  = 53.9 INCHES
 *********************************
 *********************************
 * data from finite element model:
 *   blade no.1
 * no. of nodes=244
 * beta 3/4 of input geometry:56.7
 * bet 3/4 =56.7
 *********************************
```

Fig. 5 ASTROP3 Performance Analysis Output

```
1                     propeller aerodynamic load analysis
0     number of blade groups =       8
      axial mach no.         =  0.685
      tip speed/axial speed  =  0.874
      EFFECTIVE TIP VELOCITY =  0.910
      INCOMING AIR @ 3/4 RAD = 56.740 DEGREES
0                        planform data
0               leading edge            trailing edge
      r         theta        x          theta        x
0  0.35000  -0.197E+00 -0.206E+00   0.129E+00  0.145E+00
0  0.45000  -0.200E+00 -0.226E+00   0.128E+00  0.139E+00
0  0.54000  -0.183E+00 -0.223E+00   0.145E+00  0.144E+00
0  0.62000  -0.153E+00 -0.206E+00   0.164E+00  0.153E+00
0  0.69000  -0.118E+00 -0.178E+00   0.181E+00  0.162E+00
0  0.75000  -0.800E-01 -0.144E+00   0.192E+00  0.168E+00
0  0.80000  -0.443E-01 -0.107E+00   0.198E+00  0.173E+00
0  0.85000  -0.490E-02 -0.617E-01   0.199E+00  0.177E+00
0  0.89000   0.287E-01 -0.201E-01   0.198E+00  0.181E+00
0  0.93000   0.629E-01  0.259E-01   0.194E+00  0.185E+00
0  0.96000   0.883E-01  0.633E-01   0.189E+00  0.189E+00
0  0.98000   0.105E+00  0.892E-01   0.186E+00  0.191E+00
0  1.00000   0.129E+00  0.115E+00   0.182E+00  0.193E+00
        chord partition
     number of chordwise panels=   8
     tse(j)=0.125 0.250 0.375 0.500 0.625 0.750 0.875 1.000
0    control point position=0.850
0     number of blade vibration modes=  1
      no. of interblade phase angles=  1
      phase indices=  0,
 ********************************
 *...IN PRPAN, IPRNT  = 2*1,  2,  2*0
1     vibration freq./rotor freq.=     0.000
 displacements & slopes at control pts.:
MODE/PANEL
  1 /  1  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.090357 -0.068952 -0.047264 -0.024603 -0.000520  0.025009  0.051528  0.078023
  1 /  2  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.081630 -0.054285 -0.043165 -0.025335 -0.003303  0.015998  0.051798  0.079432
  1 /  3  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.083415 -0.060099 -0.036782 -0.013466  0.009851  0.033167  0.056484  0.079800
  1 /  4  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.075877 -0.053921 -0.031965 -0.010008  0.011948  0.033905  0.055861  0.077817
  1 /  5  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.056416 -0.029986 -0.018278 -0.005483  0.010427  0.024402  0.044129  0.070259
  1 /  6  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        -0.048313 -0.025243 -0.012407  0.001839  0.013974  0.024005  0.036161  0.056567
```

Fig. 5 ASTROP3 Performance Analysis Output (cont.)

