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User's Manual for UCAP: Unified Counter-rotation Aero-acoustics Program

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Summary

This is the user's manual for UCAP (Unified Counter-rotation Aero-acoustics Program), the counter-rotation derivative of the UAAP (Unified Aero-Acoustic Program). The purpose of this program is to predict steady and unsteady airloading on the blades and the noise produced by a counter-rotation Prop-Fan. The aerodynamic method is based on linear potential theory with corrections for non-linearity associated with axial flux induction, vortex lift on the blades, and rotor-to-rotor interference. The theory for acoustics and the theory for individual blade loading and wakes are derived in *Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise*, Volume 1 (NASA CR-4329). This user's manual also includes a brief explanation of the theory used for the modelling of counter-rotation.

Major sections of this volume include a general code overview, descriptions of input and output, installation instructions, and a listing of error codes.

I Introduction

This document describes the use and general structure of the Unified Counter-rotation propeller Aeroacoustic Program (UCAP), developed under NASA Contract NAS3-24222, Task Order 10. UCAP is the single and counter-rotation successor to the single rotation UAAP,* which is a computer program to predict the aerodynamic and acoustic performance of Prop-Fans using helicoidal lifting surface theory and a frequency-domain acoustic theory developed at Hamilton Standard in the 1980's (reference 1).

The major improvements of this version of UCAP over UAAP are:

The inclusion of counter-rotation. The steady interaction is modelled by perturbing the solution for one rotor by the mean velocity field caused by the other. These interaction velocities are assumed to follow streamlines.

Calculation of induced drag from blade Δc_p data instead of in the Trefftz plane. This was changed to include loading from the leading edge vortex and the tip edge vortex.

Inclusion of the vortex loading effects into the calculations of the induced velocity and the wake. The time average, non-linear axial momentum is satisfied by iteration.

Streamline contraction is added. This is modelled by forcing continuity along annuli defined by flow-field data.

Steady aerodynamic boundary conditions on the blades are calculated on conical surfaces defined by the local streamline angle.

The calculation of the required turning angle (for the flow tangency boundary correlation on the blades) has been revised. Instead of treating the axisymmetric disturbances (for example, those from the other rotor or from an external flow field) as perturbation angles, these are incorporated into the mean velocity triangle (see Figure 1).

The axisymmetric interaction component of the rotor-to-rotor interaction velocity is calculated from $\partial C_t/\partial x$, the local thrust loading, and $\partial C_p/\partial x$, the local power loading. This method requires less CPU time than the near wake formulations and will not significantly change interaction velocities at normal rotor spacings.

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* Unified Aero-Acoustic Program.

Iterative correction for interaction velocity on both rotors of a counter-rotation Prop-Fan is included.

II Theory

UCAP is a derivative of the earlier UAAP work; the details of the theory behind UAAP can be found in reference 1. The two major improvements over the interim version of UCAP, produced under Tasks I and II of this contract, are the incorporation of vortex loading into the induced flow calculation and the wake calculations, for both single and counter-rotation operation, and the modeling of contraction in rotor-rotor interference, which will be described below. UCAP works on the basis of perturbing each rotor with the velocity field produced by the other rotor. The steady loading upon a blade is divided into several parts: the potential part (subscript POT) is directly from lifting surface theory; it is calculated from

$$\{L_{POT}\}=[K]^{-1}\times\{W\}$$

where $\{L_{POT}\}$ is a vector representing the potential loading, $[K]^{-1}$ is the influence coefficient matrix, and $\{W\}$ is the turning angles required to maintain flow tangency along the blade surface. The secondary loading (that portion of loading due to induced flow) is calculated based on momentum theory using the thrust and torque at each control point and the mass flux through the rotor. The methods for calculating the secondary loading and vortex loading (the portion of the loading from the leading edge, side edge, and tip edge vortices) are described in reference 1, but the application is different. In UAAP, the calculation of the induced flow and the wake depended only upon the potential loading, $\{L_{POT}\}$. The steady potential loading was the result of non-linear iterations, where the C_p and C_t resulting from each step were used to compute a new induced flow. This was repeated until the change in C_p was small. The final potential load was then used to drive the Near Wake Calculation. The vortex loading was attached to the final performance values but never included in either the loading to drive the Near Wake Calculation or in the induced flow calculation. In the present program, the induced flow is calculated before and after the calculation of the vortex loads, so the influence of non-linear lift is included in the inflow field. The Near Wake routine calculations are driven by $\{L\}$, which includes the vortex load and is obtained by:

$$\{L\}=\{L_{POT}\}\cdot((\partial C_t^*/\partial x)/(\partial C_t/\partial x))$$

where $\partial C_t^*/\partial x$ includes the effect of vortex loading and $\partial C_t/\partial x$ includes potential loads only.

The flow chart in Figure 2 shows a schematic of the method used in counter-rotation operation for the steady aerodynamic solution. Single rotation operation bypasses steps M through V, but is otherwise similar.

Streamline contraction is a result of the conservation of mass. In UCAP this is done by dividing the flow into streamtubes which are defined by the flow field entered by means of the VELGRADS command (see Section IV, "Input Description"). If no external flow field is defined, initial streamlines will be based on the hub and tip radii of the front and rear rotors. The locations where these streamlines intersect the rotors are calculated after every steady iteration. The new locations of the streamlines at the rear rotor are computed by calculating the flow rate in each streamtube and adjusting the annular areas in order to enforce incompressible continuity. For the streamline locations on the rear rotor, the flow rate in each streamtube where it crosses the forward rotor is calculated from the induced velocity, the interference velocity caused by the rear rotor, the velocity due to the external flow field, and the streamtube area. Since the velocity where that stream-tube crosses the rear rotor is known, continuity will determine the stream tube area at that location. This is repeated until all streamlines on the rear rotor are relocated. The new locations of the streamlines where they intersect the front rotor are calculated in a similar manner: the streamtube areas on the rear rotor are held fixed while the streamlines on the front rotor are adjusted to satisfy continuity.

The streamtubes defined by the last steady iteration are used for the calculation of the unsteady rotor-to-rotor interferences. A separate document (reference 4) contains a more detailed explanation of the theory used in UCAP.

III Program Organization

UCAP is a large program, with about 30000 lines of source code excluding comments. It is divided into several modules, which communicate via common blocks, argument lists, or files. These are:

Control Module — Controls the program flow, monitors convergence of the steady aerodynamic iterations, and performs some housekeeping functions, such as assuring that the common blocks are properly loaded with default data.

Input Module — Reads the data entered by the user. Entered data are placed into named common blocks for access by the rest of the program. The input module will also set the default values for the appropriate input parameters which have them.

Blade Geometry Module — Converts the geometry data entered in any of the three available coordinate systems to the coordinate system used internally.

Steady Aerodynamics Module — Performs the calculations required for the solution of the steady aerodynamics, and passes the Δc_p's calculated to the Steady Loads Module, which performs the integrations needed to get C_p, C_t, and applies the vortex loading to get C_t^* and C_p^*. The influence coefficient matrices and thickness vectors are calculated here. The forward rotor influence coefficient matrix is written to file FWD000. The rear rotor is written to file AFT000. For single rotation, the file will be SRP000.

Steady Loads Module — Integrates Δc_p's to get C_p, C_t, $\partial C_p/\partial x$, and $\partial C_t/\partial x$, and applies the vortex loading corrections, as in UAAP, to get C_t^*, C_p^*, $\partial C_p^*/\partial x$, and $\partial C_t^*/\partial x$. This module also writes the steady portion of the input data file for the Noise Module.

Unsteady Aerodynamic Module — Calculates the complex Δc_p's resulting from a given disturbance field and writes the unsteady portion of the input data file for the Noise Module. The unsteady influence coefficient matrices calculated in this module are written to external files with names of the form AFT001, AFT002, FWD001, FWD002, etc., where the number is the interaction harmonic order. For single rotation all matrices will be written to a file named SRP000.

Steady Interaction Wake Module — Uses $\partial C_p^*/\partial x$ and $\partial C_t^*/\partial x$ to calculate the velocity field caused by one rotor upon the other. This approach discards influence of the chordwise loading distribution on the velocity field, which is considered negligible at reasonable rotor-to-rotor spacings.

Near Wake Module — Uses complex loading information supplied by the Steady Aerodynamics Module, with a correction for the vortex loads, to calculate the unsteady perturbation terms caused by one rotor upon the other. While the perturbations are unsteady, the wake is steady when viewed by an observer moving with the rotor generating the wake. When an inflow field incorporating unsteady components is input, the UCAP wake is based on the steady component only. The unsteady portion does not impact the wake. For single rotor operation, only, this module will calculate the velocities caused by the rotor at specified upstream or downstream points (WAKEEXEC command).

Noise Module — Calculates the radiated noise from data contained in an input data file at locations requested by the user.

Utility Routines — Includes sub-programs for interpolation, splining, data management, and printout. These routines are called from many places in the program.

Figure 3A shows the subroutine calling tree of the program. Figure 3B shows the subroutine cross reference listing. Figure 3C is a subroutine reference and purpose listing. Figure 3D shows the labeled common area reference listing.

UCAP uses a large number of named common blocks, but no unnamed (blank) common blocks, for data storage and for data exchange between modules. These are listed in Table I. Further information concerning the actual system requirements is in Section VII, "Program Installation".

IV Input Description

The primary input mode is expected to be a predefined input data set. Upon program execution the primary input file, file number 5, is immediately read and echoed to both the primary output file, file number 6, (to obtain a complete copy of the input on the output file) and to a scratch file, file number 11. All subsequent primary input is obtained by reading file number 11.

No other input files are required by the code except as the user may define for restart capabilities. Several scratch files are generated by the program; they are defined in the Section VIII, "File Requirements".

There are many input values which act as tolerances on iterations, or convergence criteria. These have been defaulted within the code to "recommended" values. Although they explicitly appear in the input description, they need not be input. Input data which need not be input appears at the end of each section, and the input location number appears within parentheses.

The next sections present a description of all the input necessary to run the code.

Commands

The code is command driven. Commands are used to identify the input sections, the input values, and to execute various functions of the code. Sub-commands are used to execute options within functions. The general input format of the command is:

(starting in column 1)

COMMANDX(SUBCOMMD) where "COMMANDX" is an 8 character word, including trailing blanks, and "SUBCOMMD" is also an 8 character word, including trailing blanks.

Load

Some commands require that numerical input must be read in next. For this purpose a location-specified, free-field input routine is used which reads between columns 1 and 72. Locations for input are indicated by "L" followed by a number indicating the desired start of a location.

Some of the location specified input controls integration mesh sizes, Fourier series convergence, and other program tolerances. These locations have been identified by parenthesis () around the location number and can usually be ignored by the user. However, if these values are input, the parenthesis () should be omitted from the location field.
Input for this "LOAD" format is illustrated below:

(starting in column 1)

```
C   THIS IS AN OPTIONAL COMMENT RECORD (or Records)
L   10  1.1  2   3.5
C   THIS IS ANOTHER OPTIONAL COMMENT RECORD (or Records)
    12.7   13.1
L   91       6.5
END
```

This will cause the locations shown below to have the following values:

LOCATION	VALUE
10	1.1
11	2.0
12	3.5
13	12.7
14	13.1
91	6.5

Notes: "Scientific notation" is not allowed, e.g. 2.1 E+03 is not allowed. Implied repetitions are not allowed, e.g. 3*2.1 is not allowed. The "END" record is required to terminate each entry into the LOAD routine.

Command Summary

A list of accepted commands is shown below. Since this is a command driven code, command order is important, and therefore the commands are listed below in the required logical sequence for execution.

HEADER	-	Input page header cards
RUNPARMS	-	Input flight parameters
CRPPARMS	-	Input counter-rotation parameters
AIRPARMS	-	Input options for 2-D drag look-up.
BLADEGEO	-	Input propeller/blade geometry (2-D,RXY or XYZ coordinates).
LSTPARMS	-	Input options to panel aero code.
NOIZPARM	-	Input options to the noise portion of the code.
VELGRADS	-	Input axial velocity field on a defined grid.
VORTPARM	-	Input options to vortex flow calculation.
WAKEPARM	-	Input options to wake calculation.
INTERPRM	-	Input options for rotor-to-rotor interaction calculations
AEROEXEC	-	Execute the aero code.
WAKEEXEC	-	Execute the wake calculation.
NOIZEXEC	-	Execute the noise portion of the code.
ENDCASE	-	End of input and calculations for the current case.
ENDJOB	-	End of job, terminate the program.

Specific Input Description

Input requirements/options are provided below for each command, in the order listed above.

HEADER:
This command enters page heading records. Records following the HEADER command are sequentially read until an "END" command is found. Up to 10 page heading records may be entered.

RUNPARMS:
This command enters run parameters using "LOAD" format. The location, default, and input descriptions are:

LOC.	Default	Variable	Description
1	0	RUNBUG	Debug Option, 1 turns on.
2	59.0	QDEGF	Ambient temperature, °F.
3	1.0	QRHOR	Ambient density/Sea Level Std. density.
4	0	QADVF	Advance ratio, $J = V_o/nD$, for a single rotor or for the forward rotor of a counter-rotation Prop-Fan.
5	0	QMX	Free-stream Mach number.
16	0	QADVR	Advance ratio, $J = V_o/nD$, for the aft rotor of a counter-rotation Prop-Fan.

CRPPARMS:

This command is used to control counter-rotation operation of the program and to enter certain parameters specific to counter-rotation, such as the rotor-to-rotor spacing. If this command is omitted, UCAP will run in single rotation mode; this is to permit existing UAAP input data to be used for single rotation without change.

LOC	Default	Variable	Descriptions
1	0.0	CRPBUG	Printout control. 0: Minimal printout 1: Printout specific data after each front/rear rotor iteration
2	0.0	SWITCH	0.0: Run single rotation. This was chosen to ensure compatibility with UAAP data decks. 1.0: Run counter-rotation
3	-1.0	SPACE	Distance between rotor pitch change axes, normalized by forward rotor diameter. For counter-rotation cases, this *must* be entered by the user; if nothing is entered the program will stop.
4	0.0	COUNT	Number of front-rear rotor iterations. Maximum is 25.
6	1000.0	CRPTOL	Tolerance. When the change in power coefficient between iterations is less than this value, the steady performance is considered converged. Values less than 1.0×10^{-5} will be reset to 10000. This value was selected for convenience in program debugging. The user must enter a value less than 1. for iteration to occur. See Appendix for recommended values.

7	0.0	FWDHRM	Highest forward rotor wake harmonic to use for the excitation of the rear rotor.
8	0.0	AFTHRM	Highest rear rotor induction field harmonic to use for the excitation of the forward rotor.

LSTPARMS:
This command enters input options to the panel aero portion of the code using "LOAD" format. This command has two sub-commands: AFT and FWD. Use LSTPARMS(FWD) to enter parameters for the forward rotor in counter-rotation cases. Use LSTPARMS(AFT) to enter parameters for the rear rotor in a counter-rotation case. Use LSTPARMS, *with no sub-commands*, for single rotation cases. The location, default value and input description are:

(* See Figure 4 for pictorial description)

	LOC.	Default	Variable	Description
	1	0	ZSTBUG	Debug Option, 1 turns on.
*	2	10	QNCP	Number of chordwise panels, maximum of 10.
*	4	8	QNSM	Number of spanwise modes (control point radii). Maximum of 10.
	20	1	QPART1	0 generate $[K]^{-1}$ and W_T. 1 generate $[K]^{-1}$ and read W_T. 2 read $[K]^{-1}$ and generate W_T. 3 read in $[K]^{-1}$ and W_T The code requires an inverse kernel matrix $[K]^{-1}$ and thickness vector, W_T, to obtain the aerodynamic loading on the blade. The $[K]^{-1}$ matrix and W_T vector require a significant amount of CPU time, and an option to utilize

			previously generated $[K]^{-1}$ matrices and W_T vectors has been incorporated into the code. **Note:** For counter-rotation operation, the program requires that the $[K]^{-1}$ matrix be available for every QQ and QK (see below). If any $[K]^{-1}$ matrix is required for a given rotor, all $[K]^{-1}$ matrices must be calculated for that rotor.
21	0	QQ	Order of unsteady loading, harmonic, = 0 for steady loading. For single rotation operation, this parameter must be set to a value greater than zero for unsteady aerodynamics. For counter-rotation, enter 0, as this parameter is calculated for the unsteady rotor-to-rotor interactions.
22	0	QK	Number of circumferential modes for unsteady loading, = 0 for steady loading. For single rotation operation, this parameter must be set to a value greater than zero for unsteady aerodynamics. For counter-rotation, enter 0, as this parameter is calculated for the unsteady rotor-to-rotor interactions.

	28	2	QNBOPT	= 1 for supersonic leading edge element, use when supersonic flow expected at leading edge. = 2 for subsonic leading edge element.
	29	10	QITNON	Max number of non-linear iterations, for single rotation operation. =0 for linear calculation. This parameter is ignored for counter-rotation operation.
*	101	.2, .35, .45,.55, .65,.75, .85,.95	QZAR	Spanwise locations of control point radii, The number of these must agree with QNSM, fraction of R_{tip}.
*	141	.5,.5, .5,.5, .5,.5 .5,.5	QCONTP	Chordwise location of control points within each panel normalized to the panel width. There must be QNSM of these. All control points are at the same location at a given radius.
	181	.4,.4 .4,.4 .4,.4, .4,.4, .4,.4,	QCHW	Width for chordwise averaging of downwash, normalized to panel width. There must be QNSM of these input. The downwash averaging width is constant at a given radius.

51	0, 0	QWMU	Complex downwash vector for flowfield for external to propeller unsteady loading calculation. These can be obtained from Section 13, equation (13.8) of reference 1. A routine to generate these is in the appendix. The values of QWMU must be input sequentially starting in location 351, as real part, imaginary part for each control point across the 1st spanwise station, and then proceeding outward along the blade span. Thus, there must be (QNCP*QNSM) pairs of values input for QWMU.

The following input locations may be ignored.

(3)	.02	QDR	Radial extent of singular integral at control point radius for wake calculation radius.
(5)	1024	QN	Number of points in FFT for terms in kernel integration, max. of 2048, must be a power of 2.
(6)	.004	QDELTA	Axial step size for FFT.
(7)	4	QMODOP	Spanwise mode shape option (use default value).
(8)	.0001	QTOLF	Tolerance for W (omega) integration.
(9)	.001	QTOLT	Tolerance for other integrations.
(10)	.005	QTOLS	Tolerance for summations
(11)	20	QMM1	Loop limit for harmonic summation in wake kernel.

(12)	30	QMM2	Loop limit for harmonic summation in bound kernel.
(13)	10	QMM3	Loop limit for harmonic summation in thickness vector.
(14)	--	QITABK	File number allocated for $[K]^{-1}$ matrix storage. The default is 8 for single rotation or for the FWD sub-command and 18 for the AFT sub-command.
(15)	--	QITABT	File number allocated for W_T (thickness vector) storage. The default is 9 for single rotation or for the FWD sub-command and 19 for the AFT sub-command.
(16)		QINT4	Not currently used.
(17)	0	QPRINT	Additional debug print - not recommended.
(18)	0	QPRIN1	Additional debug print - not recommended.
(19)	0	QPRIN2	Additional debug print - not recommended.
(23)	.025	QKDOWN	Radial step size for non--singular bound kernel
(24)	.010	QKSTART	Width of singular region for bound kernel integration
(25)	5	QMM4	Loop limit for summation in sound power calculation.
(26)	.9	QMBLEN	Trailing edge effective Mach number for blending to supersonic trailing edge elements.

(27)	1024	QNO	Number of points in FFT integration for n = 0 term in kernel, max = 2048, must be a power of 2.
(221)	.002	QINMES	Step size for radial integration in wake kernel.

BLADEGEO:
This command enters the propeller/blade geometry using the "LOAD" format. For any propeller and flight condition, the shaft power required, and the thrust produced by the propeller are a function of the blade angle. In using this code it is recommended that the blade angle be adjusted so that the power or thrust calculated by this program matches a desired value. (see Sections 3 and 6 of reference 2 for further explanation).

Nine sub-commands exist to allow input of the geometry in different forms:
For single rotation these are:
BLADEGEO(2-DCOORD), BLADEGEO(RXYCOORD), and BLADEGEO(XYZCOORD).
For the forward rotor in counter-rotation these are:
BLADEGEO(2-DCOFWD), BLADEGEO(RXYCOFWD), and BLADEGEO(XYZCOFWD).
For the aft rotor in counter-rotation these are:
BLADEGEO(2-DCOAFT), BLADEGEO(RXYCOAFT), and BLADEGEO(XYZCOAFT)

The 2-DCOORD, RXYCOORD, and XYZCOORD sub-commands must not be used in counter-rotation operation. The 2-DCOFWD, RXYCOFWD, XYZCOFWD, 2-DCOAFT, RXYCOAFT, and XYZCOAFT sub-commands must not be used in single rotation. These are described below.

BLADEGEO(2-DCOORD)
BLADEGEO(2-DCOFWD)
BLADEGEO(2-DCOAFT):
These sub-commands all use the same form of the blade geometry, which is expected to be the most widely used. The 2-DCOORD sub-command is used for single rotation cases, 2-DCOFWD is used for the forward rotor of a counter-rotation Prop-Fan, and 2-DCOAFT is used for the aft rotor of a counter-rotation Prop-Fan. Input takes the form of the spanwise variation of thickness ratio, chord/diameter ratio, twist, airfoil section designation and stacking axis coordinates. This command(sub-command) will calculate the blade surface coordinates and interpolate these into a form required by the other parts of the program. To insure that there are no errors in the blade output description, only a limited amount of extrapolation of the input blade coordinates is allowed. Thus, it is best to provide input stations, X, and streamline angles, SLA, which will define the root and tip sections of the blade such that the output stations, ZBLDST, can be interpolated and not extrapolated. The code requires exactly ten (10) inputs defining X. The input described below is illustrated in Figures 5 and 6.

Note that there are empty locations in the input. These are not used by the program.

LOC.	Default	Variable	Description
1	0	BLDBUG	Debug option, 0 is off, 1 is on.
31	0	BLADE	Number of blades
32	0	D	Propeller diameter, ft.
33	0	SCO	Propeller hub/tip ratio
41-50	0	X	Spanwise input stations, 10 are required, fractions of R_{tip}.
51-60	0	HOB	Spanwise airfoil maximum thickness/chord ratio.
61-70	0	BOD	Spanwise chord/diameter variation.
71-80	0	CLD	Spanwise variation of design lift coefficients.
81-90	0	DTHET	Spanwise twist variation, in degrees. Twist should be input such that twist at the 75% radius is 0.
347	0	THTDES	The 75% radius value of blade angle at which the blade is to be "designed", degrees.
348	0	THTCUT	The 75% radius value of blade angle at which this calculation is to be run, degrees.

			Note: Propeller blades are assumed to be "designed" at one value of blade angle. The input values of thickness/chord, chord/diameter, camber, twist and stacking line are assumed to be defined at the value of blade angle in Location 347. Location 348 defines the blade angle at which this calculation is to be run.
381-390	0	SLA	Spanwise variation of streamline angle, degrees. Blade airfoil sections are assumed to be on cones which approximate the streamlines through the propeller. This input is the cone half-angle, positive as shown in Figure 5.
711-720	0	XSWP	Spanwise variation of X coordinate of mid-chord stacking line, fraction of R_{tip}, see Figure 6.
721-730	0	YSWP	Spanwise variation of Y coordinate of mid-chord stacking line, fraction of R_{tip}, see Figure 6.
731-740	0	ZSWP	Spanwise variation of Z coordinate of mid-chord stacking line, fraction of R_{tip}, see Figure 6.
900	21	ZNPCOV	Number of output stations in the chordwise direction, max 49.

901-949	0., 5., 10, 15, 20 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100	PCTCHD	Chordwise location of output stations. Both upper and lower airfoil surfaces are output at the same chordwise locations, % chord.
950	21	ZNIS	Number of output stations in the spanwise direction, max of 49.
951-999	.10,.30, .40,.50, .55,.60, .65,.70, .75,.80, .825,.85, .875,.90, .925,.95, .96, .97, .98, .99 1.0	ZBLDST	Spanwise location stations at which the blade surface will be defined, radius ratios, r/R_{tip}.

The following input locations may be ignored.

(346)	2	SWPOPT	Input sweep option. The default value is required.
(349)	1	ZKCUT	Type of airfoil section defined 0 planar, 1 conical. (default). 2 cylindrical
(741-751)	1	BAFL	Integer characterizing the 2-D airfoil at each spanwise station. Only NACA 16 series airfoils can be generated with this deck.

BLADEGEO(RXYCOORD)
BLADEGEO(RXYCOFWD)
BLADEGEO(RXYCOAFT):
An optional method for input of the blade geometry has been provided. This form allows for up to 50 input stations. Additionally, it requires a table of the displacement of the mean camber line from the chord line. The RXYCOORD sub-command is used to enter data for single rotation cases. The RXYCOFWD and RXYCOAFT sub-commands are used to enter data for the forward and aft rotor, respectively, of a counter-rotation Prop-Fan. This option requires that the blade sections being described be on cylinders whose axis is the centerline of rotation. The input is illustrated in Figures 7 through 9.

LOC.	Default	Variable	Description
1	0	BLSBUG	Debug Option, 0 is off, 1 is on.
2	0	STANO	Number of spanwise input stations, max of 50.
3	0	PCTNO	Number of chordwise input stations, max of 50.
4	0	DIAMET	Propeller diameter, ft.
5	0	SPINNER	Propeller hub/tip ratio.
6	0	BLADES	Number of propeller blades.
51-100	0	CTSTA	Spanwise input stations, r/R_{tip}.
101-150	0	PCTCD	Chordwise input stations, %chord.
At each spanwise station			
151-200	0	THKOB	Maximum blade thickness, fraction of chord.
201-250	0	CHDOD	Blade chord, fraction of diameter.

251-300	0	CAMBR	Equivalent NACA Series 16 camber. Obtained by taking the non-dimensional maximum height of the blade mean camber line / .05515 , fraction of chord.
301-350	0	TWIST	Blade section chord angle, deg.
351-400	0	XMC	X-coordinate of mid-chord stacking line, fraction of R_{tip}.
401-450	0	YMC	Y-coordinate of mid-chord stacking line, fraction of R_{tip}.
451-500	0	ZMC	Z-coordinate of mid-chord stacking line, fraction of R_{tip}.
501-550	0	XSLA	Streamline angle, deg. This is the flow angle relative to the centerline of rotation, and is used in the sweep angle calculation.

Blade mean camber line displacement table.

1003	0	PCTND	Number of chordwise points in mean camber line displacement table.
1004	0	STAND	Number of spanwise points in mean camber line displacement table.
1005	0	CAMLN	Ascending array of chord fractions, PCTND values.
			Followed immediately by :

1005 + PCTND	0	CAMLN	Ascending array of spanwise radii, fraction of R_{tip}. Starting after last input location, STAND values. Followed immediately by :
1005 + PCTND+STAND	0	CAMLN(I,K) I=1,STAND K=1,PCTND	Array (PCTND*STAND) of mean camber line displacements from chord line at each radial station, at 1st chordwise location, fraction of chord. This is followed by a similar array for the 2nd chordwise location, and continues through the PCTND chordwise location.

<u>BLADEGEO(XYZCOORD)</u>
<u>BLADEGEO(XYZCOFWD)</u>
<u>BLADEGEO(XYZCOAFT)</u>:
This form of blade geometry inputs the blade description in XYZ coordinates of each blade surface. The XYZCOORD sub-command is to be used for single rotation. For counter-rotation operation use the XYZCOFWD sub-command to enter data for the forward rotor; use the XYZCOAFT sub-command to enter data for the aft rotor. Figure 10 illustrates the coordinate system used. Note that this XYZ coordinate system is different than the 2-D or the RXY system.

LOC.	**Default**	**Variable**	**Description**
1	0	BLDBUG	Print option. 0 is minimal 1 is additional.
2	0	DIAME	Propeller Diameter, ft.
3	0	SPINN	Hub to tip ratio.
4	0	BLADE	Number of blades
5	0	STINN	Number of radial stations in input.

6	0	CDINN	Number of chordwise stations in input.
7	0	STOUTN	Number of output radial stations needed to define the blade.
8	0	CDOUTN	Number of output chordwise stations needed to define the blade.
51	0	STOUTV	Values of radial stations, fraction of radius.
101	0	CDOUTV	Values of chordwise stations fraction of chord.

An "END" record is required to terminate the "LOAD" input. The "END" record is immediately followed by the xyz coordinates of the blade as follows:

For each of the STINN radial input stations the following input records are required:

a) A label record

b) For each of the CDINN chordwise input stations the X, Y, and Z coordinates of the face (pressure) side of the blade are input. With one set of X, Y, Z, coordinates in free-field format per record. The units are inches.

c) Another label record

d) For each of the CDINN chordwise input stations the X, Y, and Z coordinates of the camber (suction) side of the blade surface are input. With one set of X, Y, Z coordinates in free-field format per record. The units are inches.

VELGRADS:
This command will input or initialize the axial velocity ratio at the propeller. These ratio may be due to the spinner-hub and or nacelle effects on the freestream flow, but the result must appear to the code as an axisymmetric flowfield.

LOC.	Default	Variable	Description
1	0	V1BUG	Debug option
2	0	V1OPT	Velocity ratio input option, 0 : initialize velocity field to 1.0, fraction of freestream velocity. No further input is required. 1 : input the velocity ratio.
For option V1OPT=1. only:			The axisymmetric velocity ratio is input on a grid of radial and axial points which encompass the blade outer boundaries. The flowfield values are interpolated at specific "nodal" points required by the code.
3	0	VINRD	Number of radial stations in grid.
4	0	VINAS	Number of axial stations in grid.
5	0	VIVRF	Reference velocity, by which local velocities are normalized, same units as VIRD, VIVV, and VIAX.
6	0	VITIP	Reference radius, by which local radii are normalized, same units as VIRD and VIAX.

7	0	VICLL	Centerline location. The axial location of the forward (or only) blade pitch axis is assumed to be 0. This value is subtracted from the input values of VIAX after input so that the axial location of the forward (or only) blade centerline will be at 0. Same units as VIAX.

The following inputs are repeated for each of the axial stations in the grid, (K=1,VINAS).

25	0	VIRD(I,K) I=1,VINRD	Radial locations of 1st set of up-stream grid up-stream grid points, same units as VITIP.
25+		VIVV(I,K) I=1,VINRD	Velocities at VIAX(I), VIRD(I), I=1,VINRD same units as VIVRF.
25+		VIAX(I,K) I=1,VINRD	Axial locations of VIVV(I), same units as VITIP.