```
  1 /  7  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
         -0.041390 -0.015866 -0.001013  0.009967  0.020210  0.028777  0.036639  0.053204
  1 /  8  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
         -0.026070 -0.004319  0.009748  0.021938  0.030835  0.038817  0.045671  0.060100
  1 /  9  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
         -0.009459  0.010508  0.026549  0.038987  0.048638  0.056009  0.061637  0.067698
  1 / 10  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
          0.007998  0.026605  0.039117  0.046297  0.052461  0.060335  0.075515  0.084866
  1 / 11  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
          0.022219  0.040187  0.052464  0.060234  0.068186  0.083121  0.095524  0.107970
  1 / 12  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
          0.189797  0.030168 -0.129461 -0.289091 -0.448720 -0.608349 -0.767978 -0.927608
1$$$$$$$$$$$ vibration mode index:    1
 *********** interbladephase index:0
                              pressure distribution
         leading edge                          trailing edge
  0.4000E+00
  0.3033E+00 -0.2346E-01 -0.7060E-01 -0.1006E+00 -0.1180E+00 -0.1257E+00 -0.1213E+00 -0.9298E-01
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.4950E+00
  0.3221E+00 -0.1848E-01 -0.5559E-01 -0.1115E+00 -0.1426E+00 -0.1502E+00 -0.1720E+00 -0.1191E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.5800E+00
  0.3337E+00 -0.1815E-01 -0.8673E-01 -0.1329E+00 -0.1584E+00 -0.1674E+00 -0.1588E+00 -0.1186E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.6550E+00
  0.3074E+00 -0.2725E-01 -0.9421E-01 -0.1356E+00 -0.1587E+00 -0.1652E+00 -0.1543E+00 -0.1165E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.7200E+00
  0.2427E+00 -0.4529E-01 -0.8093E-01 -0.1206E+00 -0.1448E+00 -0.1449E+00 -0.1445E+00 -0.1204E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.7750E+00
  0.1912E+00 -0.5275E-01 -0.8837E-01 -0.1222E+00 -0.1318E+00 -0.1273E+00 -0.1198E+00 -0.1044E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.8250E+00
  0.1352E+00 -0.7147E-01 -0.1003E+00 -0.1178E+00 -0.1225E+00 -0.1114E+00 -0.9460E-01 -0.8632E-01
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.8700E+00
  0.5890E-01 -0.8745E-01 -0.1105E+00 -0.1214E+00 -0.1114E+00 -0.9109E-01 -0.6826E-01 -0.6423E-01
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.9100E+00
 -0.3930E-01 -0.1074E+00 -0.1246E+00 -0.1173E+00 -0.8989E-01 -0.5415E-01 -0.3092E-01 -0.2379E-01
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.9450E+00
```

Fig. 5 ASTROP3 Performance Analysis Output (cont.)

```
************ total blade forces:cfx,cfy,cfz:
-0.6970E-02  0.0000E+00  0.1234E-01  0.0000E+00 -0.3064E-02  0.0000E+00

*********** total blade moments: cmx,cmy,cmz:
-0.7849E-02  0.0000E+00 -0.4364E-02  0.0000E+00  0.2271E-02  0.0000E+00

performance parameters:
      advance ratio:
 0.3592E+01
    thrust and power coefficients:
 0.1376E+00  0.5954E+00
    efficiency :
 0.8301E+00


*********************************
*...IN PERF, RETURN FROM PRPAN
+++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++


 *    operating conditions:
 *   ROTOR SPEED(RPM) = 1500.
 *   MACH NO.         = 0.685
 *   REF. TIP RADIUS  = 53.9 INCHES
 *********************************
 .....PRINT FLAGS: 2*0,  2,  0,  2
 *********************************
 *...IN PRPAN, IPRNT  = 2*0,  2,  0,  2
1     vibration freq./rotor freq.=     0.000


 ************ total blade forces:cfx,cfy,cfz:
 -0.1107E-01  0.0000E+00  0.1907E-01  0.0000E+00 -0.2428E-02  0.0000E+00

 *********** total blade moments: cmx,cmy,cmz:
 -0.1262E-01  0.0000E+00 -0.7446E-02  0.0000E+00  0.1696E-02  0.0000E+00

 performance parameters:
       advance ratio:
  0.3401E+01
     thrust and power coefficients:
  0.2185E+00  0.8515E+00
     efficiency :
  0.8725E+00


*********************************
*...IN PERF, RETURN FROM PRPAN
+++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Fig. 5 ASTROP3 Performance Analysis Output (cont.)

```
1 DATE: 12/19/90      TIME: 10:34:04
 ASTROP3/SR7L FLUTTER ANALYSIS, WIDE BAND FREQUENCY INTERPOLATION
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 +  pressure        = 13.6 psi
 +  speed of sound = 13380. inches/sec
 +  density         = 1.0635421763737E-7 lbm/(in**3)
 ++++++++++++++++++++++++++++
  data for blade1 is writen to DAT31 by subroutine cnnet
  ..... STARTING SUBROUTINE CNNET
  ..... COMPLETED READING CNNET ELEMENT CONNECTIVITY
        CTRIA ELEMENTS READ: 449
GRID        127          -7.3136 -2.9637 41.0000
GRID        140           9.1913  8.1437 41.0000
GRID        141          -5.4239 -1.6950 43.5000
GRID        154           9.4272  8.8009 43.5000
  ..... COMPLETED READING CNNET GRID POINT GEOMETRY DATA
   NO. ELEMS, GRDPTS     = 449,  244
   LE1, TE1;  LE2,TE2    = 127,  140,  141,  154
   RPM                   = 1420.
      BETA1 = 0.9784384994579
      BETA2 = 0.955559672999
      RTIP, R2, R1 = 53.018,  43.5,  41.
      BETAG = 0.9897543670245
      BLADE SETTING ANGLE = 56.70874798515
      INPUT SETTING ANGLE = 56.7
      ... program currently can only handle 1 value for bet34
      DBET                  = 8.7479851486777E-3
.....reading frequencies and mode shapes
  READING FREQS AND MODE SHAPES FROM MSC    OUTPUT
                           0.432172E+02       0.100000E+01
                           0.938468E+02       0.100000E+01
                           0.106040E+03       0.100000E+01
                           0.143162E+03       0.100000E+01
                           0.174288E+03       0.100000E+01
                           0.223927E+03       0.100000E+01
 READING MODE SHAPES FROM MSC    OUTPUT
 COMPLETED READING 6 MODE SHAPES
.....COMPLETED SUBROUTINE CNNET
```

Fig. 6 ASTROP3 Wide Band Frequency Stability Output

```
*****************************************************
*        aeroelastic stability analysis             *
*      using normal mode structural model           *
*****************************************************
*    operating conditions:
*  rotor speed(rpm)=1420.
*  mach no.= 0.685
*  tip radius=53.9
modes 1 to 6 are for blade 1
*********************************
* data from finite element model:
*   blade no.1
* no. of nodes=244
* beta 3/4 of input geometry:56.7
* bet 3/4 =56.7
*********************************

                  structural model
 mode     freq(hz)     gen. mass     mass ratio   jdist
-------------------------------------------------------
   1       43.22         1.00         60.045        2
   2       93.85         1.00         60.045        2
   3      106.04         1.00         60.045        2
   4      143.16         1.00         60.045        2
   5      174.29         1.00         60.045        2
   6      223.93         1.00         60.045        2
-------------------------------------------------------

####################################################
        analysis using 3 frequencies:
30.,  130.,  230.
####################################################
.....PRINT FLAGS: 6*0
1                  propeller aerodynamic load analysis
0     number of blade groups =      8
      axial mach no.         =  0.685
      tip speed/axial speed  =  0.874
      EFFECTIVE TIP VELOCITY =  0.910
      INCOMING AIR @ 3/4 RAD = 56.740 DEGREES
0                        planform data
0               leading edge             trailing edge
      r         theta        x           theta       x
0  0.35000  -0.197E+00 -0.206E+00   0.129E+00  0.145E+00
0  0.45000  -0.200E+00 -0.226E+00   0.128E+00  0.139E+00
0  0.54000  -0.183E+00 -0.223E+00   0.145E+00  0.144E+00
0  0.62000  -0.153E+00 -0.206E+00   0.164E+00  0.153E+00
0  0.69000  -0.118E+00 -0.178E+00   0.181E+00  0.162E+00
0  0.75000  -0.800E-01 -0.144E+00   0.192E+00  0.168E+00
```