<u>WAKEPARM</u>:
This command provides input parameters to the propeller wake calculation procedure. This input is used in both the performance calculations, and in the "Wake" calculation option. The variables used for propeller efficiency and wake calculation are listed below.

LOC.	Default	Variable	Description
1	0	WAKBUG	Debug option. 1 print WAKEPARM input data. 0 do not print data.
6	1	YIPLOT	Wake output. 1 is on 0 is off.
8	1	YNPSKN	Skin friction drag. 1 : included, 0 : not included.

20	0	YIPRT	Output option: 0 : no output 1 : V_r/V and V_x/V 2 : Fluctuating lift
23	0	YIVWK	The viscous wake shape is described by 1 of 3 options: 0 : gauss pulse 1 : cosine squared 2 : cosine
25	11	YNORPE	No. of output radii.
751	.24,.35, .45,.55, .65,.75, .80,.85, .90,.95, .98	YROUTP	Output radii, r/R_{tip}.

The following input locations may be ignored.

(2)	.05	YK	Spanwise integration mesh size, fraction of radius.
(9)	.0001	YTOL	Fourier series sum convergence tolerance.
(10)	99	YMM1	Max. no. of Fourier coefficients to calculate, max. of 99.
(12)	.001	YTOL1	Tolerance for high frequency form of Fourier coefficient.
(13)	0	YLASTM	Last Fourier coefficient for detailed output.
(16)	0.7	YZO	Origin of special routine for interpolation of circulation curve.
(17)	0.5	YZNORM	Circulation curve normalizing factor.
(18)	1.0	YAOPT	0 to not iterate on induced angle.

(21)	0	YMM2	Turns on diagnostic print for Fourier coefficient up to YMM2 when YIPRT = 2.

The following inputs are required in addition to the above if wakes are to be calculated. Output radii are divided into those within the tip radius, YNOR, and those beyond the tip radius, YNPX.

LOC.	Default	Variable	Description
4	0	YNOR	Number of output radii which are less than or equal to 1.0 (within tip radius).
5	0	YNPX	Number of output radii which are greater than 1.0 (outside of tip).
50	0	YXNCS	No. of output axial locations, max of 10 at each radius.
51	0	YXMMU	No. of Fourier coefficients used in calculation of chordwise wake component.
52	0	YXMMV	No. of Fourier coefficients used in calculation of radial wake component.
53	0	YXMMW	No. of Fourier coefficients used in calculation of downwash wake component.
351		ROUT	Output radii, fraction of radius. There should be YNOR+YNPX of these.
701	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of radius, for 1st output radius. There should be YXNCS of these.

11	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of radius, for second output radius. There should be YXNCS of these.
721	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of R_{tip}, for third output radius. There should be YXNCS of these.

For K=1,YNOR+YNPX

The following input location may be ignored.

(54)	0.01	YFPHW	Width of averaging function for wake calculations = X/R_{tip}.

AIRPARMS:
This command will input options which are used to obtain the 2-D airfoil drag from built-in tables of lift and drag coefficients.

LOC.	**Default**	**Variable**	**Description**
1	0	AIRBUG	Debug Option, 1 to print

The following input locations may be ignored.

(2)	24	AIRNUM	2-D Airfoil data pack number wanted for this run. Currently, only NACA 16 is available in this code.
(3)	5	AIRTYP	0 : Isolated 2D airfoil 1 : Isolated 2D airfoil w/cascade correction. 4 : Isolated 2D airfoil w/sweep correction. 5 : Isolated 2D airfoil w/sweep and cascade.
(13)	0	AIRCOR	0 : no drag correction input 1 : drag correction input

(15)	0	CDMLT	2D drag multiplier, used if AIRCOR = 1.
(17)	0	DCDT	2D drag increment, used if AIRCOR = 1.

CDMLT and DCDT are used to alter the drag of the stored airfoil data. They may be used to simulate another airfoil, to account for a rough airfoil or provide a better match with test efficiency. The altered drag coefficient is computed as:

$$C_{D(altered)} = C_D*CDMLT + DCDT$$

NOIZPARM:
This command will input the options which are used to control the acoustic calculations.

NOTES: B is number of blades, M is noise harmonic order
B * ZMMAX must be less than 1001
MX is flight Mach number (may not be 0 for near-field calculation)

LOC.	Default	Variable	Description
1	0	ZNZDBG	Debug option : 0 no print; 1 print input parameters; 2 print file 50 input.
2	0	ZNFIND	0 for far-field theory 1 for near-field theory
3	1	ZMMAX	Max noise harmonic order group to calculate.
4		ALT	Distance from prop axis to observer, ft.
9		ZNX	Number of axial directivities for noise calculations, 20 max.
10	1	ZXORX1	Axial directivities are 1 : visual or 0 : retarded.
11		X1	Visual observer positions along axis (+ ahead of prop),ft. (calculated if X is input).
		or	
31		X	Retarded positions observer, ft. (calculated if X1 is input).

59	1	ZIBLW	1 to add boundary layer and wake displacement thickness to blade thickness monopole noise. 0 to omit (for comparison with other predictions).
69	90.	PHIF	Azimuthal observer directivity angle for unsteady loading, degrees to front rotor — normally use the default. PHIF increases in the direction of rotation; zero corresponds to the phase reference position for calculation of unsteady air loads. Thus, the observer position is specified relative to the unsteady flow field reference.
70	90.	PHIR	Azimuthal observer directivity angle for unsteady loading, degrees to rear rotor. Important only when BPFF = BPFR. Gives the phase difference between rotors. PHIR increases in the direction of rotation; zero corresponds to the phase reference position for calculation of unsteady air loads. Thus, the observer position is specified relative to the unsteady flow field reference.

The following input locations may be ignored.

(51)	10	ZJMINI	With ZNJ1, controls chordwise integration mesh.
(52)	8	ZNJ1	Number of chordwise points = ZJMINI + M + B * ZNJ1, 1001 max pts.

(53)	10	ZJMIN2	Used with ZNJ2, controls spanwise integration mesh.
(54)	10	ZNJ2	Number of spanwise points is JMAX (must be less than 2001) which is calculated as follows : if ZNJ2 > 0, JMAX = ZJMIN2 + M*B*ZNJ2; if ZNJ2 < 0, JMAX = ZJMIN2 - ZNJ2 if ZNJ2 = 0, JMAX = ZJMIN2 + ZNJ2 points/phase cycle.
(55)	6	ZIW	Output file number.
(56)	1	ZSTART	Start harmonic order.
(57)	1	ZMINC	Increment in harmonic order.
(58)	2	ZLHSOR	Indicates what type of unsteady flow: 1 = blade wakes; 2 = flowfield.
(60)	0	ZPRUNS	If not 0, print diagnostic unsteady loading noise table.
(61)	0	ZITRAP	If not 0, max diagnostic print.
(62)	0	ZNFOUT	If not 0, print harmonic table to file number ZNFOUT; allocate appropriately.
(63)	0	ZKK	See note below.
(64)	0	ZKXTND	See note below.
(65)	10	ZKMIN	See note below.
(66)	10	ZOMEGA	See note below.
(67)	0	ZIPEXT	If not 0, print load diagnostics.

(68)	0	ZIPSIC	If not 0, do "instant" quadrupole noise calculation (not recommended).
(71)	1	ZNAIR	Code for airfoil thickness distribution (specify for all radial stations): 1 = series 16 3 = series 64 5 = series 65 7 = biconvex parabolic (analytic) 8 = 4 digit series

ZKK, ZKXTND, ZKMIN, and ZOMEGA :

In the near-field option, the program evaluates a Fourier transform numerically using rectangular integration. The range for this frequency integration is 1/(1+MX) to 1/(1-MX), where MX is the flight Mach number. The number of steps in the integration range determines the trade-off between precision and running time. The integrand is typically a fluctuating quantity whose rate of oscillation, dI/dw, is computed by the program as a function of several factors such as harmonic order, Mach number, and observer position. To achieve uniform precision over a range of conditions, the program determines the number of points (ZKK) in the frequency integration range from two input numbers: the first is the minimum points in the range (ZKMIN) and the second is the number of mesh points per oscillation of the integrand (ZOMEGA). The number of integration points is then ZKK = ZKMIN + ZOMEGA * dI/dw. Default values are ZKMIN = 10 and ZOMEGA = 10, which from numerical tests give a reasonable compromise between precision and running time. If the user wishes to experiment, he can override either of the two default values.

Reducing the number of points will reduce running time and storage requirements, but also reduce the precision of the calculation. Determining the satisfactory level of tradeoff between precision and running time for other than the defaults is up to the user.

In some cases a significant contribution to the noise can be caused by frequencies outside the range of frequency integration noted above. To account for this, ZKXTND points are included outside both the upper and lower bounds of the integration. If ZKXTND equals zero then it is automatically computed by the program, otherwise the input value of ZKXTND is used. However, ZKK + 2*ZKXTND must be less than 401. If this is not true then the code will reduce ZMMAX by one until this condition is met.

INTERPRM:
This command inputs parameters for the control of the non-zero harmonic terms in the calculation of the interference between the front and rear rotors in counter-rotation cases. These are a sub-set of the WAKEPARM parameters. Normally, these default values should be used.

LOC	Default	Variable	Description
The following locations are optional and may be ignored:			
(1)	0.0	INTBUG	Printout control: set to 1 to increase amount of printout regarding inter-rotor wake.
(2)	0.05	INTXK	Spanwise integration mesh size, fraction of R_{tip}.
(3)	0.7	INTZO	Origin of special routine for interpolation of circulation curve.
(4)	0.5	INTZNM	Circulation curve normalization factor.
(5)	1.0	INTAPT	0 to not iterate on induced angle.
(6)	1.0	INTVWK	The viscous wake shape is described by one of three options: 0: Gaussian pulse 1: cosine squared pulse 2: cosine pulse
(7)	0.01	INTFPH	Width of averaging function for wake calculation, in terms of R_{tip}.
(8)	1.0	INTSKN	Skin friction drag. 1: included 2: not included
(9)	0.001	INTTOL	Fourier series sum convergence tolerance.
(10)	0.0001	INTOL1	Tolerance for high frequency form of Fourier series.

(11)	99.0	INTMM1	Maximum number of Fourier coefficients to calculate, limit of 99.
(12)	0.0	INTMMU	Number of Fourier coefficients used in calculating the chordwise component of the wake.
(13)	0.0	INTMMV	Number of Fourier coefficients to be used in calculating the radial portion of the wake.
(14)	0.0	INTMMW	Number of Fourier coefficients to be used in calculating the downwash portion of the wake.
(15)	0.0	INTPLT	Wake output; 1 is on; 0 is off.
(16)	0.0	INTPRT	Output option. 0: no output 1: print V_r/V and V_x/V 2: print fluctuating lift.

VORTPARM:
This command inputs the options which are available to control the Vortex Flow Aerodynamic calculations. This command has two sub-commands: FWD and AFT. Use VORTPARM(FWD) to enter parameters for the front rotor in a counter-rotation case. Use VORTPARM(AFT)* to enter parameters for the rear rotor in counter-rotation cases. Use VORTPARM, *with no sub-commands*, for single rotation cases.

LOC.	Default	Variable	Description
1	0	VTXDBG	Debug option: if = 0, input not printed, if = 1, input printed.
2	1	DOLEAD	If = 1, then calculate additional lift due to leading edge vortex.
3	1	DOSIDE	If = 1, then calculate additional lift or radial force due to tip edge flow.
4	1	DOAUGL	If = 1, then calculate additional lift due to leading edge vortex shed over aft portion of blade at the tip (augmented lift).
5	.97	ZAUGFF	Radius at which augmented lift acts, r/R_{tip}.
6	0	TIPLOR	Indicates whether tip edge flow results in extra lift (0) or radial force (1).

TIPLOR is set by the user to determine the type of edge flow.
0 for separated tip flow, where the tip vortex gives extra flow at the tip.
1 for attached tip flow which produces a radial tip edge force.

*The AFT and FWD subcommands are eight characters long. The trailing blanks are not required.

The following input locations may be ignored:

(7)	0	PRTPRF	1: print results on every iteration. 0: do not print results on every iteration
(8-57)	0.2, at all radii.	VTXDLX	Chord-wise distance from leading edge at which vortex loads are assumed to act, in terms of fraction of local chord. There is one value of VTXDLX for each output station in the spanwise direction, specified as ZNIS (location 950) in the 2-D coordinate inputs under blade geometry (BLADEGEO section above).

AEROEXEC(PRNTCASE):
This command(sub-command) will process all of the input and execute the code to the point where the Compressible Panel Method prints the data it has received. The aerodynamic calculations will not be performed. This is useful in verifying the input before doing the actual aero calculations.

AEROEXEC(EXECCASE):
This command(sub-command) will process all of the input and execute the aerodynamic calculations.

NOIZEXEC(EXECCASE):
This command(sub-command) will execute the noise calculation section of the code. This should be placed after the AEROEXEC record.

WAKEEXEC(EXECCASE):
This command(sub-command) will execute the potential and viscous wake calculations. This should be placed after the AEROEXEC or NOIZEXEC record. This command should only be used with single rotation operation of the code.

ENDCASE:
This command signifies the end of all commands for the current case, and is required.

ENDJOB:
This command will terminate execution, and is required.

V Output Description

This section presents a description of the output from the UCAP program and includes output print from AEROEXEC (the panel code performance calculation). The output from NOISEXEC (the noise calculation) is described in Section VI.

The output of this program expands on the output of the UAAP program (reference 3). The outputs of the blade geometry routines, the vortex routines, and the lifting surface (steady) solution routines have changed due to the improvements in the code: these changes are applicable to single and counter--rotation operation. Also, the program output has been expanded due to the addition of counter-rotation; the outputs for streamline contraction, rotor-to-rotor interference velocities, and rotor control point location are new.

The debug option, described under the various input section commands, controls the scope of output. These options normally have values of either 0.0 (the default), for minimal printout, or 1.0, yielding additional output. Most pages have a title followed by the header information (entered *via* the HEADER command). The header consists of a brief description of the page contents. This includes, after the first colon, the subroutine name which is doing the printing of this page, 2) the input command option currently in effect, 3) the time and date at the start of the run, and 4) the program/version identification.

<u>Output Description when DEBUG = 1</u>

This output description follows the order shown in Section IV, "Input Description".

<u>OUTPUT</u>:
The output starts with an echo of the input data set, which is discussed in the input description, and shown in Figure 11.

<u>RUNPARMS</u>:
The debug option of 1. will print the page shown in Figure 12, which shows the input parameters, defined in the input section, along with the location number and the input or defaulted value.

<u>CRPPARMS</u>:
The debug option of 1 will print the page shown in Figure 13, which shows the parameters, defined in the input section, to be used for counter-rotation. FWD->AFT HARM. and AFT->FWD HARM specify the number of unsteady interference harmonics for the front rotor upon the aft rotor and the aft rotor upon the front rotor, respectively.

AIRPARMS:
Figure 14 presents the additional output for debug = 1. Again, the parameters are defined in the input section. A few lines of airfoil description are given, defining the airfoil selected, used to determine profile drag.

BLADEGEO:
Setting DEBUG = 1. in the BLADEGEO section of input yields an additional page of input definition, given in Figure 15. The sample shown in Figure 15 is for the forward rotor of a counter-rotation Prop-Fan. The items output and the form of the output is the same for either rotor of a counter-rotation Prop-Fan or the rotor of a single rotation Prop-Fan, so samples for those cases will not be included. Definitions of the parameters follow:

PARAMETER	DESCRIPTION
DEBUG	Debug option for additional printout.
BLADN	Number of blades.
DIAMETER	Propeller diameter, feet.
SCO	Inner-most blade station at 50% chord.
SWEEP TYPE	Defined in input as SWPOPT.
DESIGN ANGLE	Defined in input as THTDES.
RUNNING ANGLE	Defined in input as THTCUT.
TYPE CUT	Defined in input as ZKCUT.
X	Station radius/blade tip radius (R_{tip}).
T/B	Blade thickness/blade chord.
B/D	Blade chord/propeller diameter.
CAMBER	Design lift coefficient.
DELTA THETA	Blade twist, from plane of rotation, degrees.
XSWP	Defined in input.
YSWP	Defined in input.
ZSWP	Defined in input.

AIRFOIL TYPE	Defined in input as BAFL.
NO. OF % CHORD	Defined in input as ZNPCOV.
LIST OF % CHORD	Defined in input as PCTCHD.
NO. OUT STATIONS	Defined in input as ZNIS.
LIST - STATIONS	Defined in input as ZBLDST.

LSTPARMS:
Selecting the debug option, LSTBUG = 1, will print additional input definition as shown in Figure 16, which lists the available input options, their location number and the selected or defaulted values. Refer to the input description for more detail on input items. This is repeated for both rotors of a counter-rotation Prop-Fan.

NOIZPARM:
The debug option of 1 will print the page shown in Figure 17, which shows the input parameters, defined in the input section.

VELGRADS:
The debug option of 1 will result in the printout shown in Figure 18. Note that this input is not from the same test case as most of the other output sections and the positions and velocities are not normalized.

VORTPARM:
The debug option of 1 will print the page shown in Figure 19, which shows the input parameters, defined in the input section. The form of the VORTPARM output is identical for both the front and rear rotor in counter-rotation cases. Values of "X FOR LEV ACTION" are the chordwise positions (VTXDLX) at which the vortex loads act (see inputs).

WAKEPARM:
For counter-rotation operation, no items should be entered under the WAKEPARMS command: this description is superfluous. For single rotation, the printout in Figure 20 will be obtained. The input parameters are defined in the input section.

INTERPRM:
If the debug parameter for INTERPRM is set to 1, the output in Figure 21 results. The input parameters are defined in the input section. The following table relates the input and output designations.

OUTPUT ITEM	CORRESPONDING INPUT ITEM
Debug Switch	INTBUG
K	INTXK
ZO	INTZO
ZNORM	INTZNM
AOPT	INTAPT
IVWK	INTVWK
FPHW	INTFPH
NPSKN	INTSKN
TOL	INTTOL
TOLI	INTOLI
MMI	INTMMI
IPLOT	INTPLT
IPRT	INTPRT

Aerodynamic Output

AEROEXEC:

Figures 22 through 28 show the printout when LSTPARMS and CRPPARMS debug variables are set to one. Figure 22 shows the output for the GETXMB routine, which calculates the locations of the control points on each rotor relative to the other. This routine prints out seven blocks of information: some general propeller information, the geometry information for the forward rotor, the location of the forward rotor control points relative to the rear rotor, the forward rotor leading edge sweep information, the geometry for the rear rotor, the location of the rear rotor control points relative to the forward rotor, and the rear rotor leading edge sweep information.

Figure 23 shows the blade description. MCA and FA are shown in Figure 24. These describe the location, in space, of the mid chord line of the blade.

Figure 25 shows the locations of the front row control points relative to the pitch change axis of the rear rotor. DELTA PHI is the angle measured from the helicoidal surface to the control point. XMBAR is the distance, parallel to the axis of rotation, from the pitch change axis to the control point. MBAR is the control point number at a given radius. MU is the control point number counting from the forward control point at the root to the aft-most at the tip.

Figure 26 is the list of forward rotor inner and outer wake points. The inner wake points are those within a circular cylinder defined by the tips of the rear rotor. Outer wake points would be outside this cylinder.

Figure 27 is output of the LESWP routine, which calculates leading edge sweep. The sweep angle is shown in degrees at the stations specified by ZNIS and ZBLDST in the BLADEGEO inputs.

Figure 28 is the list of rear rotor inner and outer wake points. The inner wake points are those within a circular cylinder defined by the tips of the forward rotor. Outer wake points would be outside this cylinder.

Figure 29 shows the re-mapping of each rotor's control points, relative to the other rotor assuming the upstream influence follows streamlines. Since no data were entered under VELGRADS in this case, the default number of 5 streamlines (4 streamtubes) is used, the streamlines are concentric cylinders and the re-mapping does not move anything. Note that the first control radius is below the spinner cut-off, and therefore outside the inner streamtube (thus has the null streamtube 0 assigned to it), and that the outer 4 control radii are all contained in the outer streamtube (streamtube 4).

Figure 30 shows the information passed to the lifting surface solver (F271). This is:

PARAMETER	DESCRIPTION
TEMP, DEGF	Ambient temperature, °F
RHO/RHO STD	Ambient density/standard density
SPEED OF SOUND	Ambient speed of sound, fps
ADVANCE RATIO	V/nD, where V is flight velocity, in fps, n is propeller rotation rate in revolutions/second, and D is diameter, in feet.
FLIGHT MACH NO.	Flight Mach number
FLIGHT SPD KTS	Flight velocity, knots (nautical miles per hour)
RPM	Propeller rate of rotation, rpm
TIP HEL. MACH	Mach number based on resultant of flight and tip speeds.
START BLENDING	Defined in LSTPARMS input as QMBLEN
DIAMETER	Propeller diameter, feet
NO. BLADES	Number of blades
NO. INPT STA.	Number of input stations
FREQ. OF UNST.	Defined in LSTPARMS input as QQ
NO. NODAL DIA.	Defined in LSTPARMS input as QK
K - DOWN	Defined in LSTPARMS input as QKDOWN
K - START	Defined in LSTPARMS input as QKSTART
INPUT STATIONS	Blade radial station/blade tip radius
B/D	Blade chord/propeller diameter
TOTAL TWIST	Operating twist from plane of rotation, degrees
MCA/D	Distance from pitch change axis to blade mid-chord point along the helix/propeller diameter, see Figure 24. This and FA/D

	(next item) are functions of blade geometry and advance ratio.
FA/D	Perpendicular distance from helix to the intersection of the blade mid-chord and mid-camber point/diameter, see Figure 24.
T/B	Maximum blade thickness/blade chord
CLD	Blade design lift coefficient
SWEEP	Sweep angle between mid-chord line and resultant inflow velocity

<u>LST CAMBER TABLE</u>:
Another output table is shown in Figure 31. This is a table of the blade camber angle, measured from the plane of rotation as a function of local blade radius (normalized by tip radius) and fraction of the local chord.

<u>ANSO</u>:
Figure 32 gives the initial output from subroutine ANSO. This includes the contributors to the velocity triangle at each radial station and each control point. There are eleven columns; they are describe below.

Parameter	**Description**
I,MBAR, MU	Indexing information. I is station number, counting from root; MBAR is control point number, counting from leading edge of blade. MU is control point index, counting from leading edge to trailing edge, from root to tip.
R/R	Radial location of station in terms of R/R_{tip}.
TH+CAMB	Angle from plane of rotation to camber surface of the blade at this location, measured in degrees.

THICKNESS	W_T, thickness vector or the contribution to turning due to airfoil thickness, measured in degrees. In this case the W_T could not be calculated due to numerical problems on the IBM 3090. Typically the magnitude of this is less than 2°.
V-AXIAL	Axial component of the local change in velocity, $\Delta V/V_o$, due to induced flow and the presence of another rotor. This will be zero for the first pass for the forward rotor.
V-SWIRL	Tangential component of the local change in velocity, $\Delta V/V_o$, due to induced flow and the presence of another rotor. This will be zero for the first pass through the forward rotor.
PI*X/J	$\pi \cdot (r/R_{tip})/J$, the tangent of the advance angle at each radial station.
CENTER BODY	The local change in velocity due to the presence of the center body; this is from the velocity field which has been entered via the VELGRADS command. This is zero as no velocities were entered via the VELGRADS command.
WMU	Turning required to ensure the flow is tangent to the camber surface.

Also printed here is the coefficient of sound power, which is:

$$\text{acoustic power loss}/(\text{density}*(\text{rev/unit time})^3*(\text{diam})^5)$$

<u>PERFORMANCE</u> <u>RESULTS</u>:
Figure 33 shows the performance results for the individual rotor:

$$C_p = P/\rho n^3 D^5$$
$$C_t = T/\rho n^2 D^4$$
$$\text{Efficiency} = J(C_t/C_p)$$

where n is rotor rotational speed
D is diameter
ρ is fluid density
P is power
T is thrust

The units of n, D, and ρ, P, and T must be consistent.

Included are potential loads plus profile drag losses and the various non-linear lift terms which may result from leading edge sweep.

VORTEX CALC.:
Figures 34 through 38 show the vortex calculation outputs. Figure 34 shows the operating conditions. Figure 35 shows the angle of attack (A.O.A) at the leading edge, three dimensional angle, (ALPHA 3-D), induced angle, advance angle, and blade angle. Figure 36 shows the coefficients from the potential calculations. CDPOT does not include leading edge thrust. L.E. K, MAG is the leading edge suction force coefficient. This is calculated within the lifting surface portion of the code. It is used to calculate the leading edge force coefficient. Figure 37 shows the lift and drag coefficients which result from the vortex calculations. The incremental lift and drag coefficients illustrate the relative magnitude of the vortex components. Note that the tip edge vortex can cause lift (separated flow) or radial forces (attached flow). The terms "TIP VORTEX" and "SE VORTEX" (side edge) are used interchangeably. Figure 38 shows the elemental performance. MODOPT and NBOPT are LSTPARMS inputs and are explained in the LSTPARMS input section.

PERFORMANCE RESULTS:
Figure 39 shows the performance of each individual rotor. CP is the standard propeller power coefficient, $CP=P/(\rho n^3 D^5)$. CT is the standard propeller thrust coefficient, $CT=T/(\rho n^2 D^4)$. This information is repeated for each pass through each rotor.

INTFRS:
Figure 40 shows the velocities calculated as a result of the steady interference between rotors. The first section is a tabulation of the change in axial velocity due to the center body (VX-BODY), which is zero for this case as no velocities were entered with the VELGRADS command, and the rotor's induced velocity. VX-POT is the change in axial velocity, $\Delta V_x/V_0$ due to potential flow. VX-2DARY is the increment due to non-potential loading, e.g., vortex flow. The second section shows the velocity increment due to rotor loading at the rear rotor control points.

PRTPRF:
Figure 41 shows the performance summary at one of the intermediate steps. In part A of this Figure the performance without the vortex loading is shown, in part B the performance with the vortex loading. Both parts are divided into two sections: a coefficient section and a ratio section. In the coefficient section, the power, thrust, and torque coefficient and the efficiency are shown. The last coefficient, ROLLING MOMENT, is defined as

$$C_{rm}=(Q_{fwd}-Q_{aft})(\rho n^2 D^5)$$

where Q_{fwd} and Q_{aft} are the forward and rear rotor torque, respectively. All coefficients in the "TOTAL" column are based on the diameter and rotation rate of the forward rotor, hence FWD + AFT do not equal TOTAL. The ratio section has the ratio of tip speed, diameter, and angular speed of the aft rotor to the forward rotor. Also given are ratios of area, power, thrust, and torque for forward rotor to total, aft rotor to total, and aft rotor to forward rotor.

ADJUST:
Figure 42 shows the output of the routine which performs streamline adjustment. The first section shows the axial velocities at each control point. The second section shows the flow rates through each stream tube. The third section shows the new boundaries to the stream tubes after continuity is enforced.

CPMAP:
Figure 43 shows the re-location of the control points which are used for calculation of the flow induced by the rear rotor on the forward rotor.

CPMAP:
Figure 44 shows the relocation of the control points which are used for the calculation of the wake flow from the front rotor upon the rear rotor.

The output produced for each iteration is not included here; there is about 26 pages of printout per iteration with the DEBUG variable set to 1 in all input sections. Due to volume, they are not included here.

PROPELLER EFFICIENCY PROGRAM:
Figure 45 and 46 present the rotor-to-rotor interference field calculated by the near wake module. The information in Figure 45 is the steady calculation. At each station, there are two sets of data. The first is a single line with:

STATION	Station number, (1 = innermost) radial location in terms of R_{tip} of radius gener-

	ating influence field (here, the forward rotor)
PHI	Advance angle, degrees
SIGMA1 SIGMA2 SIGMA1/SIGMA2	Internally calculated values used in calculations of wake velocities which depend on radius and operating condition
TWIST	Angle between chordline and plane of rotation

Next there are ten lines (One line for each of QNCP points at each radius)

MBAR	Chord-wise control point number
XMBAR	Axial distance from pitch change axis, normalized by tip radius of rotor generating influence field
WMU (STEADY)	Perturbation angle produced by field
DOWN WASH	Down wash component of WMU
CHORDWISE	Chord-wise component of WMU
VISCOUS WAKE	Portion of WMU produced by the viscous deficit caused by profile drag of the front rotor
AXIAL	Axial component of WMU
SWIRL	Swirl component of WMU

Figure 46 shows a sample printout for the higher harmonic portion of the rotor-to-rotor interference field.

The first five lines show:

- Direction of interference
- Harmonic of blade pass frequency, m
- Number of blades, B
- Harmonic of shaft frequency, described in Section IV, "Input Description", under LSTPARMS as QK, and calculated as:

$$K_{front}=m*B_{aft}$$

$$K_{aft}=m*B_{front}$$

Q-order, described in Section IV, "Input Description", under LSTPARMS as QQ, and calculated as:

$$Q_{front}=K_{front}-(1+(n_{front}/n_{aft}))$$

$$Q_{aft}=K_{aft}-(1+(n_{aft}/n_{front}))$$

K and Q are calculated for the rotor receiving the interference.

Next, is one line for information for items which are constant at a given radius:

STATION	Station number and distance from center of rotation normalized by R_{tip}.
WAKEPNT	This is the normalized contracted radius for this station.
PHI	Advance Angle, degrees.
SIGMA1, SIGMA2, SIGMA1/SIGMA2	Internally calculated values used for calculations in the wake. These depend on radius and operating condition.
TWIST	Angle between chordline and plane of rotation, degrees.

After the line for each radius, there is one line for each chordwise point (QNCP):

MBAR, MU	Indexing information.
XMBAR	Distance from pitch change axis of rotor generating interference field.
DPHI	Angle from helicoidal surface to control point, degrees.
WMU	Unsteady loading downwash vector. This is the QWMU value described under LSTPARMS in Section IV, "Input Description".
DOWNWASH	Component of WMU normal to camber line of blade at this radial station.
CHORDWISE	Component of WMU tangent to chordline at this radial station.
VISCOUS WAKE	Component of WMU due to viscous wake.

VI. Noise Outputs

NOZOUT:
The first page of the noise program output (see Figure 47) summarizes the observer positions selected by the user. The first few lines repeat the header information. Then, the computer time used is presented. Then, the observer locations selected by the user are printed. First, the sideline distance for the front (or single) and/or rear rotors is printed. Then, for the front rotor, the retarded axial positions, the visual axial positions, and the corresponding retarded and visual radiation angles are printed. The relationships between the visual and retarded distances and angles are also shown in Figure 47. Finally, the front rotor azimuthal observer angle is printed.

The rear rotor is offset axially from the front rotor by a fraction of the front rotor radius. This fraction is printed, and the corresponding retarded and visual axial positions and radiation angles are printed. Listing of the rear rotor azimuthal observer position completes the observer geometry printout in figure 47.

The local ambient conditions are then listed, giving the temperature, ambient pressure normalized by sea level standard, and local speed of sound.

On the next page, in Figure 48, the front and rear rotor operating conditions are printed. FLIGHT MACH NUMBER is the free-stream Mach number. TIP ROTATIONAL MACH is the tip speed divided by the speed of sound. TIP RELATIVE MACH NUMBER is the resultant of the flight and tip rotational Mach numbers. MT/MX is the ratio of tip Mach number to flight Mach number. BPF is the blade passing frequency, measured in Hertz. The FOOT DIAMETER is tip diameter, in feet, of the rotor.

On the next page (Figure 49) is a header indicating the beginning of the noise calculation results. Following the header is a summary of the noise calculation results for the first directivity. This type of page is repeated for as many directivities as were requested by the user. The X POSITION ANGLE for visual and retarded axial position and angles for front and rear rotor is shown. Then, for each possible noise radiation frequency, a summary of the noise radiated by the front and rear rotors is given. The M COUNTER and K COUNTER are given for the front rotor. Thus, K COUNTER = 0 corresponds to steady loading, and the steady sources are also printed. The roles of the M COUNTER and K COUNTER are reversed for the rear rotor, so M COUNTER = 0 corresponds to steady loading for the rear rotor. Results are presented for each harmonic up to MMAX, and then a new page (not shown) presents results for the next axial observer location.

Finally, a summary of the total noise at each frequency is presented in Figure 50. The header information is followed by a listing of the observer coordinates. The computed radiation frequency and the total combined noise for the front and rear rotors are presented at each frequency. This output format is repeated for all requested directivities and harmonics.

VII. Program Installation

UCAP is written in FORTRAN-77, mostly adhering to ANSI X3.9-1978, with the common additions of the double precision complex (complex*16) data type and the IMAG intrinsic function. UCAP requires the IMSL Libraries, version 1.1 (formerly IMSL 10), mostly for FFT's, Bessel functions, and matrix inversions. The IMSL Libraries are copyrighted; they are not supplied with UCAP. A list of the routines directly called from UCAP is provided in Table II.

The target operating environments for this program are the Cray series of super-computers. This program was developed on an IBM 3090 running MVS/XA and a Sun workstation running Sun's version of UNIX. Based on experience with the interim (Task 2) version of UCAP and with UAAP, this program is expected to be operated on the Cray with double precision turned off (by a compiler option) and with the single precision version of the IMSL routines. Many complex numbers are operated on within UCAP; Table III presents a list of subprograms where AIMAG or IMAG is used. In the IBM and Sun dialects of FORTRAN-77, the IMAG intrinsic function is required when operating on complex*16 data. This is replaced by AIMAG for Cray FORTRAN, which does not support the complex*16 data type. Because of the different IMSL calls and the need to use AIMAG, directives for *cpp* (the C pre-processor, a utility supported by UNICOS and most UNIX systems) were included into the distribution source code to select single precision IMSL calls and AIMAG on Cray systems versus double precision IMSL calls and IMAG on other systems.

On Cray systems running UNICOS, selection of single/double precision IMSL subroutine calls and IMAG/AIMAG intrinsic function use would be done by compiling with:

```
cf77 -DCRAY -c -dp ucap.F
```

if the FORTRAN compiler supports the C pre-processor or

```
cpp -DCRAY ucap.F > ucap.f
    cf77 -dp -c ucap.f
```

where the FORTRAN compiler does not.

On Cray systems, *segldr* would then be used to link the resulting object code (ucap.o) with the IMSL Libraries in order to produce an executable copy of the program.

VIII. File Requirements

UCAP requires several files for input, output, and data transfer. The input data file (number 5), and the input data files for the noise routines (numbers 49 and 50) are fixed record length files. These must have a minimum of 80 characters per record, excluding the new line or carriage return used to terminate lines in the UNIX system; these will have to be padded with blanks. The input data files for the noise routines generated by UCAP are properly formed for program operation.

File Number	File Contents	File Remarks
5	Input Data	Fixed record length, with a minimum of 80 characters per record. A typical input file will contain about 400 lines (32,000 bytes).
6	Printed Output	Standard FORTRAN printed output: up to 133 characters per record, with the first character reserved for carriage control. This will be about 10000 lines.
	The following files are generated by the program:	
11	Copy of Input Data	Fixed record length, 80 characters per record. This is a "scratch" file which need not be retained after program execution. This will be the same size as file used for unit number 5.
40	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
41	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).

49	Aft Rotor Input Data for Noise Routines	Fixed record length, 80 characters per record. This will be about 400 lines for the steady and 200 additional lines for each harmonic specified in CRPPARMS.
50	Forward Rotor Input Data for Noise Routines.	Fixed record length, 80 characters per record. This will be about 400 lines for the steady and 200 additional lines for each harmonic specified in CRPPARMS.
51	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
52	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
AFTTHV FWDTHV SRPTHV	Aft Rotor Thickness Vector Forward Rotor Thickness Vector Single Rotor Thickness Vector	Unformatted, i.e., written without FORTRAN format control. These may be saved for later use. Size is about 800 bytes (100 Cray words).

Due to the necessity of generating numerous influence coefficient matrices, UCAP uses the FORTRAN OPEN statement to assign file names at run time, when running counter-rotation. Any influence coefficient matrix file may be retained for use in later program runs. However for counter-rotation the program must re-generate **all** influence coefficient matrices for a given rotor if any **new** influence coefficient matrix is required for that rotor.

File Name	File Contents	File Remarks
SRP000	Single rotation influence coefficient matrix. This is used for steady and unsteady matrices.	Unformatted. Approximately 20,000 Cray words (160,000 bytes).
AFT000 FWD000	Counter-rotation steady influence coefficient matrices, for the aft or forward rotor.	Unformatted. Approximately 20,000 Cray words (160,000 bytes) each.

AFT001 through AFT0nn	Counter-rotation unsteady influence coefficient matrices, for the aft rotor. The trailing number (0nn) is incremented by one for each unsteady matrix required for the number of interaction orders (forward to rear rotor) specified in CRPPARMS.	Unformatted. Each is approximately 20,000 Cray words (160,000 bytes) each.
FWD001 through FWD0nn	Counter-rotation unsteady influence coefficient matrices, for the forward rotor. The trailing number (0nn) is incremented by one for each unsteady matrix required for the number of interaction orders (forward to rear rotor) specified in CRPPARMS.	Unformatted. Each is approximately 20,000 Cray words (160,000 bytes) each.

IX. Error Messages

This section contains a description of the printed error messages, along with possible causes and remedies in alphabetized order.

"AIRFOIL NO. = ... OFF AIRFOIL DATA AND IOFF ..."

The program obtains profile drag from airfoil data tables as a function of lift, mach number, airfoil thickness ratio, and airfoil chord. This message indicates one or more of the above parameters exceeded the limits of the stored data.
Recommendation : check the output for reasonable values of drag coefficients. Use AIRPARMS inputs CDMULT and DCD to correct unreasonable values.

"AIRFOIL ... OFF AIRFOIL DATA "

Same as above.

"BDSO ... "

There are a number of errors, generally resulting in program termination, which are associated with the blade geometry generator; these messages are prefaced with BDSO. They arise because the blade surface generated from user input in BLADEGEO was not sufficient to allow intersection with the output stations (conical surfaces) specified in BLADEGEO variable ZBLDST.
Solution: The problem can usually be avoided (with only a slight loss in program accuracy) by setting THTDES = THTCUT in BLADEGEO, and assuring that X(1) < ZBLDST(1) and X(10) > ZBLDST(ZNIS) in BLADEGEO input.

"*** CONTROL POINT STATIONS NOT WITHIN ..."

The radial difference between control points, QZAR in LSTPARMS, and ZBLDST in BLADEGEO > .02 .
Solution : Change the either QZAR or ZBLDST input values.

"FAILED TO CONVERGE ON CL ..."

An iteration failed when trying to obtain the profile drag data from the airfoil tables.
Recommendation : check the output for reasonable values of drag coefficients. Use AIRPARMS inputs CDMULT and DCD to correct unreasonable values.

"FOR OUTPUT POINT NUMBER ..."

Interpolation of the flowfield from VELGRADS is performed in two ways : radial first, axial second, and then axial first, radial second. Usually these interpolations yield the same value of velocity at a fixed radial and axial location. However, for this point the difference in interpolations exceeded 1 %. Probable cause : the flowfield is not smooth in either or both the radial and axial directions.

"FOR OUTPUT POINT NUMBER ... THE AXIAL ..."

The axial extent of coordinates input into VELGRADS was not sufficient to allow interpolation of the flowfield at either the blade leading or trailing edge.
Solution: add more points to the flowfield input in VELGRADS in the axial direction.

"FOR OUTPUT POINT NUMBER ... THE RADIAL ..."

The radial extent of coordinates input into VELGRADS was not sufficient to allow interpolation of the flowfield at either the blade root or tip.
Solution : add more points to the flowfield input in VELGRADS in the radial direction.

"INVALID INPUT CHARACTER ..."

The load routine has found a character in column 1 which is not an "L","C","E", or blank.
Possible causes : "END" record omitted; numeric data in column 1.

"THE INPUT CONTAINS AN UNKNOWN COMMAND ... "

A COMMAND was expected at this point in the input, however, the 8 printed characters do not represent a recognizable command.
Possible causes : misspelled command; no "END" record in load format, incorrect case (use UPPER CASE only); COMMAND didn't start in column 1.

"THE INPUT CONTAINS AN UNKNOWN SUBCOMMAND.."

A sub-command was found which didn't match the acceptable sub-commands.
Possible causes : incorrect spelling; incorrect placement of parenthesis.

"THE NUMBER OF HEADER CARDS ...."

More than 10 header records were encountered during processing of the HEADER command.
Possible causes : more than 10 records following the HEADER command; no "END" record after the last header record.

"V1S1X1 DIMENSIONED 20X20 ..."

The flowfield input in VELGRADS was too large; the maximum number of coordinates in the axial or radial direction is 20.
Solution : reduce the number VINRD and/or VINAS to 20.

"***** MM2 AND MM3 MUST BE LESS THAN 100 ..."

See QMM2 and QMM3 limits in LSTPARMS.

"***** NBOPT MUST BE 1 OR 2 ..."

See QNBOPT limits in LSTPARMS.

"***** NCP GREATER THAN MAX NCP ..."

See QNCN limits in LSTPARMS.

"***** NIS GREATER THAN MAX NIS ... "

See ZNIS limits in BLADEGEO.

"** NOIZEXEC CALLED WITH KEYWORD ..."

An unrecognizable sub-command was found. The sub-command must be "EXECCASE".

"***** NSM GREATER THAN MAX NSM ... "

See QNSM limits in LSTPARMS.

"***** NSM * NCP GREATER THAN ..."

Ensure that QNSM * QNCP < 1000 in LSTPARMS.

"*** NUMBER OF NODAL DIAMETERS (K) MUST ..."

If QQ = 0 then QK must equal zero in the LSTPARMS input.

"***** NX GREATER THAN ..."

See ZNPCOV limits in BLADEGEO.

"**** THE DATA FOR THIS RUN & THE DATA ..."

A label is attached to the "K-INVERSE" matrix describing the parameters used to create it. The current value of the input variable listed below the error message does not agree with that in the attached label.
Cause : This generally arises because a "K-INVERSE" matrix from a previous run was used as input to this run (see QPART1 in LSTPARMS) and the data used to generate that matrix is different than that being used to run the current case.

"*** THE NO. OF DIRECTIVITY POINTS ..."

See ZNX limits in NOIZPARM.

"*** THE NO. OF HARMONICS IS GREATER ..."
See ZMMAX limits in NOIZPARM.

"*** THE NO. OF HARMONICS IS GREATER THAN ALLOWED 150"
"*** THE NO. OF HARMONICS X THE NO. OF BLADES IS LIMITED TO 1000"
"*** THE NO. OF RADIAL INTEGRATION POINTS IS LIMITED TO 2000"
"*** THE NO. OF DIRECTIVITY POINTS IS LIMITED TO 20"
Cause - input values larger than permissible
Solution - correct input

References

1. Hanson, D.B., "Unified Aeroacoustics Analysis for High-speed Turboprop Aerodynamics and Noise: Volume I - Development of Theory for Blade Loading, Wakes, and Noise", NASA Contractor Report 4329, 1991

2. Hanson, D.B. etal "Unified Aerocoustics Analysis for High Speed Turboprop Aerodynamics and Noise: Volume III - Application of Theory for Blade Loading Wakes, Noise, and Wing Shielding", NASA Contractor Report 184193, 1991

3. Menthe, R.W., McColgan, C.J. and Ladden, R.M., "Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise: Volume IV - Computer User's Manual for UAAP Turboprop Aerocoustic Code", NASA Contractor Report 185194, 1991

Appendix A
Example QWMU Generating Program and Modified Block Data CRPBLK

This section has the listing (Figure 51) for a small, stand alone program, QWMUGEN, which will generate the unsteady downwash vector, QWMU, described under LSTPARMS (locations 351 to 550) in the section of this manual describing the inputs.

This program will generate the QWMU vector for sinusoidal gust described in Reference 1, pp 88-90. It requires these inputs:

J, advance ratio

NCP, number of chordwise panels (LSTPARMS, location 2)

NSM, number of spanwise modes (LSTPARMS, location 4)

QZAR, spanwise locations of control point radii (LSTPARMS, locations

BD, blade chord/diameter at the QZAR points

QQ, order of unsteady loading harmonic (LSTPARMS, location 21)

WZERO, peak amplitude of gust velocity divided by rotor tip speed

This program will print the elements of the QWMU vector, in a form suitable for use in the LSTPARMS section of the input.

The second listing (Figure 52) is the block data, CRPBLK, in which the default values for the items described under the CRPPARMS input section are set. This listing has the default value of CRPTOL (CRPPARMS, location 5) set to 0.01. The default values of the other variables can also be set to different values here.

Table I
Common block locations

Common Block Name	Size in bytes	subprogram {type}
airalz	2364	airbk3 {block data} air24 {subroutine} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
aircdf	312	airbk2 {block data} air24 {subroutine}} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
aircdm	392	airbk3 {block data} air24 {subroutine} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}

Table I (continued)

airdat	4000	air24 {subroutine} airdgr {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
airp01	400	airbk1 {block data} airdrg {subroutine} airprm {subroutine} lstuns {subroutine}
bdsc01	644	bds018 {subroutine} bldbk3 {block data}
bdsc02	8	bds018 {subroutine}
bdsc03	3628	bds014 {subroutine} bldbk4 {block data}
besar	6400000	bessav {subroutine} bsint {subroutine} bsjint {subroutine} bsyint {subroutine}
besdel	8	bessav {subroutine} bsint {subroutine} bsjint {subroutine} bsyint {subroutine}
bldg01	4000	bldbk {block data} bldct1 {subroutine} bldgi1 {subroutine} fetch {subroutine} retrev {function} store {subroutine}
bldg02	8000	fetch {subroutine} retrev {function} store {subroutine}

Table I (continued)

bldg03	60800	bldct3 {subroutine} bldgi3 {subroutine} fetch {subroutine} retrev {function} store {subroutine}
bldgc3	121600	fetch {subroutine} store {subroutine}
bldgeo	24000	bldbk2 {block data} bldct1 {subroutine} bldct3 {subroutine} bldgi1 {subroutine} bldgi2 {subroutine} bldgi3 {subroutine} bldgp1 {subroutine} fetch {subroutine} lstuns {subroutine} mcafa {subroutine} retrev {function} store {subroutine}
bldgxo	48000	fetch {subroutine} retrev {function} store {subroutine}
com002	72	ggs011 {subroutine} ggs107 {subroutine}
crpp01	36	crpblk {block data} crpprm {subroutine} lstuns {subroutine} lstvvc {subroutine} newpg1 {subroutine} nrk001 {subroutine} retrev {function} wak001 {subroutine}
crpsr1	24	velgrd {subroutine}
crpsr2	4	velgrd {subroutine}

Table I (continued)

dtetme	32	airprm {subroutine} bldgem {subroutine} bldgi1 {subroutine} bldgi2 {subroutine} bldgi3 {subroutine} bldgp1 {subroutine} hdrbk1 {block data} header {subroutine} inptrw {subroutine} intfr1 {subroutine} intprm {subroutine} lstctl {subroutine} lstprm {subroutine} lstuns {subroutine} MAIN {main routine} newpg1 {subroutine} noisez {subroutine} runprm {subroutine} vtxprm {subroutine} wak001 {subroutine} wakpr1 {subroutine} wakprm {subroutine]
headr1	728	hdrbk2 {block data} header {subroutine} lstctl {subroutine} lstuns {subroutine} newpg1 {subroutine}
headr2	4	hdrbk2 {block data} header {subroutine} lstctl {subroutine} lstuns {subroutine} newpg1 {subroutine}
hsqspl	4424	lstsw1 {subroutine} noznhf {subroutine} qsplin {subroutine} vtxinp {subroutine}
intp01	64	intblk {block data} intfrs {subroutine} intfr1 {subroutine} lstctl {subroutine} lstuns {subroutine}
kclsav	40	isoarf {subroutine}

Table I (continued)

lstp01	2800	fetch {subroutine} lstbk1 {block data} lstprm {subroutine} lstuns {subroutine} retrev {function} store {subroutine}
lstp02	5600	fetch {subroutine} retrev {function} store {subroutine}
lstr01	29800	airdrg {subroutine} fetch {subroutine} intrf1 {subroutine} lstuns {subroutine} lstvvc {subroutine} store {subroutine}
lstr02	4400	fetch {subroutine} intfr1 {subroutine} lstuns {subroutine} store {subroutine} wak001 {subroutine}
lstsr2	8800	fetch {subroutine} store {subroutine}
lstspr	59600	fetch {subroutine} store {subroutine}
nozdat	632	nozbk1 {block data} nozclc {subroutine} nozprm {subroutine}
nozs16	6408	nozbk2 {block data} nozffc {subroutine} noznfc {subroutine}
output	4	bds014 {subroutine}
provrs	4	idblk {block data} lstuns {subroutine} newpg1 {subroutine}
rncp01	400	lstctl {subroutine} lstuns {subroutine} mcafa {subroutine} runblk {block data} runprm {subroutine}

Table I (continued)

v1iic1	4900	lstctl {subroutine} lstuns {subroutine} vel002 {subroutine} velbk1 {block data} velgrd {subroutine} vttbin {subroutine}
vtxc02	480	fetch {subroutine} retrev {function} store {subroutine}
vtxcom	240	fetch {subroutine} retrev {function} store {subroutine} vtxblk {block data} vtxout {subroutine} vtxprm {subroutine}
wakp01	4000	fetch {subroutine} lstuns {subroutine} retrev {function} store {subroutine} wak001 {subroutine} wakblk {block data} wakprm {subroutine}
wakp02	8000	fetch {subroutine} retrev {function} store {subroutine}
wakr01	24000	fetch {subroutine} intfr1 {subroutine} lstuns {subroutine} store {subroutine} wak001 {subroutine} wakpr1 {subroutine}
waksp2	48000	fetch {subroutine} store {subroutine}
work	2119852	f271 {subroutine} f271no {subroutine} intfr3 {subroutine} lstctl {subroutine} lstuns {subroutine} nrk001 {subroutine} wak003 {subroutine}
work1	3200	f271 {subroutine}

Table I (continued)

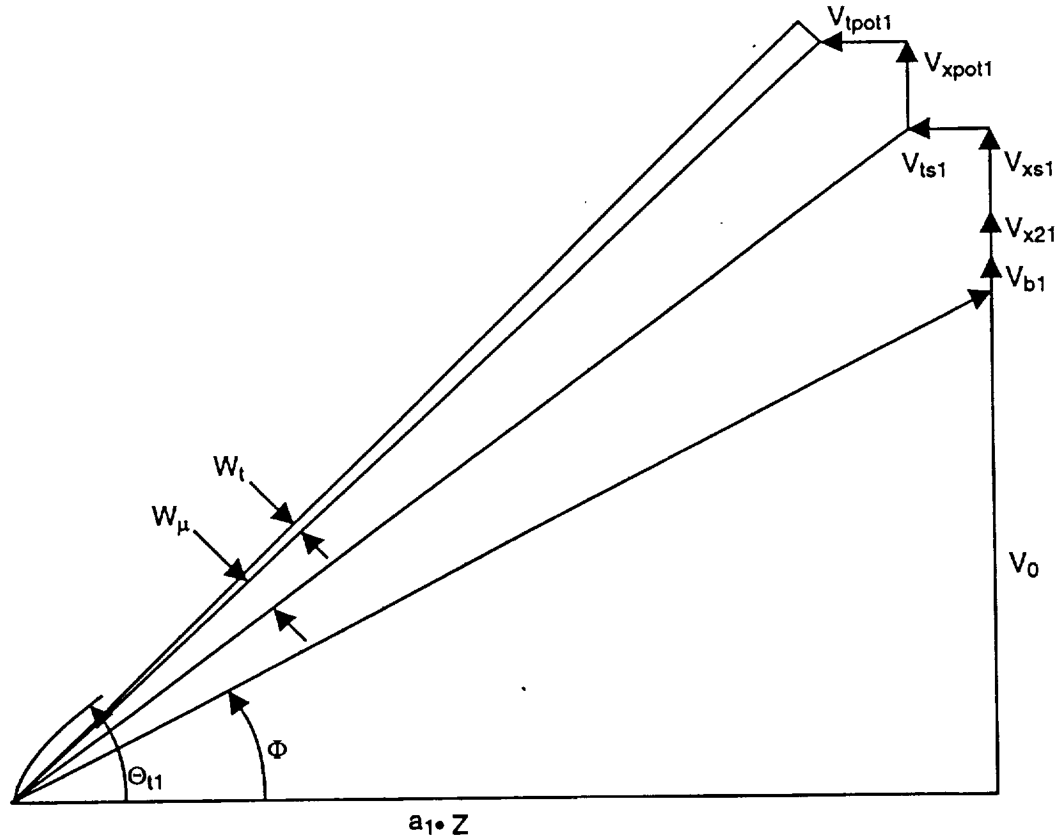
		f271no {subroutine} lstuns {subroutine}
worksp	100000	MAIN {main routine}
xindex	12	bds014 {subroutine]

Table II
Locations of IMSL routines used within UCAP

IMSL Routine	Used by
bsi0	ik0, iksub0, stdiki, sum3, sum4, tik0
bsi1	sum3
bsins	nozhnk, wake
bsj0	iksub0
bsj1	wingf
bsjns	bessav, bsint, bsjint, nozffc, nozhnk, noznfc
bsk0	ik0, iksub0, stdiki, sum3, sum4, tik0
bsk1	sum3, wingf
bskes	nozhnk, wake
bsys	bessav, bsint, bsyint, iksub0, nozhnk, wingf
csint	f001
csval	f001, ffun
ctime	jobtim
dtime	MAIN, endjob
erfc	imnsub, imnsin
fftcb	fftcx, fftcx0, fftcxn
iidex	fetch, retrev, store
iicsr	fetch, retrev, store
iwkin	MAIN
lincg	kmatrx
linrg	f271no, kmatr0
tdate	MAIN

Table III
Locations where AIMAG is used within UCAP

ansn1
bds024
bound
fftcxn
iksub
iksub0
lstctl
nozffc
noznj2
noznfc
noznj2
nozout
nozstt
nozunt
r4aray
wingf



V_{xpot1}	$\Delta V_x/V_0$ due to potential loading of forward rotor.
V_{tpot1}	V_t/V_0 due to potential loading of forward rotor.
V_{ts1}	V_t/V_0 due to secondary (non-potential) loading of forward rotor.
V_{xs1}	$\Delta V_x/V_0$ due to secondary (non-potential) loading of forward rotor.
V_{x21}	$\Delta V_x/V_0$ from rear rotor loading at forward rotor.
V_{b1}	$\Delta V_x/V_0$ due to presence of center body.
V_0	Freestream velocity. Normalized freestream velocity is unity.
$a_1 \cdot Z$	$(\pi/J_1) \cdot (r/R_1)$, where J is advance ratio, R_1 is tip radius, r is local radius.
Φ	Advance angle, measured from plane of rotation.
Θ_{t1}	Camber plus twist angle for each panel, measured from plane of rotation.
W_t	Turning due to blade thickness.
W_μ	Turning required for boundary condition (no flow through the blade) to be met.
ΔV_x	Change in axial velocity
V_t	Tangential (swirl) velocity

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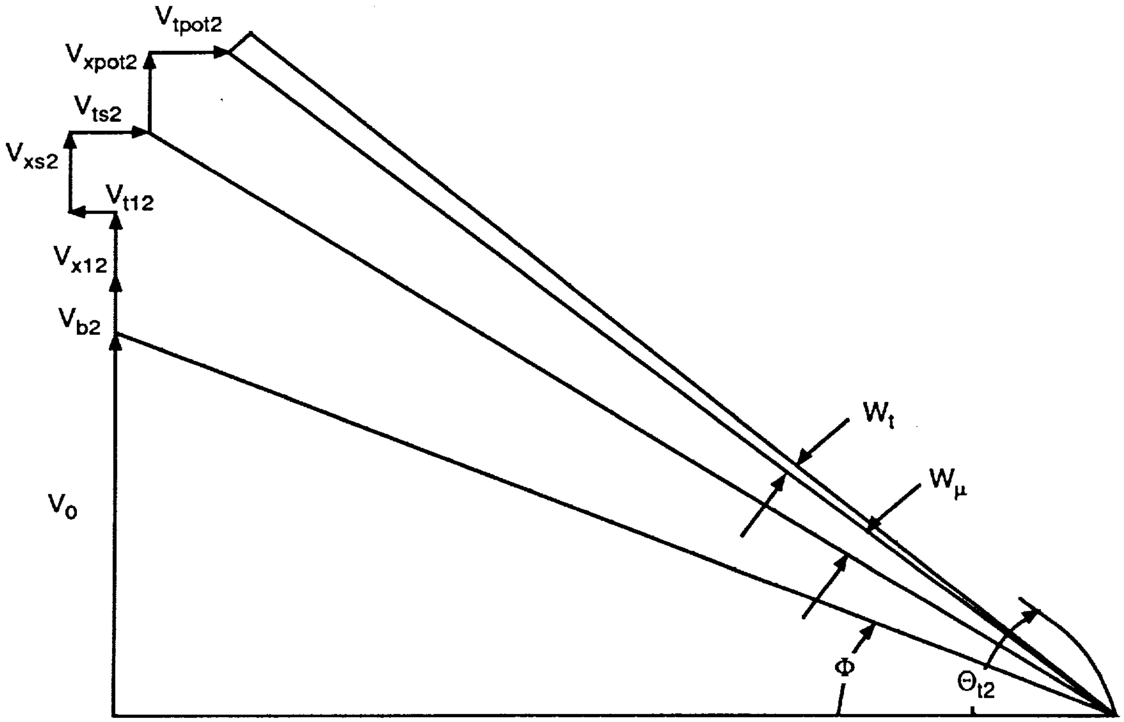
Figure 1 (part a) Forward Rotor Velocity Diagram



V_{xpot2}	$\Delta V_x/V_0$ due to potential loading of rear rotor.
V_{tpot2}	V_t/V_0 due to potential loading of rear rotor.
V_{ts2}	V_t/V_0 due to secondary (non-potential) loading of rear rotor.
V_{xs2}	$\Delta V_x/V_0$ due to secondary (non-potential) loading of rear rotor.
V_{x12}	$\Delta V_x/V_0$ from forward rotor loading at rear rotor.
V_{t12}	V_x/V_0 from forward rotor loading at rear rotor.
V_{b2}	$\Delta V_x/V_o$ due to presence of center body.
V_0	Freestream velocity. Normalized freestream velocity is unity.
$a_2 \cdot Z$	$(\pi/J_2)\cdot(r/R_2)$, where J is advance ratio, R_2 is tip radius, r is local radius.
Φ	Advance angle, measured from plane of rotation.
Θ_{t2}	Camber plus twist angle for each panel, measured from plane of rotation.
W_t	Turning due to blade thickness.
$W\mu$	Turning required for boundary condition (no flow through the blade) to be met.
ΔV_x	Change in axial velocity
V_t	Tangential (swirl) velocity

Figure 1 (part b) Rear Rotor Velocity Diagram

A Calculate axisymmetric streamlines. This is done off line.

B Calculate, off line, streamline angles where streamlines cross blade mid-chord line. These angles are measured from the axis of rotation.

C Calculate table of camber plus twist angles, along conical surfaces defined by streamline angles calculated in step **B**, for front and rear rotors.

D Calculate the location of the rear rotor control points in relation to stream tubes defined by the axisymmetric streamlines.

E Calculate forward (or single) rotor influence coefficient matrix. Store for later use.

F Calculate turning angle due to blade thickness for forward (or single) rotor. Store for later use.

G Calculate potential loading. $\mathbf{L}=[K]^{-1}\times\mathbf{W}$, where $[K]^{-1}$ is influence coefficient matrix, and **W** is the turning angle required to satisfy the boundary conditions.

H Calculate induced velocity from potential loading using momentum theory.

J Calculate total loading, including vortex effects.

K Calculate induced velocity from total loading, including vortex effects.

L Calculate axial $\Delta V/V_\infty$ and swirl, $V\theta/V_\infty$ at rear rotor mapping points, calculated in step **D**, above. These velocities will be applied at the rear rotor control points, as shown in Figure 1.

*Steps **M** through **V** are only applied in counter-rotation. For single rotation, jump to step **W**.*

M Calculate locations of forward rotor control points relative to annular stream tubes defined by the axisymmetric streamlines.

N Calculate rear rotor influence coefficient matrix. Store it for later use.

P Calculate turning angle due to blade thickness.

Q Calculate potential loading, as in step **G**, above.

R Calculate induced velocity from potential loading, using momentum theory.

S Calculate total loading, including vortex effects.

T Calculate induced velocity field from total loading, including vortex effects.

U Calculate axial $\Delta V/V_\infty$ induced by rear rotor at forward rotor mapping points, calculated in step **M**, above. Note there is no swirl ahead of a rotor.

V Calculate synthetic streamline radial locations in order to enforce incompressible continuity, $\nabla\cdot\mathbf{V}=0$.