Fig. 6 ASTROP3 Wide Band Frequency Stability Analysis Output (cont.)

```
0  0.80000  -0.443E-01 -0.107E+00   0.198E+00  0.173E+00
0  0.85000  -0.490E-02 -0.617E-01   0.199E+00  0.177E+00
0  0.89000   0.287E-01 -0.201E-01   0.198E+00  0.181E+00
0  0.93000   0.629E-01  0.259E-01   0.194E+00  0.185E+00
0  0.96000   0.883E-01  0.633E-01   0.189E+00  0.189E+00
0  0.98000   0.105E+00  0.892E-01   0.186E+00  0.191E+00
0  1.00000   0.129E+00  0.115E+00   0.182E+00  0.193E+00
        chord partition
    number of chordwise panels=   8
    tse(j)=0.125 0.250 0.375 0.500 0.625 0.750 0.875 1.000
0   control point position=0.850
0     number of blade vibration modes=  6
      no. of interblade phase angles=  8
      phase indices=  0,  1,  2,  3,  4,  5,  6,  7,
 ********************************
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
  eigensolution for phase index:0
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
    all eigenvalues (hz)
     1,  (-12.34342808236,222.4348675411)
     2,  (-8.430483923127,142.5122943267)
     3,  (-2.254087417544,42.7697552196)
     4,  (-2.113879638344,174.0122618893)
     5,  (-1.219855809496,105.5171506033)
     6,  (-1.200094818753,93.84092603339)
    root 2 is closest to center of interpolation
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
  eigensolution for phase index:1
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
    all eigenvalues (hz)
     1,  (-12.54312095436,221.7119220797)
     2,  (-8.583149279512,141.4252431576)
     3,  (-2.382299242619,42.63035094589)
     4,  (-2.166587344366,173.9196842262)
     5,  (-1.220031205825,93.78142796405)
     6,  (-1.190494893632,105.4259691041)
    root 2 is closest to center of interpolation
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
  eigensolution for phase index:2
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
    all eigenvalues (hz)
     1,  (-12.5760826653,221.2953421176)
     2,  (-9.25344098654,141.1448732931)
     3,  (-2.59807750405,42.73643134739)
     4,  (-2.249934260488,173.8465502081)
     5,  (-1.234516161238,105.2925202502)
     6,  (-1.233387459689,93.70915066049)
    root 2 is closest to center of interpolation
```

Fig. 6 ASTROP3 Wide Band Frequency Stability Analysis Output (cont.)

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 eigensolution for phase index:3
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
   all eigenvalues (hz)
    1,   (-12.99975390008,221.2281778156)
    2,   (-10.31529778295,141.4286228785)
    3,   (-2.77742084113,42.85729924807)
    4,   (-2.389843186313,173.8014780576)
    5,   (-1.329497379935,105.1528152133)
    6,   (-1.257827465067,93.63373725742)
   root 2 is closest to center of interpolation
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 eigensolution for phase index:4
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
   all eigenvalues (hz)
    1,   (-13.8590017778,221.452519162)
    2,   (-11.64162682301,142.8099467078)
    3,   (-3.120981896248,42.7199777722)
    4,   (-2.5788288919,173.8881887375)
    5,   (-1.421250438564,104.9922544073)
    6,   (-1.29082466778,93.56502825796)
   root 2 is closest to center of interpolation
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 eigensolution for phase index:5
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
   all eigenvalues (hz)
    1,   (-14.6361012224,222.7163237579)
    2,   (-12.05358761691,144.8242135549)
    3,   (-3.631083398106,43.18397697827)
    4,   (-2.604189299876,174.0030701909)
    5,   (-1.615156347791,104.9022109986)
    6,   (-1.326662795546,93.56162490391)
   root 2 is closest to center of interpolation
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 eigensolution for phase index:6
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
   all eigenvalues (hz)
    1,   (-13.28286105292,223.8411181207)
    2,   (-9.868719933715,147.6344631766)
    3,   (-2.980591163725,43.84469516651)
    4,   (-2.575553329305,174.3271464039)
    5,   (-1.811372654675,105.1901832782)
    6,   (-1.36140829403,93.65895697999)
   root 2 is closest to center of interpolation
```

Fig. 6 ASTROP3 Wide Band Frequency Stability Analysis Output (cont.)

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 eigensolution for phase index:7
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
   all eigenvalues (hz)
    1,  (-12.53322284232,222.4257905631)
    2,  (-6.894192917693,144.4584332531)
    3,  (-2.23366030958,43.18575496496)
    4,  (-2.137688713755,174.2443855429)
    5,  (-1.542132154408,105.5776711497)
    6,  (-1.333205251912,93.8227079924)
   root 2 is closest to center of interpolation
```