W Convergence monitor: converged if $|c_{p,i}-c_{p,i-1}|$ is less than a limiting value for both rotors.

X Noise module: acoustic analysis

Figure 2: Conceptual flow chart of UCAP

```
**** TSO FOREGROUND HARDCOPY **** 14:26:48 93112
DSNAME=TSOG04F.TREE.DATA
MAIN
 1        IWKIN
 1        JOBTIM
 1        DTIME
 1        TDATE
 1        INPTRW
  2           NEWPG1
 1        STORE
 1        LSTCTL
  2           SPZERO
  2           SETIO
  2           GETXMB
   3              MCAFA
    4                 FETCH
    4                 NEWPG1
    4                 TOLSTS
    4                 PRNTXX
    4                 PRNTIN
    4                 LSTSW1
     5                    QSPLIN
      6                       SPFUNC
      6                       SPCOEF
       7                          SPL5D3
      6                       SPSVAL
       7                          SPLSEV
      6                       SPMVAL
       7                          SPLSEV
     5                    LSTCGA
     5                    LSTXYZ
    4                 STORE
   3              UNLIN
   3              LESWP
  2           KINFIL
  2           THVFIL
  2           LSTDY
   3              FETCH
   3              NEWPG1
   3              PRNTXX
   3              F27INO
    4                 JOBTIM
    4                 EXIT
    4                 BLEND
     5                    DUNLIN
     5                    IMILU
    4                 MUNUAR
    4                 DLINRG
    4                 ANSONO
     5                    DUNLIN
     5                    DUNBAR
     5                    ANSON1
      6                       DUNLIN
      6                       IMILU
     5                    NEWPG1
     5                    UVINT
     5                    AIRDRG
      6                       AIRFLX
       7                          ISOARF
        8                             ISOAFL
         9                                AIR24
          A                                   LIFT24
           B                                      LNEAR1
          A                                   DRAG24
           B                                      LNEAR1
         9                                AIROFF
          A                                   AIR24
           B                                      LIFT24
            C                                         LNEAR1
           B                                      DRAG24
            C                                         LNEAR1
       7                          CASARF
        8                             ISOARF
         9                                ISOAFL
          A                                   AIR24
           B                                      LIFT24
            C                                         LNEAR1
           B                                      DRAG24
            C                                         LNEAR1
          A                                   AIROFF
           B                                      AIR24
            C                                         LIFT24
             D                                            LNEAR1
            C                                         DRAG24
             D                                            LNEAR1
        8                             STARC
         9                                UNINT
        8                             ZEROAL
         9                                ISOARF
          A                                   ISOAFL
           B                                      AIR24
            C                                         LIFT24
             D                                            LNEAR1
            C                                         DRAG24
             D                                            LNEAR1
           B                                      AIROFF
            C                                         AIR24
             D                                            LIFT24
              E                                               LNEAR1
             D                                            DRAG24
              E                                               LNEAR1
        8                             DZROAL
         9                                UNBAR
         9                                UNINT
        8                             CLFACT
         9                                UNBAR
       7                          SWPARF
        8                             ISOARF
         9                                ISOAFL
          A                                   AIR24
           B                                      LIFT24
            C                                         LNEAR1
           B                                      DRAG24
            C                                         LNEAR1
          A                                   AIROFF
           B                                      AIR24
            C                                         LIFT24
             D                                            LNEAR1
            C                                         DRAG24
             D                                            LNEAR1
```

Figure 3A: UCAP Calling Tree

```
8                      CASARF
 9                       ISOARF
  A                        ISOAFL
   B                         AIR24
    C                          LIFT24
     D                           LNEARI
    C                          DRAG24
     D                           LNEARI
   B                         AIROFF
    C                          AIR24
     D                           LIFT24
      E                            LNEARI
     D                           DRAG24
      E                            LNEARI
 9                       STARC
  A                        UNINT
 9                       ZEROAL
  A                        ISOARF
   B                         ISOAFL
    C                          AIR24
     D                           LIFT24
      E                            LNEARI
     D                           DRAG24
      E                            LNEARI
    C                          AIROFF
     D                           AIR24
      E                            LIFT24
       F                             LNEARI
      E                            DRAG24
       F                             LNEARI
 9                       DZROAL
  A                        UNBAR
  A                        UNINT
 9                       CLFACT
  A                        UNBAR
8                      LNEARI
6                  NEWPG1
6                  AIRP02
 7                   PRNTIN
 7                   PRNTXX
6                  PRNTXX
4              CSPSUB
 5               BSINT
  6                DBSJNS
  6                DBSYS
 5               DUNLIN
3            F271
 4             JOBTIM
 4             NEWPG1
 4             PRNTDP
 4             PRNTIN
 4             DTABLP
 4             PRNTCD
 4             EXIT
 4             DUNLIN
 4             BESSAV
  5              EXIT
  5              DBSJNS
  5              DBSYS
 4             BLEND
  5              DUNLIN
```

```
  5              IMILU
 4             MUNUAR
 4             KMATRX
  5              DUNLIN
  5              AIK2
  5              JOBTIM
  5              WAKE
   6               EXIT
   6               DUNLIN
   6               DBSINS
   6               DBSKES
   6               IKCOMB
   6               CHECK
   6               IMNSUB
   6               WAKESN
    7                DUNLIN
    7                SUM1
    7                CHECK
    7                SUM2
    7                SUM3
     8                 IKPCMB
     8                 IPKCMB
    7                SUM4
     8                 IKCOMB
    7                SUM5
     8                 IKCOMB
    7                SUM6
    7                IMNSIN
  5              BOUND
   6               SMWAK0
   6               SMWAK
   6               DUNLIN
   6               IIEXYV
    7                EXIT
   6               DEFZ0
   6               MSUM
    7                INFFNS
     8                 IKSUB
      9                  IKNEW
       A                   BSJINT
        B                    DBSJNS
       A                   BSYINT
        B                    DBSYS
       A                   JYNEW
      9                  JYCOMB
     8                 IKSUB0
      9                  SPECIN
     8                 FFTCX
      9                  DFFTCB
     8                 R4ARAY
     8                 PLTFFT
      9                  IMILU
    7                CHECK
   6               WING
    7                WINGIN
     8                 WINGF
      9                  DBSYS
     8                 FFTCX
      9                  DFFTCB
     8                 R4ARAY
     8                 PLTFFT
```

Figure 3A: UCAP Calling Tree (continued)

```
9                                       IMILU
6                           CENTER
6                           RADINT
7                               EXIT
7                               CUNLIN
7                               CTRAP
5                       DLINCG
4                   KMATR0
5                       AIK2
5                       DUNLIN
5                       WAKM0
6                           DUNLIN
6                           WAKM01
7                               DUNLIN
7                               IMNSIN
5                       BOUND0
6                           DUNLIN
6                           IIEXPS
7                               EXIT
6                           Z0DEF
6                           INFFN0
7                               IKNEW
8                                   BSJINT
9                                     DBSJNS
8                                   BSYINT
9                                     DBSYS
8                                   JYNEW
7                               IKNHP
8                                   JYCOMB
7                               IK0
7                               FFTCX0
8                                   DFFTCB
7                               PLTFF0
8                                   IMILU
5                       JOBTIM
5                       WAKEQ0
6                           EXIT
6                           DUNLIN
6                           DBSINS
6                           DBSKES
6                           CHECK
6                           IMNSUB
6                           WAKES0
7                               DUNLIN
7                               IKPCMB
7                               IPKCMB
7                               CHECK
7                               IKCOMB
7                               IMNSIN
5                       BOUND
6                           SMWAK0
6                           SMWAK
6                           DUNLIN
6                           IIEXYY
7                               EXIT
6                           DEFZ0
6                           MSUM
7                               INFFNS
8                                   IKSUB
9                                     IKNEW
A                                       BSJINT
```

```
B                                         DBSJNS
A                                       BSYINT
B                                         DBSYS
A                                       JYNEW
9                                     JYCOMB
8                                   IKSUB0
9                                     SPECIN
8                                   FFTCX
9                                     DFFTCB
8                                   R4ARAY
8                                   PLTFFT
9                                     IMILU
7                               CHECK
6                           WING
7                               WINGIN
8                                   WINGF
9                                     DBSYS
8                                   FFTCX
9                                     DFFTCB
8                                   R4ARAY
8                                   PLTFFT
9                                     IMILU
6                           CENTER
6                           RADINT
7                               EXIT
7                               CUNLIN
7                               CTRAP
5                       DLINRG
4                   THICK
5                       PSIK2
5                       THICK0
6                           DUNLIN
6                           IIEXPS
7                               EXIT
6                           Z0DEF
6                           INF
7                               IKNEW
8                                   BSJINT
9                                     DBSJNS
8                                   BSYINT
9                                     DBSYS
8                                   JYNEW
7                               TIKSUB
7                               TIK0
7                               FFTCX0
8                                   DFFTCB
7                               PLTFF0
8                                   IMILU
5                       THICK3
6                           DUNLIN
6                           IIEXPS
7                               EXIT
6                           Z0DEF
6                           INF
7                               IKNEW
8                                   BSJINT
9                                     DBSJNS
8                                   BSYINT
9                                     DBSYS
8                                   JYNEW
7                               TIKSUB
```

Figure 3A: UCAP Calling Tree (continued)

```
7            TIK0
7            FFTCX0
8               DFFTCB
7            PLTFF0
8               IMILU
6         CHECK
4   ANS
5      LSTVVC
6         NEWPG1
6         PRNTDP
6         PRNTIN
6         DUNLIN
6         VEL003
7            EXIT
7            NEWPG1
7            PRNTDP
7            PRNTXX
7            PRNTIN
7            BDS024
8               BDS016
9                  ERRSXT
8               BDS025
9                  BDS026
9                  BDS023
6         PRNTXX
5      DUNBAR
5      DSLOCB
5      DUNLIN
5      ANSN1
6         NEWPG1
6         DUNLIN
6         IMILU
4   ANS0
5      LSTVVC
6         NEWPG1
6         PRNTDP
6         PRNTIN
6         DUNLIN
6         VEL003
7            EXIT
7            NEWPG1
7            PRNTDP
7            PRNTXX
7            PRNTIN
7            BDS024
8               BDS016
9                  ERRSXT
8               BDS025
9                  BDS026
9                  BDS023
6         PRNTXX
5      DUNBAR
5      ANS0N1
6         DUNLIN
6         IMILU
5      NEWPG1
5      UVINT
5      AIRDRG
6         AIRFLX
7            ISOARF
8               ISOAFL
```

```
9                  AIR24
A                     LIFT24
B                        LNEAR1
A                     DRAG24
B                        LNEAR1
9                  AIROFF
A                     AIR24
B                        LIFT24
C                           LNEAR1
B                        DRAG24
C                           LNEAR1
7            CASARF
8               ISOARF
9                  ISOAFL
A                     AIR24
B                        LIFT24
C                           LNEAR1
B                        DRAG24
C                           LNEAR1
A                     AIROFF
B                        AIR24
C                           LIFT24
D                              LNEAR1
C                           DRAG24
D                              LNEAR1
8               STARC
9                  UNINT
8               ZEROAL
9                  ISOARF
A                     ISOAFL
B                        AIR24
C                           LIFT24
D                              LNEAR1
C                           DRAG24
D                              LNEAR1
B                        AIROFF
C                           AIR24
D                              LIFT24
E                                 LNEAR1
D                              DRAG24
E                                 LNEAR1
8               DZROAL
9                  UNBAR
9                  UNINT
8               CLFACT
9                  UNBAR
7            SWPARF
8               ISOARF
9                  ISOAFL
A                     AIR24
B                        LIFT24
C                           LNEAR1
B                        DRAG24
C                           LNEAR1
A                     AIROFF
B                        AIR24
C                           LIFT24
D                              LNEAR1
C                           DRAG24
D                              LNEAR1
8               CASARF
```

Figure 3A: UCAP Calling Tree (continued)

```
    9                        ISOARF
     A                         ISOAFL
      B                          AIR24
       C                           LIFT24
        D                            LNEAR1
       C                           DRAG24
        D                            LNEAR1
      B                          AIROFF
       C                           AIR24
        D                            LIFT24
         E                             LNEAR1
        D                            DRAG24
         E                             LNEAR1
    9                        STARC
     A                         UNINT
    9                        ZEROAL
     A                         ISOARF
      B                          ISOAFL
       C                           AIR24
        D                            LIFT24
         E                             LNEAR1
        D                            DRAG24
         E                             LNEAR1
       C                           AIROFF
        D                            AIR24
         E                             LIFT24
          F                              LNEAR1
         E                             DRAG24
          F                              LNEAR1
    9                        DZROAL
     A                         UNBAR
     A                         UNINT
    9                        CLFACT
     A                         UNBAR
   8                       LNEAR1
  6                  NEWPG1
  6                  AIRP02
   7                   PRNTIN
   7                   PRNTXX
  6                  PRNTXX
 4               CSPSUB
  5                BSINT
  6                  DBSJNS
  6                  DBSYS
  5                DUNLIN
3             VTXCAL
 4              VTXINI
 4              VTXKST
 4              VTXDLE
 4              VTXCSE
 4              VTXCDZ
 4              VTXAUG
 4              VTXPRF
 4              VTXDBO
 4              VTXOUT
  5               NEWPG1
3             VTXOUT
 4              NEWPG1
3             VTXNWT
3             VTXWRD
3             MOMCAL
```

```
3             STORE
2           NEWPG1
2           LSTUNS
3             FETCH
3             NEWPG1
3             PRNTXX
3             F271
 4              JOBTIM
 4              NEWPG1
 4              PRNTDP
 4              PRNTIN
 4              DTABLP
 4              PRNTCD
 4              EXIT
 4              DUNLIN
 4              BESSAV
  5               EXIT
  5               DBSJNS
  5               DBSYS
 4              BLEND
  5               DUNLIN
  5               IMILU
 4              MUNUAR
 4              KMATRX
  5               DUNLIN
  5               AIK2
  5               JOBTIM
  5               WAKE
   6                EXIT
   6                DUNLIN
   6                DBSINS
   6                DBSKES
   6                IKCOMB
   6                CHECK
   6                IMNSUB
   6                WAKESN
    7                 DUNLIN
    7                 SUM1
    7                 CHECK
    7                 SUM2
    7                 SUM3
     8                  IKPCMB
     8                  IPKCMB
    7                 SUM4
     8                  IKCOMB
    7                 SUM5
     8                  IKCOMB
    7                 SUM6
    7                 IMNSIN
  5               BOUND
   6                SMWAK0
   6                SMWAK
   6                DUNLIN
   6                IIEXVY
    7                 EXIT
   6                DEFZ0
   6                MSUM
    7                 INFFNS
     8                  IKSUB
      9                   IKNEW
       A                    BSJINT
```

Figure 3A: UCAP Calling Tree (continued)

```
B                         DBSJNS
A                       BSYINT
B                         DBSYS
A                       JYNEW
9                     JYCOMB
8                   IKSUB0
9                     SPECIN
8                   FFTCX
9                     DFFTCB
8                   R4ARAY
8                   PLTFFT
9                     IMILU
7                 CHECK
6               WING
7                 WINGIN
8                   WINGF
9                     DBSYS
8                   FFTCX
9                     DFFTCB
8                   R4ARAY
8                   PLTFFT
9                     IMILU
6               CENTER
6               RADINT
7                 EXIT
7                 CUNLIN
7                 CTRAP
5             DLINCG
4           KMATR0
5             AIK2
5             DUNLIN
5             WAKM0
6               DUNLIN
6               WAKM01
7                 DUNLIN
7                 IMNSIN
5             BOUND0
6               DUNLIN
6               IIEXPS
7                 EXIT
6               Z0DEF
6               INFFN0
7                 IKNEW
8                   BSJINT
9                     DBSJNS
8                   BSYINT
9                     DBSYS
8                   JYNEW
7                 IKNWP
8                   JYCOMB
7                 IK0
7                 FFTCX0
8                   DFFTCB
7                 PLTFF0
8                   IMILU
5             JOBTIM
5             WAKEQ0
6               EXIT
6               DUNLIN
6               DBSINS
6               DBSKES
```

```
6               CHECK
6               IMNSUB
6               WAKES0
7                 DUNLIN
7                 IKPCMB
7                 IPKCMB
7                 CHECK
7                 IKCOMB
7                 IMNSIN
5             BOUND
6               SMWAK0
6               SMWAK
6               DUNLIN
6               IIEXYY
7                 EXIT
6               DEFZ0
6               MSUM
7                 INFFNS
8                   IKSUB
9                     IKNEW
A                       BSJINT
B                         DBSJNS
A                       BSYINT
B                         DBSYS
A                       JYNEW
9                     JYCOMB
8                   IKSUB0
9                     SPECIN
8                   FFTCX
9                     DFFTCB
8                   R4ARAY
8                   PLTFFT
9                     IMILU
7                 CHECK
6               WING
7                 WINGIN
8                   WINGF
9                     DBSYS
8                   FFTCX
9                     DFFTCB
8                   R4ARAY
8                   PLTFFT
9                     IMILU
6               CENTER
6               RADINT
7                 EXIT
7                 CUNLIN
7                 CTRAP
5             DLINRG
4           THICK
5             PSIK2
5             THICK0
6               DUNLIN
6               IIEXPS
7                 EXIT
6               Z0DEF
6               INF
7                 IKNEW
8                   BSJINT
9                     DBSJNS
8                   BSYINT
```

Figure 3A: UCAP Calling Tree (continued)

```
9           DBSVS
8          JYNEW
7         TIKSUB
7         TIK0
7         FFTCX0
8          DFFTCB
7         PLTFF0
8          IMILU
5     THICK3
6      DUNLIN
6      IIEXPS
7         EXIT
6      Z0DEF
6      INF
7         IKNEW
8          BSJINT
9           DBSJNS
8          BSVINT
9           DBSYS
8          JYNEW
7         TIKSUB
7         TIK0
7         FFTCX0
8          DFFTCB
7         PLTFF0
8          IMILU
6      CHECK
4    ANS
5     LSTVVC
6      NEWPG1
6      PRNTDP
6      PRNTIN
6      DUNLIN
6      VEL003
7         EXIT
7         NEWPG1
7         PRNTDP
7         PRNTXX
7         PRNTIN
7         BDS024
8          BDS016
9           ERRSXT
8          BDS025
9           BDS026
9           BDS023
6      PRNTXX
5     DUNBAR
5     DSLOCB
5     DUNLIN
5     ANSN1
6      NEWPG1
6      DUNLIN
6      IMILU
4    ANS0
5     LSTVVC
6      NEWPG1
6      PRNTDP
6      PRNTIN
6      DUNLIN
6      VEL003
7         EXIT
```

```
7         NEWPG1
7         PRNTDP
7         PRNTXX
7         PRNTIN
7         BDS024
8          BDS016
9           ERRSXT
8          BDS025
9           BDS026
9           BDS023
6      PRNTXX
5     DUNBAR
5     ANS0N1
6      DUNLIN
6      IMILU
5     NEWPG1
5     UVINT
5     AIRDRG
6      AIRFLX
7         ISOARF
8          ISOAFL
9           AIR24
A            LIFT24
B             LNEAR1
A            DRAG24
B             LNEAR1
9           AIROFF
A            AIR24
B             LIFT24
C              LNEAR1
B             DRAG24
C              LNEAR1
7         CASARF
8          ISOARF
9           ISOAFL
A            AIR24
B             LIFT24
C              LNEAR1
B             DRAG24
C              LNEAR1
A            AIROFF
B             AIR24
C              LIFT24
D               LNEAR1
C              DRAG24
D               LNEAR1
8          STARC
9           UNINT
8          ZEROAL
9           ISOARF
A            ISOAFL
B             AIR24
C              LIFT24
D               LNEAR1
C              DRAG24
D               LNEAR1
B             AIROFF
C              AIR24
D               LIFT24
E                LNEAR1
D               DRAG24
```

Figure 3A: UCAP Calling Tree (continued)

```
  E                 LNEAR1
8                 DZROAL
 9                  UNBAR
 9                  UNINT
8                 CLFACT
 9                  UNBAR
7               SWPARF
8                 ISOARF
 9                  ISOAFL
  A                   AIR24
   B                    LIFT24
    C                     LNEAR1
   B                    DRAG24
    C                     LNEAR1
  A                   AIROFF
   B                    AIR24
    C                     LIFT24
     D                      LNEAR1
    C                     DRAG24
     D                      LNEAR1
8                 CASARF
 9                  ISOARF
  A                   ISOAFL
   B                    AIR24
    C                     LIFT24
     D                      LNEAR1
    C                     DRAG24
     D                      LNEAR1
   B                    AIROFF
    C                     AIR24
     D                      LIFT24
      E                       LNEAR1
     D                      DRAG24
      E                       LNEAR1
 9                  STARC
  A                   UNINT
 9                  ZEROAL
  A                   ISOARF
   B                    ISOAFL
    C                     AIR24
     D                      LIFT24
      E                       LNEAR1
     D                      DRAG24
      E                       LNEAR1
    C                     AIROFF
     D                      AIR24
      E                       LIFT24
       F                        LNEAR1
      E                       DRAG24
       F                        LNEAR1
 9                  DZROAL
  A                   UNBAR
  A                   UNINT
 9                  CLFACT
  A                   UNBAR
8                 LNEAR1
6             NEWPG1
6             AIRP02
 7              PRNTIN
 7              PRNTXX
6             PRNTXX
```

```
    4             CSPSUB
     5              BSINT
      6               DBSJNS
      6               DBSYS
     5              DUNLIN
  3             VTXNWT
  3             STORE
 2          SLFWD
  3             UVINT
  3             INTLIN
   4              CROSSP
   4              ENDPT
   4              CKOUT
 2          SLAFT
  3             INTLIN
   4              CROSSP
   4              ENDPT
   4              CKOUT
 2          CPMAP
 2          VTTBIN
  3             UVINT
 2          INTFR1
  3             INTFR2
   4              ERRSYT
   4              NEWPG1
   4              F001
    5               DNORM
     6                DMNX
    5               IFXPLT
    5               DCSINT
    5               IMILU
   4              INTFR3
    5               HHSUB
     6                P1
     6                P2
     6                CHECKM
    5               NRK001
     6                JOBTIM
     6                NEWPG1
     6                DTABLP
     6                PRNTCD
     6                BESSAV
      7                 EXIT
      7                 DBSJNS
      7                 DBSYS
     6                BLEND
      7                 DUNLIN
      7                 IMILU
     6                MUNUAR
     6                NRK002
      7                 NRK007
       8                  EXIT
      7                 NRK004
      7                 NRK005
      7                 NRK003
       8                  Z0DEF
       8                  DUNLIN
       8                  NRK009
        9                   IK0
        9                   FFTCXN
         A                    DFFTCB
```

Figure 3A: UCAP Calling Tree (continued)

```
 9                PLTFF0
  A                 IMILU
 7            JOBTIM
 7            NRK006
 8              ZODEF
 8              DUNLIN
 8              NRK008
 9                IKNEW
  A                 BSJINT
   B                  DBSJNS
  A                 BSYINT
   B                  DBSYS
  A                 JYNEW
 9                IKNWP
  A                 JVCOMB
 9                FFTCXN
  A                 DFFTCB
 9                PLTFF0
  A                 IMILU
 8              CHECK
 5        WAK004
 6          DUNLIN
 5        NRK01A
 6          NRK01B
 6          NEWPG1
 6          IMILU
 6          IFXPLT
 2  CPYSDP
 2  INTFRS
 3    DUNLIN
 3    STDIKI
 3    DTRAP
 2  PRTPRF
 3    NEWPG1
 2  ADJUST
 3    NEWPG1
 3    UVINT
 1 AIRPRM
 2  INPTC1
 3    ENDJOB
 4      DTIME
 3    INPTC2
 2  NEWPG1
 2  PRNTXX
 2  AIRDRG
 3    AIRFLX
 4      ISOARF
 5        ISOAFL
 6          AIR24
 7            LIFT24
 8              LNEAR1
 7            DRAG24
 8              LNEAR1
 6          AIROFF
 7            AIR24
 8              LIFT24
 9                LNEAR1
 8              DRAG24
 9                LNEAR1
 4      CASARF
 5        ISOARF
```

```
 6          ISOAFL
 7            AIR24
 8              LIFT24
 9                LNEAR1
 8              DRAG24
 9                LNEAR1
 7            AIROFF
 8              AIR24
 9                LIFT24
  A                 LNEAR1
 9                DRAG24
  A                 LNEAR1
 5        STARC
 6          UNINT
 5        ZEROAL
 6          ISOARF
 7            ISOAFL
 8              AIR24
 9                LIFT24
  A                 LNEAR1
 9                DRAG24
  A                 LNEAR1
 8              AIROFF
 9                AIR24
  A                 LIFT24
   B                  LNEAR1
  A                 DRAG24
   B                  LNEAR1
 5        DZROAL
 6          UNBAR
 6          UNINT
 5        CLFACT
 6          UNBAR
 4      SWPARF
 5        ISOARF
 6          ISOAFL
 7            AIR24
 8              LIFT24
 9                LNEAR1
 8              DRAG24
 9                LNEAR1
 7            AIROFF
 8              AIR24
 9                LIFT24
  A                 LNEAR1
 9                DRAG24
  A                 LNEAR1
 5        CASARF
 6          ISOARF
 7            ISOAFL
 8              AIR24
 9                LIFT24
  A                 LNEAR1
 9                DRAG24
  A                 LNEAR1
 8              AIROFF
 9                AIR24
  A                 LIFT24
   B                  LNEAR1
  A                 DRAG24
   B                  LNEAR1
```

Figure 3A: UCAP Calling Tree (continued)

```
6          STARC
 7           UNINT
6          ZEROAL
 7           ISOARF
  8            ISOAFL
   9             AIR24
    A              LIFT24
     B               LNEAR1
    A              DRAG24
     B               LNEAR1
   9             AIROFF
    A              AIR24
     B               LIFT24
      C                LNEAR1
     B               DRAG24
      C                LNEAR1
6          DZROAL
 7           UNBAR
 7           UNINT
6          CLFACT
 7           UNBAR
5         LNEAR1
3       NEWPG1
3       AIRP02
4        PRNTIN
4        PRNTXX
3       PRNTXX
1     BLDGEM
2      BLDGI1
3       INPTC1
4        ENDJOB
5         DTIME
4        INPTC2
3       NEWPG1
3       PRNTXX
3       BLDCT1
4        QSPLIN
5         SPFUNC
5         SPCOEF
6          SPL5D3
5         SPSVAL
6          SPLSEV
5         SPMVAL
6          SPLSEV
4        UVINT
4        NEWPG1
4        PRNTIN
4        PRNTXX
4        BDS052
5         EXIT
5         BDS004
6          BDS015
7           BDS014
8            BDS010
9             CAMTHA
A              EXIT
8            BDS018
8            HS1
9             EXIT
8            PF1
9             EXIT
```

```
8            HS2
9             EXIT
8            H455S
9             EXIT
8            PF2
9             EXIT
8            BDS011
9             BDS020
8            BDS019
8            BDS013
8            MLINE
9             BDS019
9             BDS013
8            CAMTHA
9             EXIT
8            BDS012
8            BDS024
9             BDS016
A              ERRSXT
9             BDS025
A              BDS026
A              BDS023
8            BDS020
7           BDS024
8            BDS016
9             ERRSXT
8            BDS025
9             BDS026
9             BDS023
6          BDS104
7           BDS086
8            BDS096
8            BDS095
9             BDS097
8            BDS089
9             BDS088
8            BDS088
5         GGS107
5         GGS011
5         BDS024
6          BDS016
7           ERRSXT
6          BDS025
7           BDS026
7           BDS023
5         BDS053
6          BDS024
7           BDS016
8            ERRSXT
7           BDS025
8            BDS026
8            BDS023
5         BDS016
6          ERRSXT
5         GGS252
6          GGS253
6          GGS254
5         BDS054
4        EXIT
4        UNINT
4        BLDGCA
```

Figure 3A: UCAP Calling Tree (continued)

```
      5                 SLOCUB
      5                 NEWPG1
    3           BLDGP1
     4              NEWPG1
     4              PRNTXX
   2        BLDGI2
    3           INPTC1
     4              ENDJOB
      5                 DTIME
     4              INPTC2
    3           NEWPG1
    3           BLDGP1
     4              NEWPG1
     4              PRNTXX
    3           UNINT
   2        BLDGI3
    3           INPTC1
     4              ENDJOB
      5                 DTIME
     4              INPTC2
    3           NEWPG1
    3           PRNTXX
    3           EXIT
    3           BLDCT3
     4              PRNTIN
     4              BDSA52
      5                 BDS024
       6                    BDS016
        7                       ERRSXT
       6                    BDS025
        7                       BDS026
        7                       BDS023
      5                 BDS053
       6                    BDS024
        7                       BDS016
         8                          ERRSXT
        7                       BDS025
         8                          BDS026
         8                          BDS023
      5                 BDS016
       6                    ERRSXT
      5                 GGS252
       6                    GGS253
       6                    GGS254
      5                 BDS054
     4              EXIT
     4              NEWPG1
     4              PRNTXX
     4              UNINT
     4              BLDGCA
      5                 SLOCUB
      5                 NEWPG1
    3           BLDGP1
     4              NEWPG1
     4              PRNTXX
   2        STORE
  1     CRPPRM
   2        INPTC1
    3           ENDJOB
     4              DTIME
    3           INPTC2
```

```
   2        NEWPG1
   2        PRNTXX
  1     ENDCAS
   2        DTIME
  1     ENDJOB
   2        DTIME
  1     HEADER
   2        NEWPG1
  1     INTPRM
   2        INPTC1
    3           ENDJOB
     4              DTIME
    3           INPTC2
   2        NEWPG1
   2        PRNTXX
  1     LSTPRM
   2        FETCH
   2        INPTC1
    3           ENDJOB
     4              DTIME
    3           INPTC2
   2        NEWPG1
   2        PRNTXX
   2        PRNTCS
   2        STORE
  1     NOISEX
   2        NOZCLC
    3           NEWPG1
    3           JOBTIM
    3           NOZINP
    3           NOZCHK
     4              NOZNJ2
      5                 NOZTCM
     4              NOZKKC
      5                 MNX
      5                 NOZAMP
       6                    NOZHNK
        7                       DBSINS
        7                       DBSKES
        7                       DBSJNS
        7                       DBSYS
    3           NOZFFC
     4              NOZTRP
      5                 EXIT
     4              DBSJNS
     4              NOZTCM
     4              NOZAIR
     4              NOZHPL
      5                 NOZNHF
       6                    QSPLIN
        7                       SPFUNC
        7                       SPCOEF
         8                          SPL5D3
        7                       SPSVAL
         8                          SPLSEV
        7                       SPHVAL
         8                          SPLSEV
       6                    NOZHFL
       6                    NOZTRL
     4              NOZBLC
     4              NOZQPL
```

Figure 3A: UCAP Calling Tree (continued)

```
4              NOZTRL
4              NOZUNT
4              NOZSTT
3          NOZNFC
4              NOZTRP
5                  EXIT
4              NOZHNK
5                  DBSINS
5                  DBSKES
5                  DBSJNS
5                  DBSVS
4              NOZTCH
4              NOZAIR
4              NOZMPL
5                  NOZNHF
6                      QSPLIN
7                          SPFUNC
7                          SPCOEF
8                              SPL5D3
7                          SPSVAL
8                              SPL5EV
7                          SPMVAL
8                              SPL5EV
6                      NOZHFL
6                      NOZTRL
4              NOZBLC
4              NOZQPL
4              DBSJNS
4              NOZTRL
4              NOZUNT
4              NOZSTT
3          NOZOUT
4              NEWPG1
4              NOZOU2
5                  NEWPG1
5                  NOZUNT
5                  NOZSTT
5                  NOZOU3
6                      NEWPG1
6                      NOZUNT
1  NOZPRM
2      INPTC1
3          ENDJOB
4              DTIME
3          INPTC2
2      NEWPG1
2      PRNTXX
1  RUNPRM
2      INPTC1
3          ENDJOB
4              DTIME
3          INPTC2
2      NEWPG1
2      PRNTXX
1  VELGRD
2      INPTC1
3          ENDJOB
4              DTIME
3          INPTC2
2      NEWPG1
2      VEL002
```

```
3          PRNTXX
1  VTXPRM
2      FETCH
2      NEWPG1
2      INPTC1
3          ENDJOB
4              DTIME
3          INPTC2
2      PRNTXX
2      STORE
1  WAK001
2      FETCH
2      WAK002
3          ERRSVT
3          NEWPG1
3          WAKPR1
4              FETCH
4              PRNTDP
4              PRNTIN
3          EXIT
3          F001
4              DNORM
5                  DMNX
4              IFXPLT
4              DCSINT
4              IMILU
3          WAK003
4              EXIT
4              HMSUB
5                  P1
5                  P2
5                  CHECKM
4              NRK001
5                  JOBTIM
5                  NEWPG1
5                  DTABLP
5                  PRNTCD
5                  BESSAV
6                      EXIT
6                      DBSJNS
6                      DBSVS
5                  BLEND
6                      DUNLIN
6                      IMILU
5                  MUNUAR
5                  NRK002
6                      NRK007
7                          EXIT
6                      NRK004
6                      NRK005
6                      NRK003
7                          Z0DEF
7                          DUNLIN
7                          NRK009
8                              IK0
8                              FFTCXN
9                                  DFFTCB
8                              PLTFF0
9                                  IMILU
6                      JOBTIM
6                      NRK006
```

Figure 3A: UCAP Calling Tree (continued)

```
       7                      Z0DEF
       7                      DUNLIN
       7                      NRK008
        8                         IKNEW
         9                          BSJINT
          A                           DBSJNS
         9                          BSYINT
          A                           DBSYS
         9                          JYNEW
        8                         IKNWP
         9                          JYCOMB
        8                         FFTCXN
         9                          DFFTCB
        8                         PLTFF0
         9                          IMILU
       7                      CHECK
    4                 WAK004
     5                    DUNLIN
    4                 NRK010
     5                    EXIT
     5                    NRK011
     5                    NEWPG1
     5                    IMILU
     5                    IFXPLT
  2           STORE
 1        WAKPRM
  2           FETCH
  2           INPTC1
   3              ENDJOB
    4                 DTIME
   3              INPTC2
  2           NEWPG1
  2           PRNTXX
  2           STORE
```

Figure 3A: UCAP Calling Tree (continued)

```
**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSO0041.XREF1.DATA

SUBROUTINE CROSS REFERENCE LISTING

SUBR.                  SUBROUTINES NAMED


ABSVAL IS CALLED BY :
ADJUST IS CALLED BY : LSTCTL
AIRDRG IS CALLED BY : AIRPRM ANS0   ANS0NO
AIRFLX IS CALLED BY : AIRDRG
AIROFF IS CALLED BY : ISOAFL
AIRPRM IS CALLED BY : MAIN
AIRP02 IS CALLED BY : AIRDRG
AIR24  IS CALLED BY : AIROFF ISOAFL
ANS    IS CALLED BY : F271
ANSN1  IS CALLED BY : ANS
ANS0   IS CALLED BY : F271
ANS0NO IS CALLED BY : F271NO
ANS0N1 IS CALLED BY : ANS0   ANS0NO
ARCTAN IS CALLED BY :
AIK2   IS CALLED BY : KMATRX KMATR0
BDSA52 IS CALLED BY : BLDCT3
BDS004 IS CALLED BY : BDS052
BDS010 IS CALLED BY : BDS014
BDS011 IS CALLED BY : BDS014
BDS012 IS CALLED BY : BDS014
BDS013 IS CALLED BY : BDS014 MLINE
BDS014 IS CALLED BY : BDS015
BDS015 IS CALLED BY : BDS004
BDS016 IS CALLED BY : BDSA52 BDS024 BDS052
BDS018 IS CALLED BY : BDS014
BDS019 IS CALLED BY : BDS014 MLINE
BDS020 IS CALLED BY : BDS011 BDS014
BDS023 IS CALLED BY : BDS025
BDS024 IS CALLED BY : BDSA52 BDS014 BDS015 BDS052 BDS053 VEL003
BDS025 IS CALLED BY : BDS024
BDS026 IS CALLED BY : BDS025
BDS052 IS CALLED BY : BLDCT1
BDS053 IS CALLED BY : BDSA52 BDS052
BDS054 IS CALLED BY : BDSA52 BDS052
BDS086 IS CALLED BY : BDS104
BDS088 IS CALLED BY : BDS086 BDS089
BDS089 IS CALLED BY : BDS086
BDS095 IS CALLED BY : BDS086
BDS096 IS CALLED BY : BDS086
BDS097 IS CALLED BY : BDS095
BDS104 IS CALLED BY : BDS004
BESSAV IS CALLED BY : F271   NRK001
BLDCT1 IS CALLED BY : BLDGI1
BLDCT3 IS CALLED BY : BLDGI3
BLDGCA IS CALLED BY : BLDCT1 BLDCT3
BLDGEM IS CALLED BY : MAIN
BLDGI1 IS CALLED BY : BLDGEM
BLDGI2 IS CALLED BY : BLDGEM
BLDGI3 IS CALLED BY : BLDGEM
BLDGP1 IS CALLED BY : BLDGI1 BLDGI2 BLDGI3
BLEND  IS CALLED BY : F271   F271NO NRK001
BOUND  IS CALLED BY : KMATRX KMATR0
```

```
BOUND0 IS CALLED BY : KMATR0
BSINT  IS CALLED BY : CSPSUB
BSJINT IS CALLED BY : IKNEW
BSYINT IS CALLED BY : IKNEW
CAMTHA IS CALLED BY : BDS010 BDS014
CASARF IS CALLED BY : AIRFLX SWPARF
CENTER IS CALLED BY : BOUND
CHECK  IS CALLED BY : MSUM   NRK006 THICK3 WAKE   WAKEQ0 WAKESN WAKES0
CHECKM IS CALLED BY : HMSUB
CKOUT  IS CALLED BY : INTLIN
CLFACT IS CALLED BY : CASARF
CONVRG IS CALLED BY :
CPMAP  IS CALLED BY : LSTCTL
CPYSDP IS CALLED BY : LSTCTL
CROSSP IS CALLED BY : INTLIN
CRPPRM IS CALLED BY : MAIN
CSPSUB IS CALLED BY : F271   F271NO
CTRAP  IS CALLED BY : RADINT
CUNLIN IS CALLED BY : RADINT
DEF20  IS CALLED BY : BOUND
DMNX   IS CALLED BY : DNORM
DNORM  IS CALLED BY : F001
DRAG24 IS CALLED BY : AIR24
DSLOCB IS CALLED BY : ANS
DTABLP IS CALLED BY : F271   NRK001
DTRAP  IS CALLED BY : INTFRS
DUNBAR IS CALLED BY : ANS    ANS0   ANS0NO
DUNLIN IS CALLED BY : ANS    ANSN1  ANS0NO ANS0N1 BLEND  BOUND  BOUND0 CSPSUB F271   INTFRS
DUNLIN IS CALLED BY : KMATRX KMATR0 LSTVVC NRK003 NRK006 THICK0 THICK3 WAKE   WAKEQ0 WAKESN
DUNLIN IS CALLED BY : WAKES0 WAKM0  WAKM01 WAK004
DZROAL IS CALLED BY : CASARF
ENDCAS IS CALLED BY : MAIN
ENDJOB IS CALLED BY : MAIN   INPTC1
ENDPT  IS CALLED BY : INTLIN
ERRSXT IS CALLED BY : BDS016
ERRSYT IS CALLED BY : INTFR2 WAK002
ETACAL IS CALLED BY :
FETCH  IS CALLED BY : LSTDY  LSTPRM LSTUNS MCAFA  VTXPRM WAKPRM WAKPR1 WAK001
FEXP   IS CALLED BY :
FFTCX  IS CALLED BY : INFFNS WINGIN
FFTCXN IS CALLED BY : NRK008 NRK009
FFTCX0 IS CALLED BY : INF    INFFN0
FFUN   IS CALLED BY :
F001   IS CALLED BY : INTFR2 WAK002
F271   IS CALLED BY : LSTDY  LSTUNS
F271NO IS CALLED BY : LSTDY
GETXMB IS CALLED BY : LSTCTL
GGS011 IS CALLED BY : BDS052
GGS107 IS CALLED BY : BDS052
GGS252 IS CALLED BY : BDSA52 BDS052
GGS253 IS CALLED BY : GGS252
GGS254 IS CALLED BY : GGS252
HEADER IS CALLED BY : MAIN
HMSUB  IS CALLED BY : INTFR3 WAK003
HS1    IS CALLED BY : BDS014
HS2    IS CALLED BY : BDS014
H455S  IS CALLED BY : BDS014
IBIN   IS CALLED BY :
IFXPLT IS CALLED BY : F001   NRK01A NRK010
IIEXPS IS CALLED BY : BOUND0 THICK0 THICK3
IIEXYY IS CALLED BY : BOUND
```

Figure 3B: UCAP Subroutine Cross Reference Listing

```
IKCOMB IS CALLED BY : SUM4   SUM5   WAKE   WAKES0
IKNEW  IS CALLED BY : IKSUB  INF    INFFN0 NRK008
IKNWP  IS CALLED BY : INFFN0 NRK008
IKPCMB IS CALLED BY : SUM3   WAKES0
IKSUB  IS CALLED BY : INFFNS
IKSUB0 IS CALLED BY : INFFNS
IK0    IS CALLED BY : INFFN0 NRK009
IMILU  IS CALLED BY : ANSN1  ANS0N1 BLEND  F001   NRK01A NRK010 PLTFFT PLTFF0
IMNSIN IS CALLED BY : WAKESN WAKES0 WAKM01
IMNSUB IS CALLED BY : WAKE   WAKEQ0
INF    IS CALLED BY : THICK0 THICK3
INFFNS IS CALLED BY : MSUM
INFFN0 IS CALLED BY : BOUND0
INPTC1 IS CALLED BY : AIRPRM BLDGI1 BLDGI2 BLDGI3 CRPPRM INTPRM LSTPRM NOZPRM RUNPRM VELGRD
INPTC1 IS CALLED BY : VTXPRM WAKPRM
INPTC2 IS CALLED BY : INPTC1
INPTRW IS CALLED BY : MAIN
INTFRS IS CALLED BY : LSTCTL
INTFR1 IS CALLED BY : LSTCTL
INTFR2 IS CALLED BY : INTFR1
INTFR3 IS CALLED BY : INTFR2
INTLIN IS CALLED BY : SLAFT  SLFWD
INTPRM IS CALLED BY : MAIN
IPKCMB IS CALLED BY : SUM3   WAKES0
ISOAFL IS CALLED BY : ISOARF
ISOARF IS CALLED BY : AIRFLX CASARF SWPARF ZEROAL
JOBTIM IS CALLED BY : MAIN   F271   F271NO KMATRX KMATR0 NOZCLC NRK001 NRK002
JVCOMB IS CALLED BY : IKNWP  IKSUB
JVNEW  IS CALLED BY : IKNEW
KINFIL IS CALLED BY : LSTCTL
KMATRX IS CALLED BY : F271
KMATR0 IS CALLED BY : F271
LESWP  IS CALLED BY : GETXMB
LIFT24 IS CALLED BY : AIR24
LNEAR1 IS CALLED BY : DRAG24 LIFT24 SWPARF
LSTCGA IS CALLED BY : LSTSWI
LSTCTL IS CALLED BY : MAIN
LSTDY  IS CALLED BY : LSTCTL
LSTPRM IS CALLED BY : MAIN
LSTSWI IS CALLED BY : MCAFA
LSTUNS IS CALLED BY : LSTCTL
LSTVVC IS CALLED BY : ANS    ANS0
LSTXYZ IS CALLED BY : LSTSWI
MAIN   IS CALLED BY :
MCAFA  IS CALLED BY : GETXMB
MEAN   IS CALLED BY :
MLINE  IS CALLED BY : BDS014
MNX    IS CALLED BY : NOZKKC
MOMCAL IS CALLED BY : LSTDY
MSUM   IS CALLED BY : BOUND
MUNUAR IS CALLED BY : F271   F271NO NRK001
NEWPG1 IS CALLED BY : ADJUST AIRDRG AIRPRM ANSN1  ANS0   ANS0NO BLDCT1 BLDCT3 BLDGCA BLDGI1
NEWPG1 IS CALLED BY : BLDGI2 BLDGI3 BLDGP1 CRPPRM F271   HEADER INPTRW INTFR2 INTPRM LSTCTL
NEWPG1 IS CALLED BY : NRK001 NRK01A NRK010 PRTPRF RUNPRM VELGRD VEL003 VTXOUT VTXPRM WAKPRM
NEWPG1 IS CALLED BY : WAK002
NEWPG1 IS CALLED BY : LSTDY  LSTPRM LSTUNS LSTVVC MCAFA  NOZCLC NOZOUT NOZOU2 NOZOU3 NOZPRM
NOISEX IS CALLED BY : MAIN
NOZAIR IS CALLED BY : NOZFFC NOZNFC
NOZAMP IS CALLED BY : NOZKKC
NOZBLC IS CALLED BY : NOZFFC NOZNFC
NOZCHK IS CALLED BY : NOZCLC
```

```
NOZCLC IS CALLED BY : NOISEX
NOZFFC IS CALLED BY : NOZCLC
NOZHFL IS CALLED BY : NOZNHF
NOZHNK IS CALLED BY : NOZAMP NOZNFC
NOZINP IS CALLED BY : NOZCLC
NOZKKC IS CALLED BY : NOZCHK
NOZMPL IS CALLED BY : NOZFFC NOZNFC
NOZNFC IS CALLED BY : NOZCLC
NOZNHF IS CALLED BY : NOZMPL
NOZNJ2 IS CALLED BY : NOZCHK
NOZOUT IS CALLED BY : NOZCLC
NOZOU2 IS CALLED BY : NOZOUT
NOZOU3 IS CALLED BY : NOZOU2
NOZPRM IS CALLED BY : MAIN
NOZQPL IS CALLED BY : NOZFFC NOZNFC
NOZSTT IS CALLED BY : NOZFFC NOZNFC NOZOU2
NOZTCM IS CALLED BY : NOZFFC NOZNFC NOZNJ2
NOZTRL IS CALLED BY : NOZFFC NOZNFC NOZNHF
NOZTRP IS CALLED BY : NOZFFC NOZNFC
NOZUNT IS CALLED BY : NOZFFC NOZNFC NOZOU2 NOZOU3
NRK001 IS CALLED BY : INTFR3 WAK003
NRK002 IS CALLED BY : NRK001
NRK003 IS CALLED BY : NRK002
NRK004 IS CALLED BY : NRK002
NRK005 IS CALLED BY : NRK002
NRK006 IS CALLED BY : NRK002
NRK007 IS CALLED BY : NRK002
NRK008 IS CALLED BY : NRK006
NRK009 IS CALLED BY : NRK003
NRK01A IS CALLED BY : INTFR3
NRK01B IS CALLED BY : NRK01A
NRK010 IS CALLED BY : WAK003
NRK011 IS CALLED BY : NRK010
PF1    IS CALLED BY : BDS014
PF2    IS CALLED BY : BDS014
PLTFFT IS CALLED BY : INFFNS WINGIN
PLTFF0 IS CALLED BY : INF    INFFN0 NRK008 NRK009
PRNTCD IS CALLED BY : F271   NRK001
PRNTCS IS CALLED BY : LSTPRM
PRNTDP IS CALLED BY : F271   LSTVVC VEL003 WAKPR1
PRNTIN IS CALLED BY : AIRP02 BLDCT1 BLDCT3 F271   LSTVVC MCAFA  VEL003 WAKPR1
PRNTXX IS CALLED BY : WAKPRM
PRNTXX IS CALLED BY : LSTDY  LSTPRM LSTUNS LSTVVC MCAFA  NOZPRM RUNPRM VEL002 VEL003 VTXPRM
PRNTXX IS CALLED BY : AIRDRG AIRPRM AIRP02 BLDCT1 BLDCT3 BLDGI1 BLDGI3 BLDGP1 CRPPRM INTPRM
PRTPRF IS CALLED BY : LSTCTL
PSIK2  IS CALLED BY : THICK
P1     IS CALLED BY : HMSUB
P2     IS CALLED BY : HMSUB
QSPLIN IS CALLED BY : BLDCT1 LSTSWI NOZNHF
RADINT IS CALLED BY : BOUND
RETREV IS CALLED BY :
RJF    IS CALLED BY :
RLCODE IS CALLED BY :
RUNPRM IS CALLED BY : MAIN
R4ARAY IS CALLED BY : INFFNS WINGIN
SETIO  IS CALLED BY : LSTCTL
SETLMT IS CALLED BY :
SLAFT  IS CALLED BY : LSTCTL
SLFWD  IS CALLED BY : LSTCTL
SLOCUB IS CALLED BY : BLDGCA
SMWAK  IS CALLED BY : BOUND
```

Figure 3B: UCAP Subroutine Cross Reference Listing (continued)

```
SMWAK0 IS CALLED BY : BOUND
SPCOEF IS CALLED BY : QSPLIN
SPECIN IS CALLED BY : IKSUB0
SPFUNC IS CALLED BY : QSPLIN
SPL5D3 IS CALLED BY : SPCOEF
SPL5EV IS CALLED BY : SPMVAL SPSVAL
SPMVAL IS CALLED BY : QSPLIN
SPSVAL IS CALLED BY : QSPLIN
SPZERO IS CALLED BY : LSTCTL
STARC  IS CALLED BY : CASARF
STDDEV IS CALLED BY :
STDIKI IS CALLED BY : INTFRS
STORE  IS CALLED BY : MAIN   BLDGEM LSTDY  LSTPRM LSTUNS MCAFA  VTXPRM WAKPRM WAK001
SUM1   IS CALLED BY : WAKESN
SUM2   IS CALLED BY : WAKESN
SUM3   IS CALLED BY : WAKESN
SUM4   IS CALLED BY : WAKESN
SUM5   IS CALLED BY : WAKESN
SUM6   IS CALLED BY : WAKESN
SWPARF IS CALLED BY : AIRFLX
THICK  IS CALLED BY : F271
THICK0 IS CALLED BY : THICK
THICK3 IS CALLED BY : THICK
THVFIL IS CALLED BY : LSTCTL
TIKSUB IS CALLED BY : INF
TIK0   IS CALLED BY : INF
UNBAR  IS CALLED BY : CLFACT DZROAL
UNINT  IS CALLED BY : BLDCT1 BLDCT3 BLDGI2 DZROAL STARC
UNLIN  IS CALLED BY : GETXMB
UVINT  IS CALLED BY : ADJUST ANS0   ANS0NO BLDCT1 SLFWD  VTTBIN
UVISC  IS CALLED BY :
VELGRD IS CALLED BY : MAIN
VEL002 IS CALLED BY : VELGRD
VEL003 IS CALLED BY : LSTVVC
VTTBIN IS CALLED BY : LSTCTL
VTXAUG IS CALLED BY : VTXCAL
VTXCAL IS CALLED BY : LSTDY
VTXCDZ IS CALLED BY : VTXCAL
VTXCSE IS CALLED BY : VTXCAL
VTXDBO IS CALLED BY : VTXCAL
VTXDLE IS CALLED BY : VTXCAL
VTXINI IS CALLED BY : VTXCAL
VTXKST IS CALLED BY : VTXCAL
VTXNWT IS CALLED BY : LSTDY  LSTUNS
VTXOUT IS CALLED BY : LSTDY  VTXCAL
VTXPRF IS CALLED BY : VTXCAL
VTXPRM IS CALLED BY : MAIN
VTXWRD IS CALLED BY : LSTDY
WAKE   IS CALLED BY : KMATRX
WAKEQ0 IS CALLED BY : KMATR0
WAKESN IS CALLED BY : WAKE
WAKES0 IS CALLED BY : WAKEQ0
WAKM0  IS CALLED BY : KMATR0
WAKM01 IS CALLED BY : WAKM0
WAKPRM IS CALLED BY : MAIN
WAKPR1 IS CALLED BY : WAK002
WAK001 IS CALLED BY : MAIN
WAK002 IS CALLED BY : WAK001
WAK003 IS CALLED BY : WAK002
WAK004 IS CALLED BY : INTFR3 WAK003
WING   IS CALLED BY : BOUND
```

```
WINGF  IS CALLED BY : WINGIN
WINGIN IS CALLED BY : WING
ZEROAL IS CALLED BY : CASARF
Z0DEF  IS CALLED BY : BOUND0 NRK003 NRK006 THICK0 THICK3
```

Figure 3B: UCAP Subroutine Cross Reference Listing (continued)

```
**** TSO FOREGROUND HARDCOPY **** 10:54:35 93112
DSNAME=TSO0041.XREF2.DATA

SUBROUTINE REFERENCE   AND    PURPOSE    LISTING


SUBROUTINE ABSVAL            PURPOSE  :
SUBROUTINE ADJUST            PURPOSE  :
                             CALL (S) : NEWPG1 UVINT
SUBROUTINE AIRDRG            PURPOSE  :
                             CALL (S) : AIRFLX NEWPG1 AIRP02 PRNTXX
SUBROUTINE AIRFLX            PURPOSE  :
                             CALL (S) : ISOARF CASARF SWPARF
SUBROUTINE AIROFF            PURPOSE  :
                             CALL (S) : AIR24
SUBROUTINE AIRPRM            PURPOSE  :
                             CALL (S) : INPTC1 NEWPG1 PRNTXX AIRDRG
SUBROUTINE AIRP02            PURPOSE  :
                             CALL (S) : PRNTIN PRNTXX
SUBROUTINE AIR24             PURPOSE  :
                             CALL (S) : LIFT24 DRAG24
SUBROUTINE ANS               PURPOSE  :
                             CALL (S) : LSTVVC DUNBAR DSLOCB DUNLIN ANSN1
SUBROUTINE ANSN1             PURPOSE  :
                             CALL (S) : NEWPG1 DUNLIN IMILU
SUBROUTINE ANS0              PURPOSE  :
                             CALL (S) : LSTVVC DUNBAR ANS0N1 NEWPG1 UVINT  AIRDRG
SUBROUTINE ANS0NO            PURPOSE  :
                             CALL (S) : DUNLIN DUNBAR ANS0N1 NEWPG1 UVINT  AIRDRG
SUBROUTINE ANS0N1            PURPOSE  :
                             CALL (S) : DUNLIN IMILU
SUBROUTINE ARCTAN            PURPOSE  :
SUBROUTINE A1K2              PURPOSE  :
SUBROUTINE BDSA52            PURPOSE  :
                             CALL (S) : BDS024 BDS053 BDS016 GGS252 BDS054
SUBROUTINE BDS004            PURPOSE  :
                             CALL (S) : BDS015 BDS104
SUBROUTINE BDS010            PURPOSE  :
                             CALL (S) : CAMTHA
SUBROUTINE BDS011            PURPOSE  :
                             CALL (S) : BDS020
SUBROUTINE BDS012            PURPOSE  :
SUBROUTINE BDS013            PURPOSE  :
SUBROUTINE BDS014            PURPOSE  :
                             CALL (S) : MLINE  CAMTHA BDS012 BDS024 BDS020
                             CALL (S) : BDS010 BDS018 HS1    PF1    HS2    H455S  PF2    BDS011 BDS019 BDS013
SUBROUTINE BDS015            PURPOSE  :
                             CALL (S) : BDS014 BDS024
SUBROUTINE BDS016            PURPOSE  :
                             CALL (S) : ERRSXT
SUBROUTINE BDS018            PURPOSE  :
SUBROUTINE BDS019            PURPOSE  :
SUBROUTINE BDS020            PURPOSE  :
SUBROUTINE BDS023            PURPOSE  :
SUBROUTINE BDS024            PURPOSE  :
                             CALL (S) : BDS016 BDS025
SUBROUTINE BDS025            PURPOSE  :
                             CALL (S) : BDS026 BDS023
SUBROUTINE BDS026            PURPOSE  :
SUBROUTINE BDS052            PURPOSE  :

                             CALL (S) : EXIT   BDS004 GGS107 GGS011 BDS024 BDS053 BDS016 GGS252 BDS054
SUBROUTINE BDS053            PURPOSE  :
                             CALL (S) : BDS024
SUBROUTINE BDS054            PURPOSE  :
SUBROUTINE BDS086            PURPOSE  :
                             CALL (S) : BDS096 BDS095 BDS089 BDS088
SUBROUTINE BDS088            PURPOSE  :
SUBROUTINE BDS089            PURPOSE  :
                             CALL (S) : BDS088
SUBROUTINE BDS095            PURPOSE  :
                             CALL (S) : BDS097
SUBROUTINE BDS096            PURPOSE  :
SUBROUTINE BDS097            PURPOSE  :
SUBROUTINE BDS104            PURPOSE  :
                             CALL (S) : BDS086
SUBROUTINE BESSAV            PURPOSE  :
                             CALL (S) : EXIT   DBSJNS DBSYS
SUBROUTINE BLDCT1            PURPOSE  :
                             CALL (S) : QSPLIN UVINT  NEWPG1 PRNTIN PRNTXX BDS052 EXIT   UNINT  BLDGCA
SUBROUTINE BLDCT3            PURPOSE  :
                             CALL (S) : PRNTIN BDSA52 EXIT   NEWPG1 PRNTXX UNINT  BLDGCA
SUBROUTINE BLDGCA            PURPOSE  :
                             CALL (S) : SLOCUB NEWPG1
SUBROUTINE BLDGEM            PURPOSE  :
                             CALL (S) : BLDGI1 BLDGI2 BLDGI3 STORE
SUBROUTINE BLDGI1            PURPOSE  :
                             CALL (S) : INPTC1 NEWPG1 PRNTXX BLDCT1 BLDGP1
SUBROUTINE BLDGI2            PURPOSE  :
                             CALL (S) : INPTC1 NEWPG1 BLDGP1 UNINT
SUBROUTINE BLDGI3            PURPOSE  :
                             CALL (S) : INPTC1 NEWPG1 PRNTXX EXIT   BLDCT3 BLDGP1
SUBROUTINE BLDGP1            PURPOSE  :
                             CALL (S) : NEWPG1 PRNTXX
SUBROUTINE BLEND             PURPOSE  :
                             CALL (S) : DUNLIN IMILU
SUBROUTINE BOUND             PURPOSE  :
                             CALL (S) : SMWAK0 SMWAK  DUNLIN IIEXVY DEFZ0  MSUM   WING   CENTER RADINT
SUBROUTINE BOUND0            PURPOSE  :
                             CALL (S) : DUNLIN IIEXPS Z0DEF  INFFN0
SUBROUTINE BSINT             PURPOSE  :
                             CALL (S) : DBSJNS DBSYS
SUBROUTINE BSJINT            PURPOSE  :
                             CALL (S) : DBSJNS
SUBROUTINE BSYINT            PURPOSE  :
                             CALL (S) : DBSYS
SUBROUTINE CAMTHA            PURPOSE  :
                             CALL (S) : EXIT
SUBROUTINE CASARF            PURPOSE  :
                             CALL (S) : ISOARF STARC  ZEROAL DZROAL CLFACT
SUBROUTINE CENTER            PURPOSE  :
SUBROUTINE CHECK             PURPOSE  :
SUBROUTINE CHECKM            PURPOSE  :
SUBROUTINE CKOUT             PURPOSE  :
SUBROUTINE CLFACT            PURPOSE  :
                             CALL (S) : UNBAR
SUBROUTINE CONVRG            PURPOSE  :
SUBROUTINE CPMAP             PURPOSE  :
SUBROUTINE CPYSDP            PURPOSE  :
SUBROUTINE CROSSP            PURPOSE  :
SUBROUTINE CRPPRM            PURPOSE  :
                             CALL (S) : INPTC1 NEWPG1 PRNTXX
```