Fig. 6 ASTROP3 Wide Band Frequency Stability Analysis Output (cont.)

```
1 DATE: 12/19/90       TIME: 11:03:47
 ASTROP3/SR7L FLUTTER ANALYSIS, NARROW BAND FREQUENCY INTERPOLATION
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 +  pressure       = 13.6 psi
 +  speed of sound = 13380. inches/sec
 +  density        = 1.0635421763737E-7 lbm/(in**3)
 ++++++++++++++++++++++++++++
  data for bladel is writen to DAT31 by subroutine cnnet
  ..... STARTING SUBROUTINE CNNET
  ..... COMPLETED READING CNNET ELEMENT CONNECTIVITY
        CTRIA ELEMENTS READ: 449
 GRID        127         -7.3136 -2.9637 41.0000
 GRID        140          9.1913  8.1437 41.0000
 GRID        141         -5.4239 -1.6950 43.5000
 GRID        154          9.4272  8.8009 43.5000
  ..... COMPLETED READING CNNET GRID POINT GEOMETRY DATA
   NO. ELEMS, GRDPTS     = 449,  244
   LE1, TE1;  LE2,TE2    = 127,  140,  141,  154
   RPM                   = 1420.
      BETA1 = 0.9784384994579
      BETA2 = 0.955559672999
      RTIP, R2, R1 = 53.018,  43.5,  41.
      BETAG = 0.9897543670245
      BLADE SETTING ANGLE = 56.70874798515
      INPUT SETTING ANGLE = 56.7
      ... program currently can only handle 1 value for bet34
      DBET                  = 8.7479851486777E-3
 .....reading frequencies and mode shapes
   READING FREQS AND MODE SHAPES FROM MSC    OUTPUT
                           0.432172E+02       0.100000E+01
                           0.938468E+02       0.100000E+01
                           0.106040E+03       0.100000E+01
                           0.143162E+03       0.100000E+01
                           0.174288E+03       0.100000E+01
                           0.223927E+03       0.100000E+01
  READING MODE SHAPES FROM MSC    OUTPUT
  COMPLETED READING 6 MODE SHAPES
 .....COMPLETED SUBROUTINE CNNET
```

Fig. 7 ASTROP3 Narrow Band Frequency Stability Analysis Output

```
*******************************************************
*         aeroelastic stability analysis              *
*       using normal mode structural model            *
*******************************************************
*    operating conditions:
*  rotor speed(rpm)=1420.
*  mach no.= 0.685
*  tip radius=53.9
modes 1 to 6 are for blade 1
*********************************
* data from finite element model:
*   blade no.1
* no. of nodes=244
* beta 3/4 of input geometry:56.7
* bet 3/4 =56.7
*********************************

                     structural model
 mode     freq(hz)    gen. mass     mass ratio   jdist
-------------------------------------------------------
   1        43.22       1.00          60.045        2
   2        93.85       1.00          60.045        2
   3       106.04       1.00          60.045        2
   4       143.16       1.00          60.045        2
   5       174.29       1.00          60.045        2
   6       223.93       1.00          60.045        2
-------------------------------------------------------

####################################################
        analysis using 2 frequencies:
104.,  106.
####################################################
.....PRINT FLAGS: 6*0
1                    propeller aerodynamic load analysis
0     number of blade groups =       8
      axial mach no.         =  0.685
      tip speed/axial speed  =  0.874
      EFFECTIVE TIP VELOCITY =  0.910
      INCOMING AIR @ 3/4 RAD = 56.740 DEGREES
0                       planform data
0              leading edge            trailing edge
     r        theta       x           theta        x
0  0.35000  -0.197E+00 -0.206E+00   0.129E+00  0.145E+00
0  0.45000  -0.200E+00 -0.226E+00   0.128E+00  0.139E+00
0  0.54000  -0.183E+00 -0.223E+00   0.145E+00  0.144E+00
```