Figure 3C: UCAP Subroutine Reference and Purpose Listing

```
SUBROUTINE CSPSUB          PURPOSE   :
                           CALL (S)  : BSINT  DUNLIN
SUBROUTINE CTRAP           PURPOSE   :
SUBROUTINE CUNLIN          PURPOSE   :
SUBROUTINE DEF20           PURPOSE   :
SUBROUTINE DMNX            PURPOSE   :
SUBROUTINE DNORM           PURPOSE   :
                           CALL (S)  : DMNX
SUBROUTINE DRAG24          PURPOSE   :
                           CALL (S)  : LNEAR1
SUBROUTINE DSLOCB          PURPOSE   :
SUBROUTINE DTABLP          PURPOSE   :
SUBROUTINE DTRAP           PURPOSE   :
SUBROUTINE DUNBAR          PURPOSE   :
SUBROUTINE DUNLIN          PURPOSE   :
SUBROUTINE DZROAL          PURPOSE   :
                           CALL (S)  : UNBAR  UNINT
SUBROUTINE ENDCAS          PURPOSE   :
                           CALL (S)  : DTIME
SUBROUTINE ENDJOB          PURPOSE   :
                           CALL (S)  : DTIME
SUBROUTINE ENDPT           PURPOSE   :
SUBROUTINE ERRSXT          PURPOSE   :
SUBROUTINE ERRSYT          PURPOSE   :
SUBROUTINE ETACAL          PURPOSE   :
SUBROUTINE FETCH           PURPOSE   :
SUBROUTINE FEXP            PURPOSE   :
SUBROUTINE FFTCX           PURPOSE   :
                           CALL (S)  : DFFTCB
SUBROUTINE FFTCXN          PURPOSE   :
                           CALL (S)  : DFFTCB
SUBROUTINE FFTCX0          PURPOSE   :
                           CALL (S)  : DFFTCB
SUBROUTINE FFUN            PURPOSE   :
SUBROUTINE F001            PURPOSE   :
                           CALL (S)  : DNORM  IFXPLT DCSINT IMILU
SUBROUTINE F271            PURPOSE   :
                           CALL (S)  : JOBTIM NEWPG1 PRNTDP PRNTIN DTABLP PRNTCD EXIT   DUNLIN BESSAV BLEND
                           CALL (S)  : MUNUAR KMATRX KMATR0 THICK  ANS    ANS0   CSPSUB
SUBROUTINE F271NO          PURPOSE   :
                           CALL (S)  : JOBTIM EXIT   BLEND  MUNUAR DLINRG ANS0NO CSPSUB
SUBROUTINE GETXMB          PURPOSE   :
                           CALL (S)  : MCAFA  UNLIN  LESWP
SUBROUTINE GGS011          PURPOSE   :
SUBROUTINE GGS107          PURPOSE   :
SUBROUTINE GGS252          PURPOSE   :
                           CALL (S)  : GGS253 GGS254
SUBROUTINE GGS253          PURPOSE   :
SUBROUTINE GGS254          PURPOSE   :
SUBROUTINE HEADER          PURPOSE   :
                           CALL (S)  : NEWPG1
SUBROUTINE HMSUB           PURPOSE   :
                           CALL (S)  : P1     P2     CHECKM
SUBROUTINE HS1             PURPOSE   :
                           CALL (S)  : EXIT
SUBROUTINE HS2             PURPOSE   :
                           CALL (S)  : EXIT
SUBROUTINE H455S           PURPOSE   :
                           CALL (S)  : EXIT
SUBROUTINE IBIN            PURPOSE   :
SUBROUTINE IFXPLT          PURPOSE   :
```

```
SUBROUTINE IIEXPS          PURPOSE   :
                           CALL (S)  : EXIT
SUBROUTINE IIEXYY          PURPOSE   :
                           CALL (S)  : EXIT
SUBROUTINE IKCOMB          PURPOSE   :
SUBROUTINE IKNEW           PURPOSE   :
                           CALL (S)  : BSJINT BSYINT JYNEW
SUBROUTINE IKNWP           PURPOSE   :
                           CALL (S)  : JYCOMB
SUBROUTINE IKPCMB          PURPOSE   :
SUBROUTINE IKSUB           PURPOSE   :
                           CALL (S)  : IKNEW  JYCOMB
SUBROUTINE IKSUB0          PURPOSE   :
                           CALL (S)  : SPECIN
SUBROUTINE IK0             PURPOSE   :
SUBROUTINE IMILU           PURPOSE   :
SUBROUTINE IMNSIN          PURPOSE   :
SUBROUTINE IMNSUB          PURPOSE   :
SUBROUTINE INF             PURPOSE   :
                           CALL (S)  : IKNEW  TIKSUB TIK0   FFTCX0 PLTFF0
SUBROUTINE INFFNS          PURPOSE   :
                           CALL (S)  : IKSUB  IKSUB0 FFTCX  R4ARAY PLTFFT
SUBROUTINE INFFN0          PURPOSE   :
                           CALL (S)  : IKNEW  IKNWP  IK0    FFTCX0 PLTFF0
SUBROUTINE INPTC1          PURPOSE   :
                           CALL (S)  : ENDJOB INPTC2
SUBROUTINE INPTC2          PURPOSE   :
SUBROUTINE INPTRW          PURPOSE   :
                           CALL (S)  : NEWPG1
SUBROUTINE INTFRS          PURPOSE   :
                           CALL (S)  : DUNLIN STDIKI DTRAP
SUBROUTINE INTFR1          PURPOSE   :
                           CALL (S)  : INTFR2
SUBROUTINE INTFR2          PURPOSE   :
                           CALL (S)  : ERRSYT NEWPG1 F001   INTFR3
SUBROUTINE INTFR3          PURPOSE   :
                           CALL (S)  : HMSUB  NRK001 WAK004 NRK01A
SUBROUTINE INTLIN          PURPOSE   :
                           CALL (S)  : CROSSP ENDPT  CKOUT
SUBROUTINE INTPRM          PURPOSE   :
                           CALL (S)  : INPTC1 NEWPG1 PRNTXX
SUBROUTINE IPKCMB          PURPOSE   :
SUBROUTINE ISOAFL          PURPOSE   :
                           CALL (S)  : AIR24  AIROFF
SUBROUTINE ISOARF          PURPOSE   :
                           CALL (S)  : ISOAFL
SUBROUTINE JOBTIM          PURPOSE   :
SUBROUTINE JYCOMB          PURPOSE   :
SUBROUTINE JYNEW           PURPOSE   :
SUBROUTINE KINFIL          PURPOSE   :
SUBROUTINE KMATRX          PURPOSE   :
                           CALL (S)  : DUNLIN A1K2   JOBTIM WAKE   BOUND  DLINCG
SUBROUTINE KMATR0          PURPOSE   :
                           CALL (S)  : A1K2   DUNLIN WAKM0  BOUND0 JOBTIM WAKEQ0 BOUND  DLINRG
SUBROUTINE LESWP           PURPOSE   :
SUBROUTINE LIFT24          PURPOSE   :
                           CALL (S)  : LNEAR1
SUBROUTINE LNEAR1          PURPOSE   :
SUBROUTINE LSTCGA          PURPOSE   :
SUBROUTINE LSTCTL          PURPOSE   :
                           CALL (S)  : CPMAP  VTTBIN INTFR1 CPYSDP INTFRS PRTPRF ADJUST
```

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

```
                            CALL (S) : SPZERO SETIO  GETXHB KINFIL THVFIL LSTDV  NEWPG1 LSTUNS SLFWD  SLAFT
SUBROUTINE LSTDV            PURPOSE  :
                            CALL (S) : STORE
                            CALL (S) : FETCH  NEWPG1 PRNTXX F271NO F271   VTXCAL VTXOUT VTXNWT VTXWRD MOMCAL
SUBROUTINE LSTPRM           PURPOSE  :
                            CALL (S) : FETCH  INPTC1 NEWPG1 PRNTXX PRNTCS STORE
SUBROUTINE LSTSW1           PURPOSE  :
                            CALL (S) : QSPLIN LSTCGA LSTXYZ
SUBROUTINE LSTUNS           PURPOSE  :
                            CALL (S) : FETCH  NEWPG1 PRNTXX F271   VTXNWT STORE
SUBROUTINE LSTVVC           PURPOSE  :
                            CALL (S) : NEWPG1 PRNTDP PRNTIN DUNLIN VEL003 PRNTXX
SUBROUTINE LSTXYZ           PURPOSE  :
SUBROUTINE MAIN             PURPOSE  :
                            CALL (S) : ENDCAS ENDJOB HEADER INTPRM LSTPRM NOISEX NOZPRM RUNPRM VELGRD VTXPRM
                            CALL (S) : WAK001 WAKPRM
                            CALL (S) : IWKIN  JOBTIM DTIME  TDATE  INPTRW STORE  LSTCTL AIRPRM BLDGEM CRPPRM
SUBROUTINE MCAFA            PURPOSE  :
                            CALL (S) : FETCH  NEWPG1 TOLSTS PRNTXX PRNTIN LSTSW1 STORE
SUBROUTINE MEAN             PURPOSE  :
SUBROUTINE MLINE            PURPOSE  :
                            CALL (S) : BDS019 BDS013
SUBROUTINE MNX              PURPOSE  :
SUBROUTINE MOMCAL           PURPOSE  :
SUBROUTINE MSUM             PURPOSE  :
                            CALL (S) : INFFNS CHECK
SUBROUTINE MUNUAR           PURPOSE  :
SUBROUTINE NEWPG1           PURPOSE  :
SUBROUTINE NOISEX           PURPOSE  :
                            CALL (S) : NOZCLC
SUBROUTINE NOZAIR           PURPOSE  :
SUBROUTINE NOZAMP           PURPOSE  :
                            CALL (S) : NOZHNK
SUBROUTINE NOZBLC           PURPOSE  :
SUBROUTINE NOZCHK           PURPOSE  :
                            CALL (S) : NOZNJ2 NOZKKC
SUBROUTINE NOZCLC           PURPOSE  :
                            CALL (S) : NEWPG1 JOBTIM NOZINP NOZCHK NOZFFC NOZNFC NOZOUT
SUBROUTINE NOZFFC           PURPOSE  :
                            CALL (S) : NOZTRP DBSJNS NOZTCM NOZAIR NOZMPL NOZBLC NOZQPL NOZTRL NOZUNT NOZSTT
SUBROUTINE NOZHFL           PURPOSE  :
SUBROUTINE NOZHNK           PURPOSE  :
                            CALL (S) : DBSINS DBSKES DBSJNS DBSYS
SUBROUTINE NOZINP           PURPOSE  :
SUBROUTINE NOZKKC           PURPOSE  :
                            CALL (S) : MNX    NOZAMP
SUBROUTINE NOZMPL           PURPOSE  :
                            CALL (S) : NOZNHF
SUBROUTINE NOZNFC           PURPOSE  :
                            CALL (S) : NOZSTT
                            CALL (S) : NOZTRP NOZHNK NOZTCM NOZAIR NOZMPL NOZBLC NOZQPL DBSJNS NOZTRL NOZUNT
SUBROUTINE NOZNHF           PURPOSE  :
                            CALL (S) : QSPLIN NOZHFL NOZTRL
SUBROUTINE NOZNJ2           PURPOSE  :
                            CALL (S) : NOZTCM
SUBROUTINE NOZOUT           PURPOSE  :
                            CALL (S) : NEWPG1 NOZOU2
SUBROUTINE NOZOU2           PURPOSE  :
                            CALL (S) : NEWPG1 NOZUNT NOZSTT NOZOU3
SUBROUTINE NOZOU3           PURPOSE  :
                            CALL (S) : NEWPG1 NOZUNT
```

```
SUBROUTINE NOZPRM           PURPOSE  :
                            CALL (S) : INPTC1 NEWPG1 PRNTXX
SUBROUTINE NOZQPL           PURPOSE  :
SUBROUTINE NOZSTT           PURPOSE  :
SUBROUTINE NOZTCM           PURPOSE  :
SUBROUTINE NOZTRL           PURPOSE  :
SUBROUTINE NOZTRP           PURPOSE  :
                            CALL (S) : EXIT
SUBROUTINE NOZUNT           PURPOSE  :
SUBROUTINE NRK001           PURPOSE  :
                            CALL (S) : JOBTIM NEWPG1 DTABLP PRNTCD BESSAV BLEND  MUNUAR NRK002
SUBROUTINE NRK002           PURPOSE  :
                            CALL (S) : NRK007 NRK004 NRK005 NRK003 JOBTIM NRK006
SUBROUTINE NRK003           PURPOSE  :
                            CALL (S) : Z0DEF  DUNLIN NRK009
SUBROUTINE NRK004           PURPOSE  :
SUBROUTINE NRK005           PURPOSE  :
SUBROUTINE NRK006           PURPOSE  :
                            CALL (S) : Z0DEF  DUNLIN NRK008 CHECK
SUBROUTINE NRK007           PURPOSE  :
                            CALL (S) : EXIT
SUBROUTINE NRK008           PURPOSE  :
                            CALL (S) : IKNEW  IKNWP  FFTCXN PLTFF0
SUBROUTINE NRK009           PURPOSE  :
                            CALL (S) : IK0    FFTCXN PLTFF0
SUBROUTINE NRK01A           PURPOSE  :
                            CALL (S) : NRK01B NEWPG1 IMILU  IFXPLT
SUBROUTINE NRK01B           PURPOSE  :
SUBROUTINE NRK010           PURPOSE  :
                            CALL (S) : EXIT   NRK011 NEWPG1 IMILU  IFXPLT
SUBROUTINE NRK011           PURPOSE  :
SUBROUTINE PF1              PURPOSE  :
                            CALL (S) : EXIT
SUBROUTINE PF2              PURPOSE  :
                            CALL (S) : EXIT
SUBROUTINE PLTFFT           PURPOSE  :
                            CALL (S) : IMILU
SUBROUTINE PLTFF0           PURPOSE  :
                            CALL (S) : IMILU
SUBROUTINE PRNTCD           PURPOSE  :
SUBROUTINE PRNTCS           PURPOSE  :
SUBROUTINE PRNTDP           PURPOSE  :
SUBROUTINE PRNTIN           PURPOSE  :
SUBROUTINE PRNTXX           PURPOSE  :
SUBROUTINE PRTPRF           PURPOSE  :
                            CALL (S) : NEWPG1
SUBROUTINE PSIK2            PURPOSE  :
SUBROUTINE P1               PURPOSE  :
SUBROUTINE P2               PURPOSE  :
SUBROUTINE QSPLIN           PURPOSE  :
                            CALL (S) : SPFUNC SPCOEF SPSVAL SPHVAL
SUBROUTINE RADINT           PURPOSE  :
                            CALL (S) : EXIT   CUNLIN CTRAP
SUBROUTINE RETREV           PURPOSE  :
SUBROUTINE RJF              PURPOSE  :
SUBROUTINE RLCODE           PURPOSE  :
SUBROUTINE RUNPRM           PURPOSE  :
                            CALL (S) : INPTC1 NEWPG1 PRNTXX
SUBROUTINE R4ARAY           PURPOSE  :
SUBROUTINE SETIO            PURPOSE  :
SUBROUTINE SETLMT           PURPOSE  :
```

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

```
SUBROUTINE SLAFT          PURPOSE  :
                          CALL (S) : INTLIN
SUBROUTINE SLFWD          PURPOSE  :
                          CALL (S) : UVINT  INTLIN
SUBROUTINE SLOCUB         PURPOSE  :
SUBROUTINE SMWAK          PURPOSE  :
SUBROUTINE SMWAK0         PURPOSE  :
SUBROUTINE SPCOEF         PURPOSE  :
                          CALL (S) : SPL5D3
SUBROUTINE SPECIN         PURPOSE  :
SUBROUTINE SPFUNC         PURPOSE  :
SUBROUTINE SPL5D3         PURPOSE  :
SUBROUTINE SPL5EV         PURPOSE  :
SUBROUTINE SPMVAL         PURPOSE  :
                          CALL (S) : SPL5EV
SUBROUTINE SPSVAL         PURPOSE  :
                          CALL (S) : SPL5EV
SUBROUTINE SPZERO         PURPOSE  :
SUBROUTINE STARC          PURPOSE  :
                          CALL (S) : UNINT
SUBROUTINE STDDEV         PURPOSE  :
SUBROUTINE STDIKI         PURPOSE  :
SUBROUTINE STORE          PURPOSE  :
SUBROUTINE SUM1           PURPOSE  :
SUBROUTINE SUM2           PURPOSE  :
SUBROUTINE SUM3           PURPOSE  :
                          CALL (S) : IKPCMB IPKCMB
SUBROUTINE SUM4           PURPOSE  :
                          CALL (S) : IKCOMB
SUBROUTINE SUM5           PURPOSE  :
                          CALL (S) : IKCOMB
SUBROUTINE SUM6           PURPOSE  :
SUBROUTINE SWPARF         PURPOSE  :
                          CALL (S) : ISOARF CASARF LNEAR1
SUBROUTINE THICK          PURPOSE  :
                          CALL (S) : PSIK2  THICK0 THICK3
SUBROUTINE THICK0         PURPOSE  :
                          CALL (S) : DUNLIN IIEXPS Z0DEF  INF
SUBROUTINE THICK3         PURPOSE  :
                          CALL (S) : DUNLIN IIEXPS Z0DEF  INF    CHECK
SUBROUTINE THVFIL         PURPOSE  :
SUBROUTINE TIKSUB         PURPOSE  :
SUBROUTINE TIK0           PURPOSE  :
SUBROUTINE UNBAR          PURPOSE  :
SUBROUTINE UNINT          PURPOSE  :
SUBROUTINE UNLIN          PURPOSE  :
SUBROUTINE UVINT          PURPOSE  :
SUBROUTINE UVISC          PURPOSE  :
SUBROUTINE VELGRD         PURPOSE  :
                          CALL (S) : INPTC1 NEWPG1 VEL002
SUBROUTINE VEL002         PURPOSE  :
                          CALL (S) : PRNTXX
SUBROUTINE VEL003         PURPOSE  :
                          CALL (S) : EXIT   NEWPG1 PRNTDP PRNTXX PRNTIN BDS024
SUBROUTINE VTTBIN         PURPOSE  :
                          CALL (S) : UVINT
SUBROUTINE VTXAUG         PURPOSE  :
SUBROUTINE VTXCAL         PURPOSE  :
                          CALL (S) : VTXINI VTXKST VTXDLE VTXCSE VTXCDZ VTXAUG VTXPRF VTXDBO VTXOUT
SUBROUTINE VTXCDZ         PURPOSE  :
SUBROUTINE VTXCSE         PURPOSE  :
```

```
SUBROUTINE VTXDBO         PURPOSE  :
SUBROUTINE VTXDLE         PURPOSE  :
SUBROUTINE VTXINI         PURPOSE  :
SUBROUTINE VTXKST         PURPOSE  :
SUBROUTINE VTXNWT         PURPOSE  :
SUBROUTINE VTXOUT         PURPOSE  :
                          CALL (S) : NEWPG1
SUBROUTINE VTXPRF         PURPOSE  :
SUBROUTINE VTXPRM         PURPOSE  :
                          CALL (S) : FETCH  NEWPG1 INPTC1 PRNTXX STORE
SUBROUTINE VTXWRD         PURPOSE  :
SUBROUTINE WAKE           PURPOSE  :
                          CALL (S) : EXIT   DUNLIN DBSINS DBSKES IKCOMB CHECK  IMNSUB WAKESN
SUBROUTINE WAKEQ0         PURPOSE  :
                          CALL (S) : EXIT   DUNLIN DBSINS DBSKES CHECK  IMNSUB WAKES0
SUBROUTINE WAKESN         PURPOSE  :
                          CALL (S) : DUNLIN SUM1   CHECK  SUM2   SUM3   SUM4   SUM5   SUM6   IMNSIN
SUBROUTINE WAKES0         PURPOSE  :
                          CALL (S) : DUNLIN IKPCMB IPKCMB CHECK  IKCOMB IMNSIN
SUBROUTINE WAKM0          PURPOSE  :
                          CALL (S) : DUNLIN WAKM01
SUBROUTINE WAKM01         PURPOSE  :
                          CALL (S) : DUNLIN IMNSIN
SUBROUTINE WAKPRM         PURPOSE  :
                          CALL (S) : FETCH  INPTC1 NEWPG1 PRNTXX STORE
SUBROUTINE WAKPR1         PURPOSE  :
                          CALL (S) : FETCH  PRNTDP PRNTIN
SUBROUTINE WAK001         PURPOSE  :
                          CALL (S) : FETCH  WAK002 STORE
SUBROUTINE WAK002         PURPOSE  :
                          CALL (S) : ERRSYT NEWPG1 WAKPR1 EXIT   F001   WAK003
SUBROUTINE WAK003         PURPOSE  :
                          CALL (S) : EXIT   HMSUB  NRK001 WAK004 NRK010
SUBROUTINE WAK004         PURPOSE  :
                          CALL (S) : DUNLIN
SUBROUTINE WING           PURPOSE  :
                          CALL (S) : WINGIN
SUBROUTINE WINGF          PURPOSE  :
                          CALL (S) : DBSYS
SUBROUTINE WINGIN         PURPOSE  :
                          CALL (S) : WINGF  FFTCX  R4ARAY PLTFFT
SUBROUTINE ZEROAL         PURPOSE  :
                          CALL (S) : ISOARF
SUBROUTINE Z0DEF          PURPOSE  :
```

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

```
**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSOG04I.XREF3.DATA

LABELED COMMON AREA CROSS REFERENCE LISTING
LABEL                  SUBROUTINE


       IS USED   BY : MAIN
AIRALZ IS USED   BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24  CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRALZ IS USED   BY : SWPARF ZEROAL
AIRCDF IS USED   BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24  CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRCDF IS USED   BY : SWPARF ZEROAL
AIRCDM IS USED   BY : SWPARF ZEROAL
AIRCDM IS USED   BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24  CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRDAT IS USED   BY : SWPARF ZEROAL
AIRDAT IS USED   BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24  CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRP01 IS USED   BY : AIRDRG AIRPRM LSTDY  LSTUNS
BDSC01 IS USED   BY : BDS018
BDSC02 IS USED   BY : BDS018
BDSC03 IS USED   BY : BDS014
BESAR  IS USED   BY : BESSAV BSINT  BSJINT BSYINT
BESDEL IS USED   BY : BESSAV BSINT  BSJINT BSYINT
BLDGC3 IS USED   BY : FETCH  STORE
BLDGEO IS USED   BY : BLDCT1 BLDCT3 BLDGI1 BLDGI2 BLDGI3 BLDGP1 FETCH  RETREV STORE  LSTDY
BLDGEO IS USED   BY : LSTUNS MCAFA
BLDGXO IS USED   BY : FETCH  RETREV STORE
BLDG01 IS USED   BY : BLDCT1 BLDGI1 FETCH  RETREV STORE  MCAFA
BLDG02 IS USED   BY : FETCH  RETREV STORE
BLDG03 IS USED   BY : BLDCT3 BLDGI3 FETCH  STORE
COM002 IS USED   BY : GGS011 GGS107
CRPP01 IS USED   BY : CRPPRM RETREV LSTCTL LSTDY  LSTUNS LSTVVC NEWPG1 NRK001 WAK001
DTETME IS USED   BY : AIRPRM BLDGEM BLDGI1 BLDGI2 BLDGI3 BLDGP1 HEADER INPTRW INTFR1 INTPRM
DTETME IS USED   BY : WAK001
DTETME IS USED   BY : LSTCTL LSTDY  LSTPRM LSTUNS NEWPG1 NOISEX RUNPRM VTXPRM WAKPRM WAKPR1
HEADR1 IS USED   BY : HEADER LSTCTL LSTDY  LSTUNS NEWPG1
HEADR2 IS USED   BY : HEADER LSTCTL LSTDY  LSTUNS NEWPG1
HSQSPL IS USED   BY : LSTSW1 NOZNHF QSPLIN
INTP01 IS USED   BY : INTFRS INTFR1 INTPRM LSTCTL LSTDY  LSTUNS
KCLSAV IS USED   BY : ISOARF
LSTP01 IS USED   BY : FETCH  RETREV STORE  LSTDY  LSTPRM LSTUNS
LSTP02 IS USED   BY : FETCH  RETREV STORE
LSTRS2 IS USED   BY : FETCH  STORE
LSTR01 IS USED   BY : AIRDRG FETCH  STORE  INTFR1 LSTDY  LSTUNS LSTVVC WAK001
LSTR02 IS USED   BY : FETCH  STORE  INTFR1 LSTDY  LSTUNS WAK001
LSTSPR IS USED   BY : FETCH  STORE
NOZDAT IS USED   BY : NOZCLC NOZPRM
NOZS16 IS USED   BY : NOZFFC NOZNFC
OUTPUT IS USED   BY : BDS014
PROVRS IS USED   BY : LSTDY  LSTUNS NEWPG1
RNCP01 IS USED   BY : LSTCTL LSTDY  LSTUNS MCAFA  RUNPRM
VTXCOM IS USED   BY : FETCH  RETREV STORE  LSTDY  VTXCAL VTXOUT VTXPRM
VTXC02 IS USED   BY : FETCH  RETREV STORE
VIIIC1 IS USED   BY : LSTCTL LSTDY  LSTUNS VELGRD VEL002 VTTBIN
WAKP01 IS USED   BY : FETCH  RETREV STORE  LSTDY  LSTUNS WAKPRM WAK001
WAKP02 IS USED   BY : FETCH  RETREV STORE
WAKR01 IS USED   BY : FETCH  STORE  INTFR1 LSTDY  LSTUNS WAKPR1 WAK001
WAKSP2 IS USED   BY : FETCH  STORE
WORK   IS USED   BY : F271   F271NO INTFR3 LSTCTL LSTDY  LSTUNS NRK001 WAK003
WORK1  IS USED   BY : F271   F271NO LSTDY  LSTUNS
XINDEX IS USED   BY : BDS014
```

```
**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSOG04I.XREF4.DATA

LABEL COMMON AREA REFERENCE LISTING
        SUBROUTINE               USES      : LABELED COMMON


R          AIRDRG                USES      : LSTR01 AIRP01 AIRDAT AIRCDF AIRCDM AIRALZ
R          AIRFLX                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          AIROFF                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          AIRPRM                USES      : AIRP01 DTETME
R          AIRP02                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          AIR24                 USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          BDS014                USES      : BDSC03 XINDEX OUTPUT
R          BDS018                USES      : BDSC01 BDSC02
R          BESSAV                USES      : BESAR  BESDEL
R          BLDCT1                USES      : BLDG01 BLDGEO
R          BLDCT3                USES      : BLDG03 BLDGEO
R          BLDGEM                USES      : DTETME
R          BLDGI1                USES      : DTETME BLDG01 BLDGEO
R          BLDGI2                USES      : DTETME BLDGEO
R          BLDGI3                USES      : DTETME BLDG03 BLDGEO
R          BLDGP1                USES      : DTETME BLDGEO
R          BSINT                 USES      : BESAR  BESDEL
R          BSJINT                USES      : BESAR  BESDEL
R          BSYINT                USES      : BESAR  BESDEL
R          CASARF                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          CRPPRM                USES      : CRPP01
R          DRAG24                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          FETCH                 USES      : BLDG03 BLDGC3 LSTR01 LSTSPR LSTR02 LSTRS2 WAKR01 WAKSP2
R          FETCH                 USES      : WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO BLDGXO
R          F271                  USES      : WORK   WORK1
R          F271NO                USES      : WORK   WORK1
R          GGS011                USES      : COM002
R          GGS107                USES      : COM002
R          HEADER                USES      : DTETME HEADR1 HEADR2
R          INPTRW                USES      : DTETME
R          INTFRS                USES      : INTP01
R          INTFR1                USES      : LSTR02 LSTR01 INTP01 WAKR01 DTETME
R          INTFR3                USES      : WORK
R          INTPRM                USES      : DTETME INTP01
R          ISOAFL                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          ISOARF                USES      : AIRDAT AIRCDF AIRCDM AIRALZ KCLSAV
R          LIFT24                USES      : AIRDAT AIRCDF AIRCDM AIRALZ
R          LSTCTL                USES      : WORK   HEADR1 HEADR2 DTETME RNCP01 CRPP01 INTP01 VIIIC1
R          LSTDY                 USES      : INTP01 CRPP01 PROVRS HEADR1 HEADR2 DTETME WAKP01 WAKR01 BLDGEO VIIIC1
R          LSTDY                 USES      : LSTP01 LSTR02 RNCP01 AIRP01 LSTR01 WORK   WORK1  VTXCOM
R          LSTPRM                USES      : DTETME LSTP01
R          LSTSW1                USES      : HSQSPL
R          LSTUNS                USES      : INTP01 CRPP01 PROVRS HEADR1 HEADR2 DTETME WAKP01 WAKR01 BLDGEO VIIIC1
R          LSTUNS                USES      : LSTP01 LSTR02 RNCP01 AIRP01 LSTR01 WORK   WORK1
R          LSTVVC                USES      : LSTR01 CRPP01
R          MAIN                  USES      :
R          MCAFA                 USES      : BLDG01 BLDGEO RNCP01
R          NEWPG1                USES      : PROVRS DTETME HEADR1 HEADR2 CRPP01
R          NOISEX                USES      : DTETME
R          NOZCLC                USES      : NOZDAT
R          NOZFFC                USES      : NOZS16
R          NOZNFC                USES      : NOZS16
R          NOZNHF                USES      : HSQSPL
```

Figure 3D: UCAP Labeled Common Area Reference Listing

```
R     NOZPRM     USES   : NOZDAT
R     NRK001     USES   : CRPP01 WORK
R     QSPLIN     USES   : HSQSPL
R     RETREV     USES   : CRPP01 WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO
R     RETREV     USES   : BLDGXO
R     RUNPRM     USES   : DTETME RNCP01
R     STORE      USES   : WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO BLDGXO
R     STORE      USES   : BLDG03 BLDGC3 LSTR01 LSTSPR LSTR02 LSTRS2 WAKR01 WAKSP2
R     SWPARF     USES   : AIRDAT AIRCDF AIRCDM AIRALZ
R     VELGRD     USES   : VIIICI
R     VEL002     USES   : VIIICI
R     VTTBIN     USES   : VIIICI
R     VTXCAL     USES   : VTXCOM
R     VTXOUT     USES   : VTXCOM
R     VTXPRM     USES   : DTETME VTXCOM
R     WAKPRM     USES   : DTETME WAKP01
R     WAKPRI     USES   : WAKR01 DTETME
R     WAK001     USES   : WAKR01 WAKP01 LSTR02 LSTR01 DTETME CRPP01
R     WAK003     USES   : WORK
R     ZEROAL     USES   : AIRDAT AIRCDF AIRCDM AIRALZ
```

Figure 3D: UCAP Labeled Common Area Reference Listing (cont)

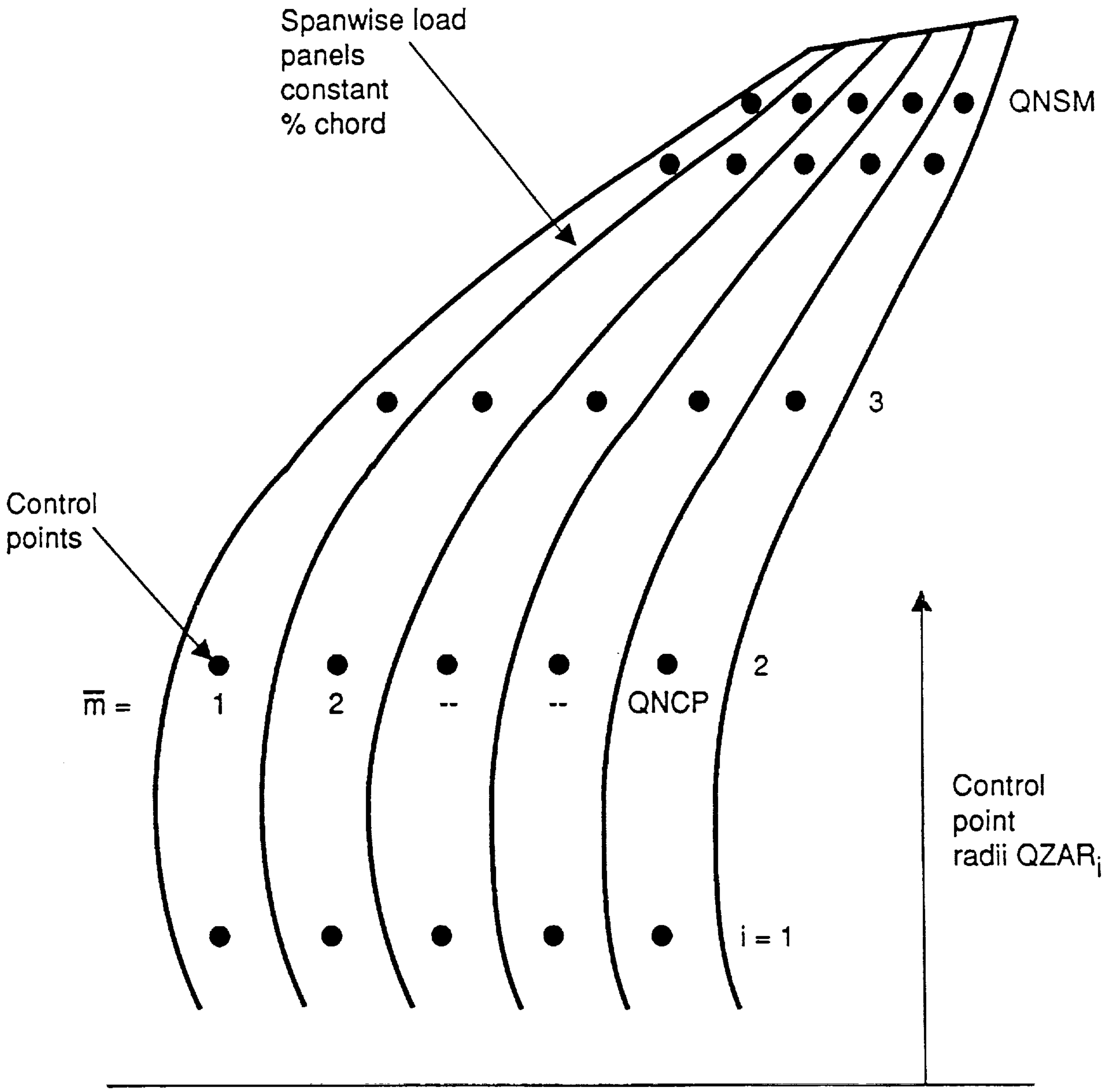


Figure 4 Spanwise load panels and control points

MFA2124.003

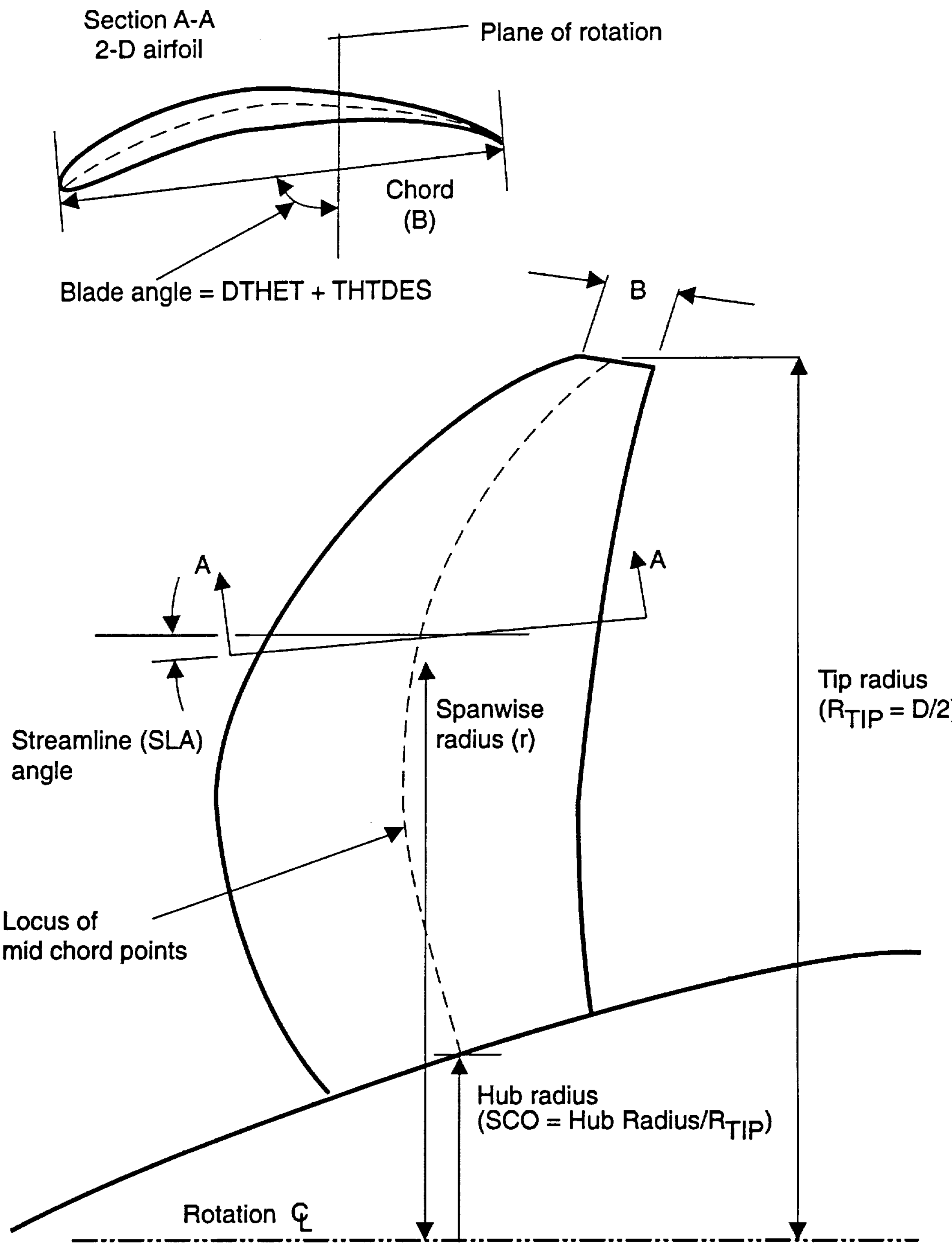


Figure 5 Blade geometry nomenclature (2-D coords)

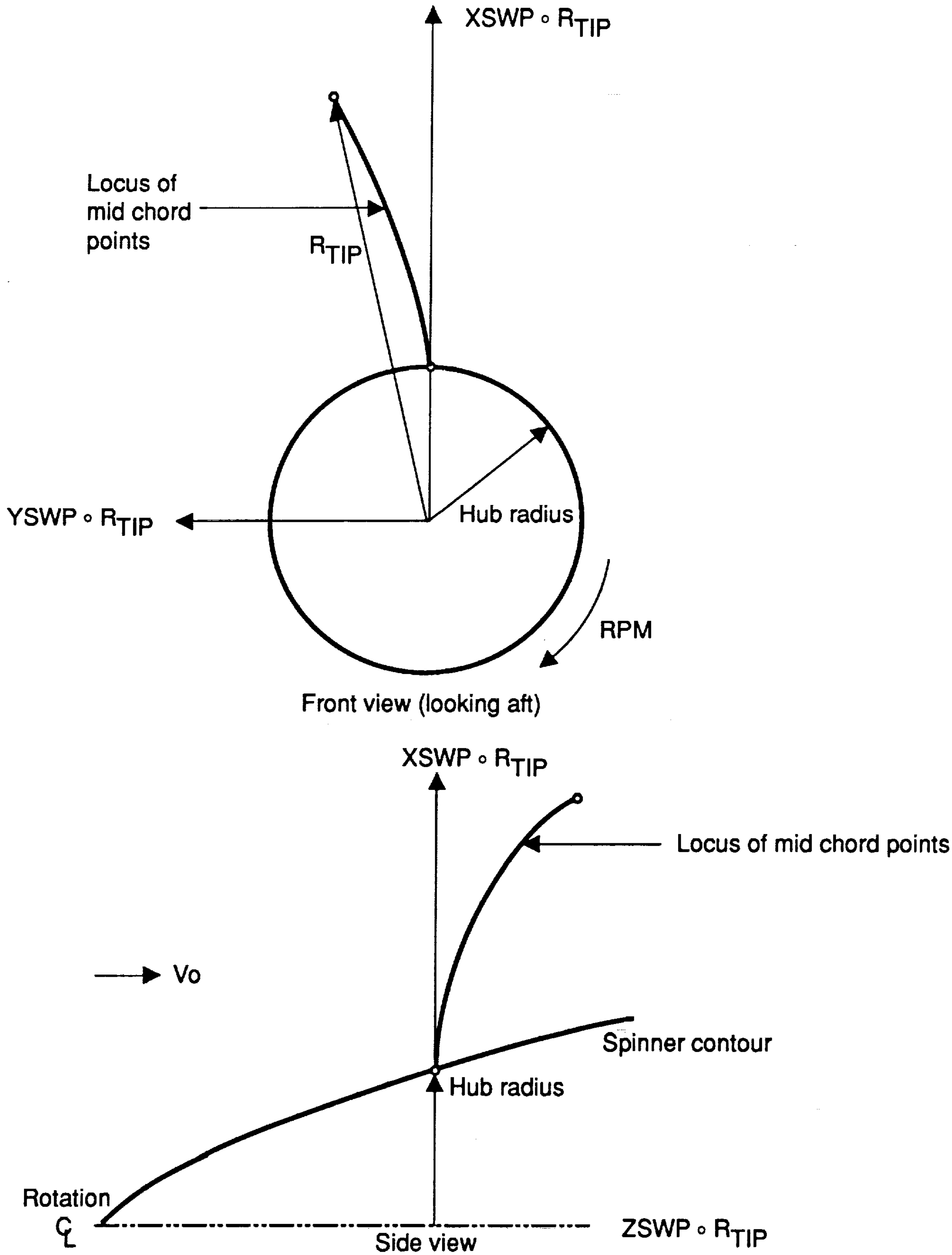


Figure 6 Blade geometry nomenclature (2-D coords)

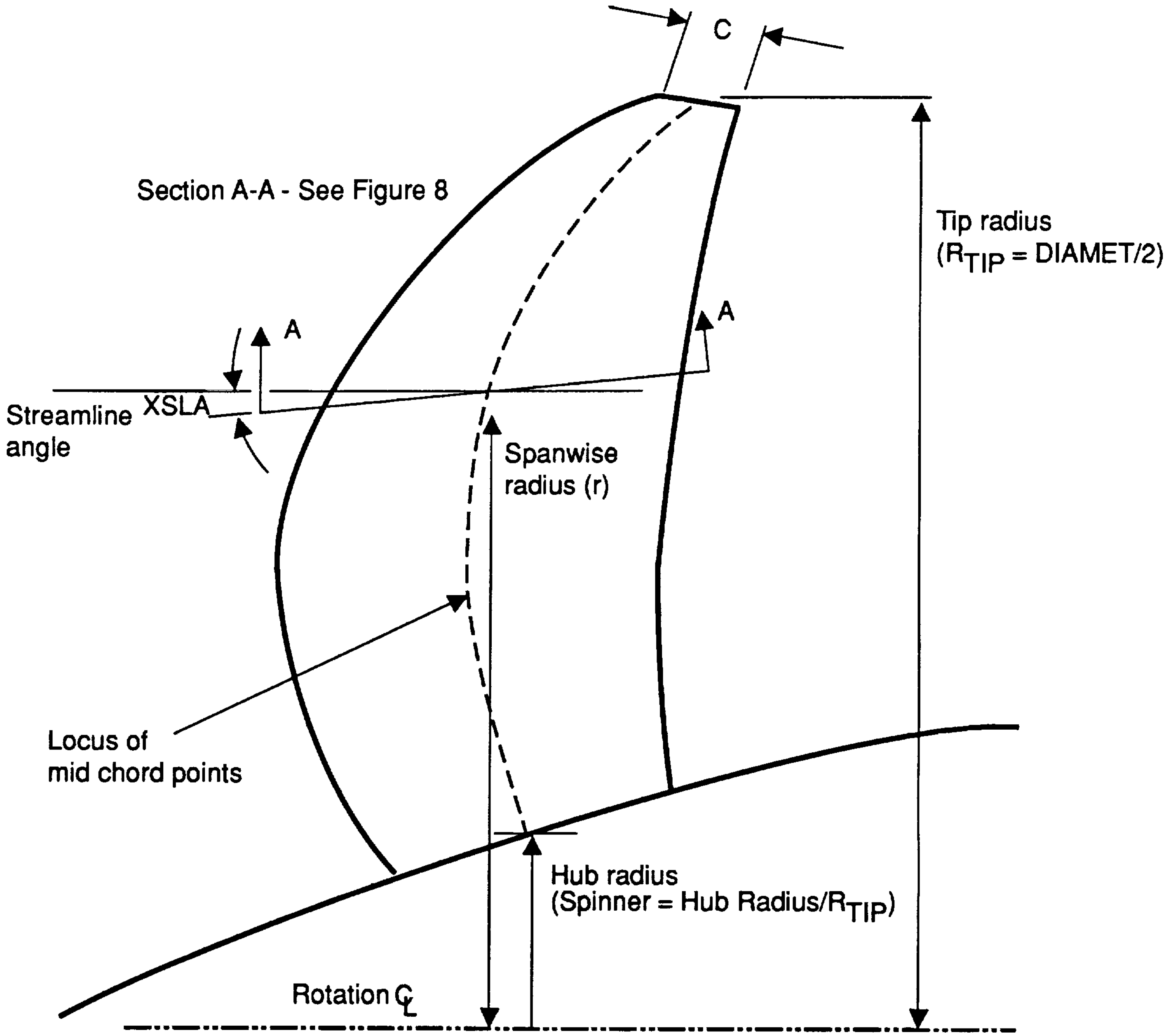


Figure 7 Blade geometry nomenclature (RXY coord)

MFC2140.005

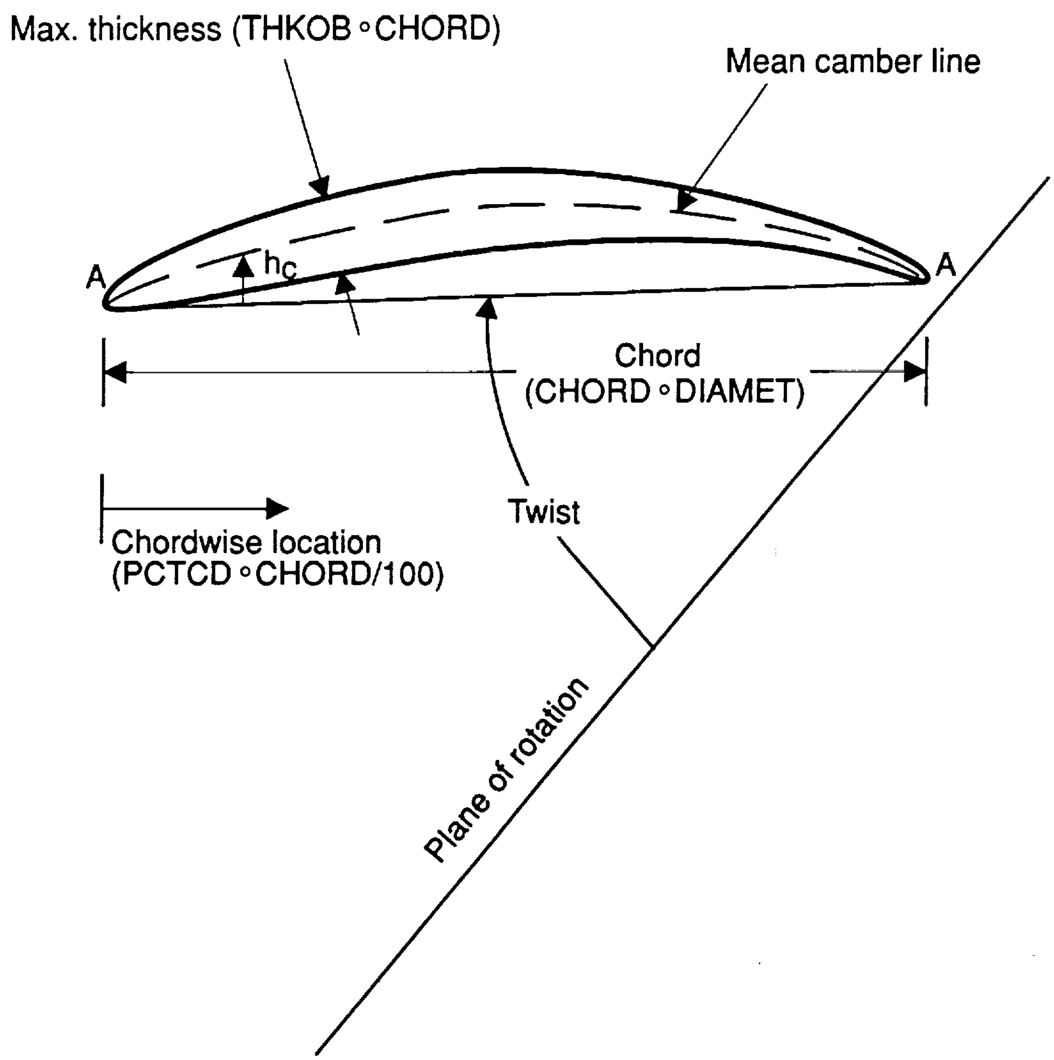


Figure 8 Blade geometry nomenclature (RXY coord)

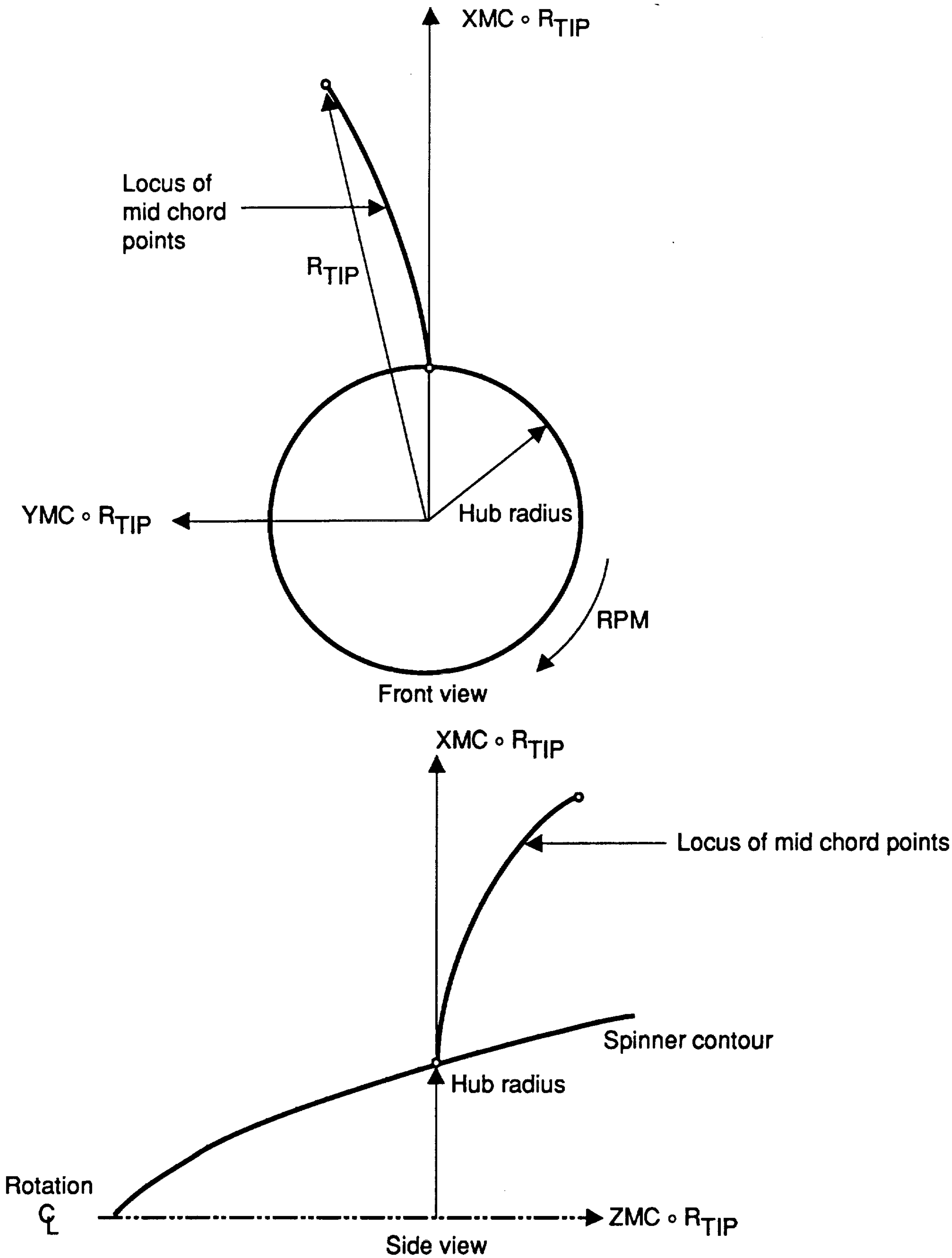


Figure 9 Blade geometry nomenclature (RXY coord)

MFC2140.007

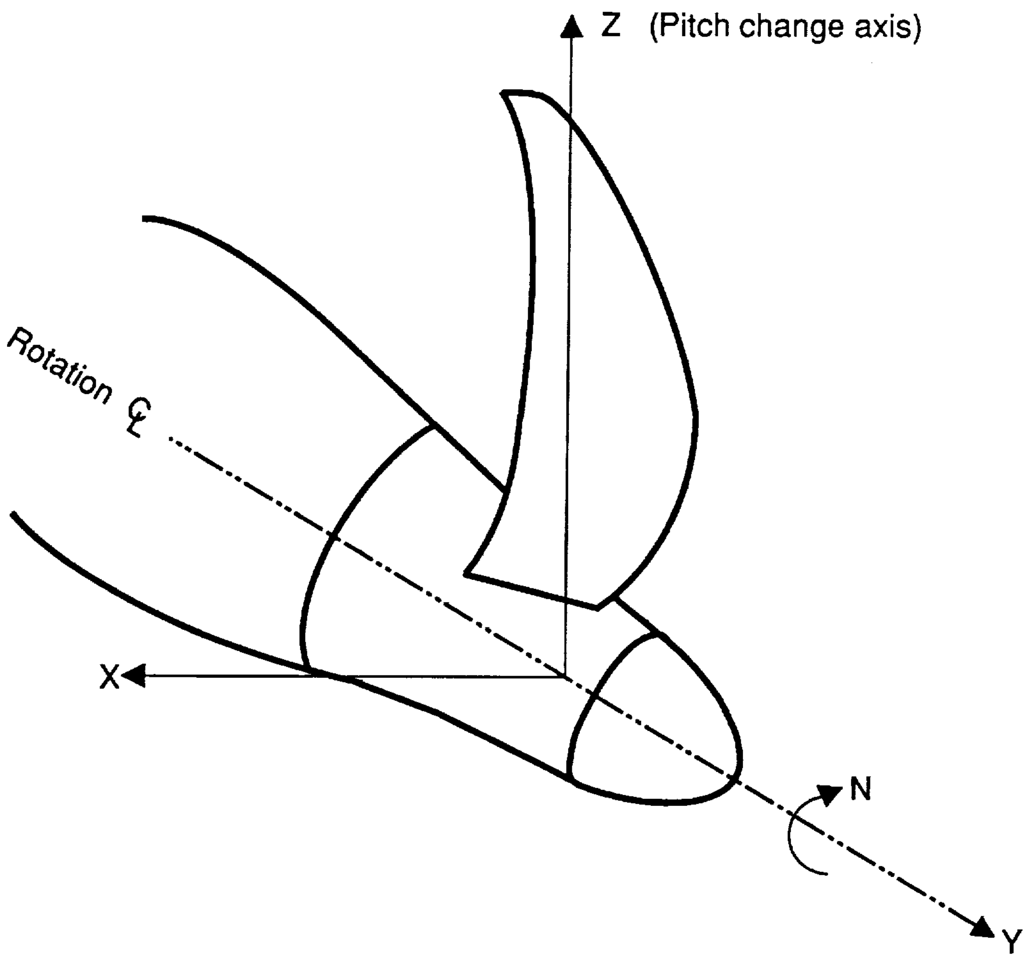


Figure 10 Blade geometry nomenclature (XYZ coords)

```
READ / PRINT ALL INPUT DATA    : INPTWR     INPUTRW               TIME:  17:00.20 DATE:   1/15/92 UCAP --- NASA    4

****************************************************************************************************************************
HEADER  (CR-2    )
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL
END
AIRPARMS
L001        1           24.0        5.0
END
VELGRADS
L002        0.0
END
RUNPARMS
L001        1.0         56.18       .9662       1.4601      .265
L016        1.4522
END
CRPPARMS
L001        1.0         1.0         0.257       20.0        0.01
L006        2.0         1.0
END
INTERPRM
L001        1.0
END
NOIZPARM
L 1 1. 0. 4. 6.12
L 9 7. 0.
L 31  6.360  4.645  2.573  0.417
     -1.447 -4.112 -8.773
END
BLADEGEO(2-DCOFWD)
C     CRP-X2 : BLADING DEFINITION AGREES WITH "BLADE DESIGN DATA BASE"
C  FRONT
C              THIS  IS GEOMETRIC VERSION OF BLADE
C              THIS  BLADE HAS 65/CA AND 16 SERIES AIRFOILS
C
C DATE :06/14/88
C
L001          1.0
L031          6.0       2.0467    0.245
L41 0.2553 0.2965 0.3665 0.4594 0.5668 0.6792 0.7866 0.8795 0.9495 1.000
L51 0.1580 0.1030 0.0664 0.0490 0.0380 0.0301 0.0248 0.0218 0.020[illegible] 0.020
L61 0.1650 0.1717 0.1840 0.1980 0.2040 0.1952 0.1740 0.1420 0.1050 .0635
L71 0.0500 0.0690 0.0930 0.1320 0.1710 0.2070 0.2300 0.2310 0.2200 .2000
L81 23.500 21.400 17.790 13.000 7.600  2.598  -1.500 -4.300 -6.150 -7.59
L91  4.     4.     4.     2.     1.     1.     1.      1.     1.    1.
L346          2.0       55.46     48.87      1.0
L381 5.03  4.22   3.42   2.69   1.98   1.35   0.85   0.468   0.21   0.02
L711 .25528 .29627 .36598 .45868 .56651 .67910 .78403 .87114 .9352 .9811
L721 -.0030 -.0097 -.0195 -.0257 -.0180 .0115  .0635  .1210 .1640  .1936
L731 -.0055 -.0165 -.0370 -.0417 -.0251 .01367 .06978 .1220 .15875 .1832
L741 4.     4.     4.     2.     1.     1.      1.     1.     1.     1.
L950 22
L951 0.100 0.300 0.400 0.500 0.550 0.600 0.650 0.700 0.750 0.800
     0.825 0.850 0.875 0.900 0.925 0.950 0.960 0.970 0.980 0.990
```

Figure 11 : Input Echo

```
    0.995 1.000
END
LSTPARMS(FWD     )
L001        1.0        10.0        0.02        8.0        1024.
C *** PART1 - 0 TO CREATE, 3 TO READ
L020        1.0
END
VORTPARM(FWD     )
L001         1.0
END
BLADEGEO(2-DCOAFT)
C     CRP-X2 : BLADING DEFINITION AGREES WITH "BLADE DESIGN DATA BASE"
C  REAR
C              THIS  IS GEOMETRIC VERSION OF BLADE
C              THIS  BLADE HAS 65/CA AND 16 SERIES AIRFOILS
C
C DATE :06/14/88
C
L001         1.0
L31         5.    2.0467 .245
L41 0.2553 0.2965 0.3665 0.4594 0.5668 0.6792 0.7866 0.8795 0.9495 1.000
L51 0.1580 0.1030 0.0664 0.0490 0.0380 0.0301 0.0248 0.0218 0.0204 0.020
L61 0.1650 0.1717 0.1840 0.1980 0.2040 0.1952 0.1740 0.1420 0.1060 .0635
L71 0.0500 0.0690 0.0930 0.1320 0.1710 0.2070 0.2300 0.2310 0.2200 .2000
L81 23.500 21.400 17.790 13.000 7.600  2.598  -1.500 -4.300 -6.150 -7.59
L91  4.     4.     4.     2.     1.     1.     1.     1.     1.     1.
L346                    2.0       55.46     48.54     1.0
L381 5.03  4.22   3.42   2.69   1.98   1.35   0.85   0.468   0.21   0.02
L711 .25528 .29627 .36598 .45868 .56651 .67910 .78403 .87114 .9352 .9811
L721 -.0030 -.0097 -.0195 -.0257 -.0180 .0115  .0635  .1210 .1640  .1936
L731 -.0055 -.0165 -.0370 -.0417 -.0251 .01367 .06978 .1220 .15875 .1832
L741 4.     4.     4.     2.     1.     1.     1.     1.     1.     1.
L950 22
L951 0.100 0.300 0.400 0.500 0.550 0.600 0.650 0.700 0.750 0.800
     0.825 0.850 0.875 0.900 0.925 0.950 0.960 0.970 0.980 0.990
     0.995 1.000
END
LSTPARMS(AFT     )
L001        1.0        10.0        0.02        8.0        1024.
C *** PART1 - 0 TO CREATE, 3 TO READ
L020        3.0
END
VORTPARM(AFT     )
L001         1.0
END
AEROEXEC(EXECCASE)
NOIZEXEC(EXECCASE)
ENDCASE
ENDJOB
```

Figure 11 : Input Echo (continued)

```
RUNPARMS INPUT / OUTPUT        : RUNPRM     RUNPARMS              TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

*****************************************************************************************************************************
 UCAP  FOR CR-2           INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

*****************************************************************************************************************************
DEBUG           (001)       1.0
TEMP.FDEG       (002)      56.2
RHO/RHO 0       (003)    0.9662
FWD ADV. RATIO  (004)     1.460
AFT ADV. RATIO  (016)     1.452
MACH NO.        (005)     0.265
```