Fig. 7 ASTROP3 Narrow Band Frequency Stability Analysis Output (cont.)

```
0  0.62000   -0.153E+00 -0.206E+00   0.164E+00  0.153E+00
0  0.69000   -0.118E+00 -0.178E+00   0.181E+00  0.162E+00
0  0.75000   -0.800E-01 -0.144E+00   0.192E+00  0.168E+00
0  0.80000   -0.443E-01 -0.107E+00   0.198E+00  0.173E+00
0  0.85000   -0.490E-02 -0.617E-01   0.199E+00  0.177E+00
0  0.89000    0.287E-01 -0.201E-01   0.198E+00  0.181E+00
0  0.93000    0.629E-01  0.259E-01   0.194E+00  0.185E+00
0  0.96000    0.883E-01  0.633E-01   0.189E+00  0.189E+00
0  0.98000    0.105E+00  0.892E-01   0.186E+00  0.191E+00
0  1.00000    0.129E+00  0.115E+00   0.182E+00  0.193E+00
        chord partition
    number of chordwise panels=   8
    tse(j)=0.125 0.250 0.375 0.500 0.625 0.750 0.875 1.000
0   control point position=0.850
0     number of blade vibration modes=  6
      no. of interblade phase angles=  1
      phase indices=  1,
 ********************************
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
  eigensolution for phase index:1
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
    all eigenvalues (hz)
     1,  (-13.90634776518,220.5892932054)
     2,  (-8.431804278037,141.4635753201)
     3,  (-2.247455484639,43.20887679589)
     4,  (-2.036096104021,174.019096371)
     5,  (-1.1865391662,93.74135425888)
     6,  (-1.168282328392,105.3845270009)
    root 6 is closest to center of interpolation

     eigenvectors:(col. i corresponds to eigenvalue i)
            mode      real part ...
                      imag part ...
   1  0.115E-02   0.920E-02  -0.284E-01  -0.155E-02  -0.127E-01  -0.958E-02
     -0.750E-02  -0.324E-01  -0.546E+00   0.508E-02   0.105E-01   0.108E-01
   2 -0.389E-02  -0.507E-02   0.243E-02  -0.198E-02  -0.320E-02   0.256E-01
      0.837E-02   0.191E-01   0.267E-03  -0.248E-02  -0.252E+00  -0.881E-03
   3 -0.426E-02  -0.467E-02  -0.813E-03  -0.348E-02  -0.197E-01  -0.249E-02
      0.928E-02   0.144E-01   0.383E-03  -0.146E-02  -0.120E-01  -0.225E+00
   4  0.809E-02  -0.994E-02   0.557E-02  -0.966E-02   0.296E-02   0.583E-02
     -0.648E-02  -0.167E+00  -0.174E-02   0.114E-01   0.111E-01   0.140E-01
   5  0.261E-02   0.566E-02  -0.935E-03  -0.159E-02  -0.105E-03  -0.302E-03
     -0.492E-02   0.467E-02   0.480E-03  -0.136E+00  -0.187E-02  -0.199E-02
   6 -0.674E-02  -0.910E-02   0.657E-03   0.627E-02  -0.133E-02  -0.135E-02
     -0.107E+00  -0.426E-02   0.657E-03  -0.966E-02   0.118E-02   0.138E-02
```

Fig. 7 ASTROP3 Narrow Band Frequency Stability Analysis Output (cont.)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1991	Final Contractor Report

4. TITLE AND SUBTITLE

ASTROP3 User's Guide

5. FUNDING NUMBERS

WU-505-62-4D
C-NAS3-25266

6. AUTHOR(S)

Richard August

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Sverdrup Technology, Inc.
Lewis Research Center Group
2001 Aerospace Parkway
Brook Park, Ohio 44142

8. PERFORMING ORGANIZATION REPORT NUMBER

E-6477

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA CR-187180

11. SUPPLEMENTARY NOTES

Project Manager, Oral Mehmed, Structures Division, NASA Lewis Research Center, (216) 433-6036.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 39

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

ASTROP3 (Aeroelastic STability and Response Of Propulsion Systems) is a Fortran computer code developed for calculating the performance and dynamic stability, i.e., classical flutter, of single rotation propfans. Three-dimensional, subsonic aerodynamics with constant pressure panel descretization, and MSC/NASTRAN finite element analysis of the blade are used to calculate the steady and unsteady aerodynamic forces. The flutter analysis is a modal based technique utilizing motion dependent aerodynamic forces based on in-vacuum frequencies and normal modes of the individual propfan blades. The execution of ASTROP3 is illustrated through the calculation of blade performance and blade aeroelastic stability for the SR7L rotor. These calculations are representative of applications for ASTROP3. All input and output files necessary for program execution are discussed, as well as other appropriate information to aide the user in applying the program.

14. SUBJECT TERMS

Aeroelasticity; Propeller; Propfan; Flutter; Performance

15. NUMBER OF PAGES

32

16. PRICE CODE

A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	