Figure 12: RUNPARMS output

```
CPRPARMS INPUT/OUTPUT.....SBR:  CRPPRM      CRPPARMS              TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**************************************************************************************************************
 UCAP  FOR CR-2            INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

**************************************************************************************************************
CRPBUG SWITCH  (001)        1.
CRP/SRP SWITCH (002)        1.
ROTOR SPACING  (003)    0.2570
ITER. LIMIT    (004)       20.
TOLERANCE      (005)   0.01000
FWD->AFT HARM. (006)        2.
AFT->FWD HARM. (007)        1.
```

Figure 13: CRPPARMS output

```
AIRFOIL DATA OPTIONS INPUT     : AIRPRM     AIRPARMS              TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

*************************************************************************************************************************
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

*************************************************************************************************************************
DEBUG          (001)        1.
AIRF.NUMB.     (002)       24.
AIRF.TYP.      (003)        5.
AIR. CL/CD     (013)    0.0000
CD MULT.       (015)    0.0000
DELTA CD       (017)    0.0000
```

Figure 14: AIRPARMS output

```
2-D COORDINATE INPUT---FORWARD:  BLDGI1     BLADEGEO  2-DCOFWD     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

***************************************************************************************************************************
 UCAP  FOR CR-2           INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

***************************************************************************************************************************
DEBUG           (001)       1.
BLADN           (031)       6.
DIAMETER        (032)       2.05
SCO             (033)   0.2450
SWEEP TYPE      (346)       2.
DESIGN  ANGLE   (347)    55.46
RUNNING ANGLE   (348)    48.87
TYPE CUT        (349)     1.00
X               (041)   0.2553    0.2965    0.3665    0.4594    0.5668    0.6792    0.7866    0.8795    0.9495    1.0000

T/B             (051)   0.1580    0.1030    0.0664    0.0490    0.0380    0.0301    0.0248    0.0218    0.0204    0.0200

B/D             (061)   0.1650    0.1717    0.1840    0.1980    0.2040    0.1952    0.1740    0.1420    0.1060    0.0635

CAMBER          (071)   0.0500    0.0690    0.0930    0.1320    0.1710    0.2070    0.2300    0.2310    0.2200    0.2000

DELTA THETA     (081)  23.5000   21.4000   17.7900   13.0000    7.6000    2.5980   -1.5000   -4.3000   -6.1500   -7.5900

XSWP            (711)   0.2553    0.2963    0.3660    0.4587    0.5665    0.6791    0.7840    0.8711    0.9352    0.9811

YSWP            (721)  -0.0030   -0.0097   -0.0195   -0.0257   -0.0180    0.0115    0.0635    0.1210    0.1640    0.1936

ZSWP            (731)  -0.0055   -0.0165   -0.0370   -0.0417   -0.0251    0.0137    0.0698    0.1220    0.1587    0.1832

AIRFOIL TYP     (741)       4.        4.        4.        2.        1.        1.        1.        1.        1.        1.

NO.OF %CHORDS   (900)      11.
LIST -%CHORDS   (901)     0.00     10.00     20.00     30.00     40.00     50.00     60.00     70.00     80.00     90.00
                        100.00
NO.OUT STATIONS(950)       22.
LIST - STATIONS(951)    0.1000    0.3000    0.4000    0.5000    0.5500    0.6000    0.6500    0.7000    0.7500    0.8000
                        0.8250    0.8500    0.8750    0.9000    0.9250    0.9500    0.9600    0.9700    0.9800    0.9900
                        0.9950    1.0000
```

Figure 15: BLADEGEO output (2-DCOFWD: 2-D coordinates, forward rotor)

```
AERO PANEL INPUT PARMS--FORWARD: LSTPRM     LSTPARMS  FWD         TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**************************************************************************************************************************
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

**************************************************************************************************************************
LSTBUG        (001)        1.
NCP           (002)       10.
DR            (003)    0.020
NSM           (004)        8.
N             (005)     1024.
DELTAX        (006)    0.0040
MODOP         (007)        4.
TOLINF        (008)  0.000100
TOLINT        (009)  0.001000
TOLSUM        (010)  0.005000
MM1           (011)       20.
MM2           (012)       60.
MM3           (013)       10.
ITABK         (014)        8.
ITABT         (015)        9.
INT4          (016)        0.
PRINT         (017)        0.
PRIN1         (018)        0.
PRIN2         (019)        0.
PART1         (020)        1.
Q             (021)    0.0000
K             (022)        0.
KDOWN         (023)    0.0250
KSTART        (024)    0.0100
MM4           (025)        5.
MBLEND        (026)      0.90
N0            (027)     1024.
NBOPT         (028)        2.
ITNON         (029)       10.
ZAR           (101)    0.2000    0.3500    0.4500    0.5500    0.6500    0.7500    0.8500    0.9500
CONTPT        (141)    0.5000    0.5000    0.5000    0.5000    0.5000    0.5000    0.5000    0.5000
KARRAY        (201)    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
INMES         (221)    0.0020    0.0020    0.0020    0.0020    0.0020    0.0020    0.0020    0.0020
```

Figure 16: LSTPARMS output

```
RUN PARAMETERS FOR NOISE CALC. : NOZPRM     NOIZPARM              TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

*****************************************************************************************************************************
 UCAP  FOR CR-2            INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

*****************************************************************************************************************************
PRINT PARMS     (001)      1.0
NEAR OR FAR     (002)      0.0
# HARMONICS     (003)      4.0
MIN. OBS. DIST.(004)      6.12
# AXIAL LOCS.   (009)      7.0
VIS. OR RET.    (010)      0.0
VISUAL X        (011)     0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                          0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
RETARDED X      (031)     6.36      4.65      2.57      0.42     -1.45     -4.11     -8.77      0.00      0.00      0.00
                          0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
ZJMIN1          (051)      0.0
ZNJ1            (052)      0.0
ZJMIN2          (053)      0.0
ZNJ2            (054)      0.0
OUTPUT FILE #   (055)      6.0
START HARMONIC (056)      1.0
HARM. INCREMENT(057)      1.0
NOT USED        (058)      0.0
BL+WAKE H/B     (059)      1.0
LOAD DIAGNOSTIC(060)      0.0
FULL DIAGNOSTIC(061)      0.0
PUNCH DB LEVELS(062)      0.0
KK,FREQ INTEG. (063)      0.0
EXTEND FREQ     (064)      0.0
ZKMIN, CALC KK (065)      0.0
ZOMEGA, CALC KK(066)      0.0
EXTRA PRINT OPT(067)      0.0
INSTANT QUAD    (068)      0.0
AZI. DIREC, FWD(069)     90.0
AZI. DIREC, AFT(070)     90.0
AIRFOIL TYPE    (071)      1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
                           1.0       1.0       1.0       1.0       1.0       1.J       1.0       1.0       1.0       1.0
                           1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
```

Figure 17: NOIZPARM output

```
AXIS. NACELLE AXIAL VEL. **   : VEL001    VELGRADS          TIME :HH:MM:SS DATE : MM/DD/YY UAAP --- NASA    1
**************************************************************************************************************

SAMPLE PERFORMANCE CALCULATION FOR SRP VERSION OF UAAP

            BLADE ROW
J = 3.10, M = 0.70, BETA 3/4 R = 55.45 DEG.

EDGE VORTEX GIVES LIFT, NOT RADIAL FORCE
FAR FIELD NOISE

**************************************************************************************************************
DEBUG OPT        (001)       1.
V/V INP.OPT      (002)       1.
NO. OF RADS.     (003)     14.0
NO. OF AX.       (004)     20.0
REF.VEL.         (005)    251.4
REF.TIP RAD.     (006)     12.3
REF.C.L.LOC.     (007)     -3.2
RAD.LOC  /R      (025)    2.360     3.533     5.038     6.622     8.334    10.062    11.797    13.924    16.260    18.572
                         21.193    24.021    27.135    31.349
AXL.LOC-Z/R      (+25)  -14.000   -14.000   -14.000   -14.000   -14.000   -14.000   -14.000   -14.000   -14.000   -14.000
                        -14.000   -14.000   -14.000   -14.000
VELOCITY /V      (+25)  209.230   213.570   222.750   229.580   234.780   238.400   240.990   243.260   245.020   246.290
                        247.370   248.230   248.960   249.700
RAD.LOC  /R      (025)    4.130     4.800     5.889     7.198     8.723    10.331    11.988    14.054    16.348    18.635
                         21.239    24.053    27.159    31.366
AXL.LOC-Z/R      (+25)  -12.500   -12.500   -12.500   -12.500   -12.500   -12.500   -12.500   -12.500   -12.500   -12.500
                        -12.500   -12.500   -12.500   -12.500
VELOCITY /V      (+25)  248.290   247.220   247.200   246.760   246.360   246.180   246.250   246.560   247.070   247.620
                        248.220   248.790   249.350   249.920
RAD.LOC  /R      (025)    5.080     5.576     6.466     7.625     9.042    10.579    12.187    14.211    16.472    18.734
                         21.317    24.115    27.208    31.402
AXL.LOC-Z/R      (+25)  -11.000   -11.000   -11.000   -11.000   -11.000   -11.000   -11.000   -11.000   -11.000   -11.000
                        -11.000   -11.000   -11.000   -11.000
VELOCITY /V      (+25)  275.440   268.570   260.640   254.730   250.980   249.110   248.350   248.150   248.330   248.640
                        249.030   249.430   249.830   250.280
RAD.LOC  /R      (025)    5.350     5.814     6.661     7.781     9.164    10.676    12.266    14.275    16.529    18.789
                         21.368    24.159    27.243    31.427
AXL.LOC-Z/R      (+25)  -10.250   -10.250   -10.250   -10.250   -10.250   -10.250   -10.250   -10.229   -10.118    -9.913
                         -9.684    -9.543    -9.500    -9.500
VELOCITY /V      (+25)  275.670   269.810   262.360   256.410   252.420   250.340   249.420   249.080   249.160   249.420
                        249.760   250.040   250.290   250.600
RAD.LOC  /R      (025)    5.550     6.007     6.836     7.931     9.291    10.786    12.369    14.377    16.631    18.890
                         21.464    24.245    27.315    31.481
AXL.LOC-Z/R      (+25)   -9.140    -9.206    -9.326    -9.443    -9.508    -9.516    -9.469    -9.266    -8.921    -8.458
                         -8.010    -7.619    -7.540    -7.540
VELOCITY /V      (+25)  259.980   258.100   255.650   253.370   251.410   250.140   249.490   249.310   249.580   249.930
                        250.340   250.710   250.990   251.160
RAD.LOC  /R      (025)    5.660     6.123     6.955     8.043     9.388    10.867    12.438    14.440    16.693    18.947
                         21.515    24.288    27.349    31.507
AXL.LOC-Z/R      (+25)   -8.050    -8.177    -8.342    -8.505    -8.648    -8.737    -8.679    -8.441    -7.897    -7.371
                         -6.781    -6.334    -6.303    -6.294
VELOCITY /V      (+25)  247.760   248.890   249.950   250.280   250.180   249.940   249.790   249.830   250.170   250.530
                        250.810   251.110   251.330   251.400
RAD.LOC  /R      (025)    5.700     6.211     7.086     8.191     9.534    11.002    12.559    14.540    16.768    19.004
                         21.558    24.321    27.373    31.525
AXL.LOC-Z/R      (+25)   -7.270    -7.364    -7.523    -7.665    -7.780    -7.843    -7.776    -7.548    -7.062    -6.589
                         -6.049    -5.674    -5.654    -5.646
```

Figure 18 VELGRADS output

VELOCITY /V	(+25)	256.510	259.300	261.400	261.270	259.810	258.080	256.560	255.080	253.900	253.150
		252.510	252.040	251.710	251.550						
RAD.LOC /R	(025)	5.760	6.282	7.169	8.280	9.623	11.086	12.634	14.602	16.816	19.042
		21.588	24.343	27.391	31.538						
AXL.LOC-Z/R	(+25)	-6.490	-6.560	-6.698	-6.825	-6.915	-6.947	-6.870	-6.658	-6.235	-5.811
		-5.319	-5.017	-5.005	-4.999						
VELOCITY /V	(+25)	256.270	259.590	262.120	262.310	260.980	259.150	257.380	255.610	254.250	253.430
		252.780	252.230	251.850	251.700						
RAD.LOC /R	(025)	5.930	6.427	7.289	8.383	9.717	11.175	12.718	14.673	16.874	19.089
		21.624	24.372	27.414	31.556						
AXL.LOC-Z/R	(+25)	-5.710	-5.763	-5.890	-5.984	-6.043	-6.049	-5.969	-5.774	-5.403	-5.025
		-4.578	-4.361	-4.348	-4.344						
VELOCITY /V	(+25)	254.970	257.000	258.720	259.250	258.910	258.000	256.800	255.390	254.220	253.500
		252.950	252.400	252.020	251.860						
RAD.LOC /R	(025)	6.150	6.602	7.416	8.481	9.798	11.245	12.779	14.727	16.920	19.126
		21.653	24.394	27.432	31.570						
AXL.LOC-Z/R	(+25)	-4.930	-4.978	-5.070	-5.145	-5.178	-5.152	-5.064	-4.886	-4.577	-4.248
		-3.849	-3.705	-3.699	-3.697						
VELOCITY /V	(+25)	255.940	254.960	253.920	253.520	253.500	253.530	253.450	253.210	252.860	252.550
		252.420	252.270	252.060	251.970						
RAD.LOC /R	(025)	6.380	6.789	7.550	8.580	9.876	11.313	12.838	14.778	16.963	19.163
		21.682	24.417	27.452	31.587						
AXL.LOC-Z/R	(+25)	-4.150	-4.185	-4.251	-4.299	-4.307	-4.255	-4.165	-4.005	-3.752	-3.471
		-3.119	-3.050	-3.050	-3.050						
VELOCITY /V	(+25)	257.010	254.040	250.660	248.700	247.990	248.110	248.650	249.450	250.240	250.790
		251.400	251.860	252.040	252.100						
RAD.LOC /R	(025)	6.500	6.911	7.669	8.689	9.973	11.397	12.915	14.849	17.030	19.225
		21.736	24.464	27.492	31.618						
AXL.LOC-Z/R	(+25)	-3.170	-3.230	-3.342	-3.414	-3.459	-3.418	-3.305	-3.106	-2.718	-2.344
		-1.984	-1.734	-1.680	-1.680						
VELOCITY /V	(+25)	250.510	249.440	248.320	247.690	247.570	247.910	248.590	249.500	250.440	251.230
		251.870	252.300	252.500	252.440						
RAD.LOC /R	(025)	6.490	6.922	7.703	8.738	10.027	11.450	12.969	14.907	17.090	19.282
		21.789	24.510	27.530	31.648						
AXL.LOC-Z/R	(+25)	-2.030	-2.157	-2.358	-2.484	-2.592	-2.650	-2.494	-2.170	-1.669	-1.220
		-0.792	-0.460	-0.453	-0.443						
VELOCITY /V	(+25)	231.000	234.410	238.870	242.240	244.870	246.760	248.220	249.670	250.890	251.740
		252.300	252.650	252.780	252.630						
RAD.LOC /R	(025)	6.620	7.063	7.850	8.877	10.152	11.563	13.069	14.990	17.155	19.333
		21.827	24.538	27.549	31.662						
AXL.LOC-Z/R	(+25)	-1.260	-1.372	-1.551	-1.659	-1.745	-1.784	-1.637	-1.344	-0.890	-0.485
		-0.093	0.180	0.186	0.194						
VELOCITY /V	(+25)	249.000	251.240	253.540	254.780	255.380	255.520	255.410	255.180	254.890	254.540
		254.060	253.540	253.120	252.770						
RAD.LOC /R	(025)	6.760	7.196	7.971	8.986	10.249	11.649	13.142	15.049	17.202	19.371
		21.857	24.561	27.568	31.676						
AXL.LOC-Z/R	(+25)	-0.490	-0.585	-0.738	-0.830	-0.898	-0.917	-0.783	-0.523	-0.124	0.246
		0.604	0.820	0.825	0.831						
VELOCITY /V	(+25)	260.060	259.830	259.180	258.430	257.710	257.080	256.510	255.970	255.560	255.150
		254.560	253.830	253.240	252.860						
RAD.LOC /R	(025)	6.890	7.317	8.081	9.087	10.342	11.734	13.219	15.114	17.255	19.413
		21.888	24.584	27.585	31.689						
AXL.LOC-Z/R	(+25)	0.280	0.201	0.067	-0.006	-0.047	-0.041	0.072	0.293	0.654	0.989
		1.292	1.470	1.472	1.476						
VELOCITY /V	(+25)	255.960	255.840	255.650	255.540	255.590	255.770	255.920	256.010	255.880	255.560
		254.910	254.090	253.430	253.000						
RAD.LOC /R	(025)	7.030	7.450	8.207	9.205	10.450	11.829	13.301	15.181	17.306	19.450
		21.915	24.604	27.602	31.703						
AXL.LOC-Z/R	(+25)	1.050	0.987	0.876	0.821	0.800	0.826	0.927	1.115	1.420	1.721
		1.989	2.110	2.111	2.113						

Figure 18 VELGRADS output (continued)

```
VELOCITY /V    (+25)  237.910  240.570  244.320  247.690  250.520  252.580  253.950  254.850  255.080  254.930
                      254.540  253.990  253.490  253.100
RAD.LOC  /R    (025)    7.160    7.563    8.304    9.295   10.537   11.911   13.372   15.238   17.349   19.483
                       21.938   24.622   27.617   31.715
AXL.LOC-Z/R    (+25)    1.820    1.773    1.688    1.649    1.647    1.693    1.781    1.938    2.195    2.454
                        2.686    2.750    2.750    2.750
VELOCITY /V    (+25)  224.980  228.480  233.830  239.220  243.990  247.460  249.850  251.690  252.790  253.300
                      253.610  253.690  253.540  253.210
RAD.LOC  /R    (025)    7.800    8.156    8.819    9.718   10.864   12.155   13.551   15.358   17.426   19.533
                       21.970   24.645   27.636   31.731
AXL.LOC-Z/R    (+25)    3.000    3.006    3.019    3.035    3.053    3.072    3.093    3.154    3.266    3.377
                        3.469    3.500    3.500    3.500
VELOCITY /V    (+25)  253.070  253.740  254.730  255.440  255.740  255.650  255.380  255.050  254.730  254.420
                      254.130  253.920  253.660  253.300
RAD.LOC  /R    (025)    8.350    8.650    9.226   10.035   11.099   12.327   13.677   15.444   17.482   19.570
                       21.996   24.665   27.652   31.743
AXL.LOC-Z/R    (+25)    4.250    4.250    4.250    4.250    4.250    4.250    4.250    4.250    4.250    4.250
                        4.250    4.250    4.250    4.250
VELOCITY /V    (+25)  280.180  277.580  273.460  269.040  264.870  261.610  259.210  257.230  255.870  255.040
                      254.450  254.040  253.750  253.410
```

Figure 18 VELGRADS output

```
VORTEX LOAD PARAMETERS--FORWARD: VTXPRM     VORTPARM  FWD         TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

************************************************************************************************************************************
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

************************************************************************************************************************************
DEBUG            (001)       1.0
LE VORTEX LIFT (002)       1.0
SIDE VORT LIFT (003)       1.0
AUG LIFT         (004)       1.0
ZEFF AUGLFT     (005)    0.9700
0-LIFT:1-RADIAL(006)       0.0
X FOR LEV ACTION          0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000
                          0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000
                          0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000
                          0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000
                          0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000
```

Figure 19: VORTPARM output

```
PROPELLER WAKE ANALYSIS INPUT   :WAKPRM     WAKEPARM          TIME :HH:MM:SS DATE : MM/DD/YY UAAP --- NASA    1
*******************************************************************************************************************

SAMPLE PERFORMANCE CALCULATION FOR SRP VERSION OF UAAP

          BLADE ROW
J = 3.10, M = 0.70, BETA 3/4 R = 55.45 DEG.

EDGE VORTEX GIVES LIFT, NOT RADIAL FORCE
FAR FIELD NOISE

*******************************************************************************************************************
DEBUG        (001)    1.0000
K            (002)    0.0500
ADVR         (003)      0.00
NOR          (004)        1.
NPX          (005)        0.
IPLOT        (006)        1.
NPSKN        (008)  1.000000
TOL          (009)  0.000100
MM1          (010)        0.
TOL1         (012)  0.001000
LAST         (013)       20.
ZO           (016)  0.700000
NORM         (017)    0.5000
AOPT         (018)    1.0000
ILFP         (019)        0.
IPRT         (020)        0.
MM2          (021)        0.
C            (022)        0.
IVWK         (023)        0.
IWK          (024)        0.
NCS          (050)        1.
MMU          (051)        0.
MMV          (052)       98.
MMW          (053)       98.
FPIM         (054)    0.0300
ROUT         (351)    0.7000
XMBAR        (701)    0.3910
```

Figure 20: WAKEPARM output

```
INTERPRM INPUT/OUTPUT.....SBR:  INTPRM      INTERPRM              TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**********************************************************************************************************************************
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

**********************************************************************************************************************************
DEBUG SWITCH  (001)        1.
K             (002)    0.0500
Z0            (003)    0.7000
ZNORM         (004)    0.5000
AOPT          (005)        1.
IVWK          (006)        1.
FPMW          (007)    0.0100
NPSKN         (008)        1.
TOL           (009)   0.00010
TOL1          (010)   0.00100
MM1           (011)       99.
IPLOT         (015)        0.
IPRT          (016)        0.

VARIABLE DESCRIPTIONS ARE SAME AS FOR WAKEPARM.
```

Figure 21: INTERPRM output

```
SUBROUTINE:  GETXMB.  DEBUG PRINTOUT STATUS:  T
                          ARGUMENT LIST INPUT ITEMS
                 FORWARD ROTOR DIAMETER:           2.0467
                 AFT ROTOR DIAMETER:               2.0467
                 FORWARD ROTOR ADVANCE RATIO:      1.4522
                 AFT ROTOR ADVANCE RATIO:          1.4601
                 MAX. NUMBER CHORDWISE PANELS:     10
                   MAX. NUMBER SPANWISE PANELS:    10
                   ROTOR TO ROTOR SPACING:          0.2570 (NORMALIZED BY FORWARD ROTOR DIAMETER)
```

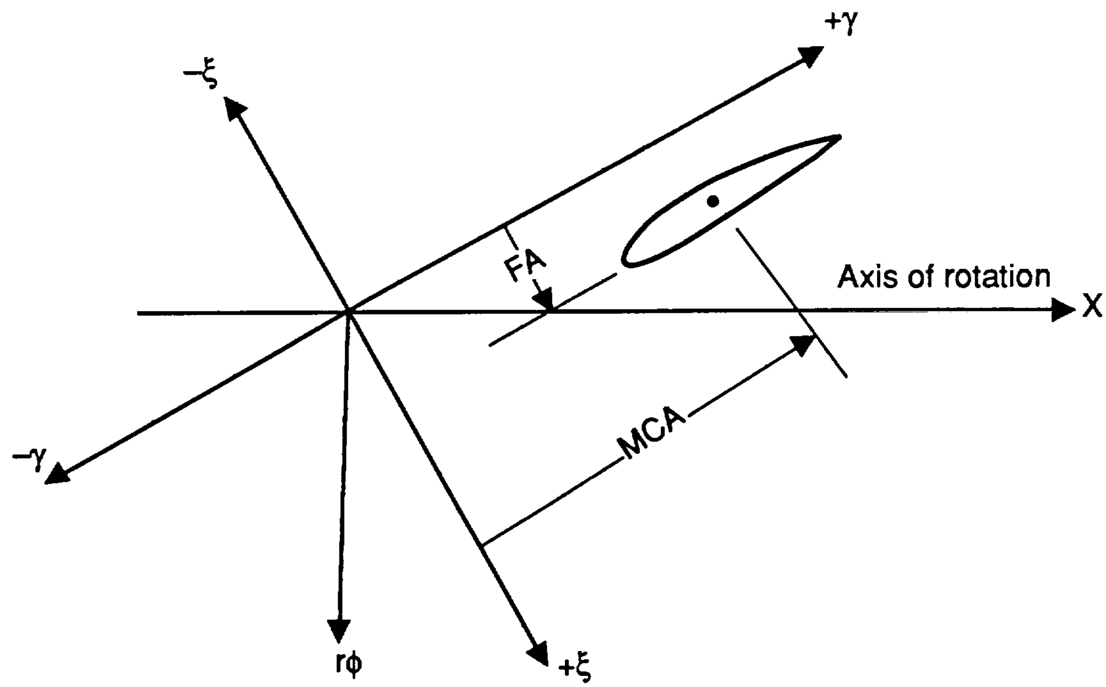
Figure 22: AEROEXEC output (GETXMB section 1)

NUMBER OF INPUT RADII: 22. ROTOR: FORWARD

STATION	RADIUS	CHORD	TWIST	HCA	FA
1	0.100	0.1747	70.004	0.01746	-.00192
2	0.300	0.1747	70.004	-.01012	0.00072
3	0.400	0.1897	65.005	-.02366	-.00224
4	0.500	0.2006	59.982	-.02244	-.00277
5	0.550	0.2026	57.477	-.01758	-.00248
6	0.600	0.2015	55.096	-.00980	-.00160
7	0.650	0.1971	52.872	0.00102	0.00003
8	0.700	0.1900	50.778	0.01506	0.00253
9	0.750	0.1805	48.846	0.03218	0.00584
10	0.800	0.1678	47.124	0.05149	0.00956
11	0.825	0.1601	46.344	0.06161	0.01146
12	0.850	0.1516	45.609	0.07183	0.01342
13	0.875	0.1422	44.912	0.08202	0.01546
14	0.900	0.1319	44.236	0.09205	0.01762
15	0.925	0.1202	43.576	0.10184	0.01986
16	0.950	0.1061	42.912	0.11137	0.02216
17	0.960	0.0996	42.635	0.11510	0.02310
18	0.970	0.0924	42.352	0.11879	0.02403
19	0.980	0.0845	42.064	0.12244	0.02498
20	0.990	0.0759	41.776	0.12607	0.02593
21	0.995	0.0713	41.636	0.12787	0.02641
22	1.000	0.0665	41.502	0.12967	0.02689

NUMBER OF SPAN-WISE MODES (CONTROL POINTS): 8
NUMBER OF CHORDWISE CONTROL POINTS: 10

Figure 23: AEROEXEC output (GETXMB section 2)



Mid chord alignment (MCA) and face alignment (FA)
(positive as shown)

γ is the path the pitch change axis has traveled along the advance helix

ζ is normal to γ and r

Figure 24 Blade section definition and definition of advance coordinate, γ.

```
FRONT ROW CONTROL POINT LOCATIONS

NUMBER  RADIUS   CHORD     PHI     TWIST      MCA       FA      %CHORD

 01     0.2000   0.1747   66.717   70.004    0.00367  -0.00060  0.50000
                                                                 MBAR  MU     XMBAR    DELTA-PHI
                                                                  01   001   -0.6555   -95.5010
                                                                  02   002   -0.6226   -88.0090
                                                                  03   003   -0.5898   -80.5170
                                                                  04   004   -0.5570   -73.0250
                                                                  05   005   -0.5242   -65.5330
                                                                  06   006   -0.4913   -58.0410
                                                                  07   007   -0.4585   -50.5489
                                                                  08   008   -0.4257   -43.0569
                                                                  09   009   -0.3928   -35.5649
                                                                  10   010   -0.3600   -28.0729

 02     0.3500   0.1822   53.018   67.504   -0.01689  -0.00076  0.50000
                                                                 MBAR  MU     XMBAR    DELTA-PHI
                                                                  01   011   -0.6934   -99.3447
                                                                  02   012   -0.6597   -92.8896
                                                                  03   013   -0.6261   -86.4346
                                                                  04   014   -0.5924   -79.9796
                                                                  05   015   -0.5587   -73.5246
                                                                  06   016   -0.5251   -67.0696
                                                                  07   017   -0.4914   -60.6146
                                                                  08   018   -0.4577   -54.1596
                                                                  09   019   -0.4241   -47.7046
                                                                  10   020   -0.3904   -41.2496

 03     0.4500   0.1951   45.925   62.494   -0.02305  -0.00250  0.50000
                                                                 MBAR  MU     XMBAR    DELTA-PHI
                                                                  01   021   -0.7064  -101.5087
                                                                  02   022   -0.6718   -94.9230
                                                                  03   023   -0.6371   -88.3372
                                                                  04   024   -0.6025   -81.7514
                                                                  05   025   -0.5679   -75.1656
                                                                  06   026   -0.5333   -68.5798
                                                                  07   027   -0.4987   -61.9940
                                                                  08   028   -0.4641   -55.4082
                                                                  09   029   -0.4294   -48.8224
                                                                  10   030   -0.3948   -42.2366

 04     0.5500   0.2026   40.199   57.477   -0.01758  -0.00248  0.50000
                                                                 MBAR  MU     XMBAR    DELTA-PHI
                                                                  01   031   -0.6942   -98.7254
                                                                  02   032   -0.6601   -92.2209
                                                                  03   033   -0.6259   -85.7164
                                                                  04   034   -0.5917   -79.2119
                                                                  05   035   -0.5576   -72.7073
                                                                  06   036   -0.5234   -66.2028
                                                                  07   037   -0.4892   -59.6983
                                                                  08   038   -0.4551   -53.1938
                                                                  09   039   -0.4209   -46.6893
                                                                  10   040   -0.3867   -40.1847
```

Figure 25 AEROEXEC output (getxmb section 3)

```
05    0.6500   0.1971   35.566   52.872    0.00102  0.00003  0.50000
                                                              HBAR  MU     XMBAR     DELTA-PHI
                                                               01   041   -0.6542    -90.3771
                                                               02   042   -0.6227    -84.3850
                                                               03   043   -0.5913    -78.3930
                                                               04   044   -0.5599    -72.4009
                                                               05   045   -0.5285    -66.4089
                                                               06   046   -0.4970    -60.4168
                                                               07   047   -0.4656    -54.4248
                                                               08   048   -0.4342    -48.4327
                                                               09   049   -0.4028    -42.4407
                                                               10   050   -0.3713    -36.4486

06    0.7500   0.1805   31.786   48.846    0.03218  0.00584  0.50000
                                                              HBAR  MU     XMBAR     DELTA-PHI
                                                               01   051   -0.5925    -77.8969
                                                               02   052   -0.5653    -72.7129
                                                               03   053   -0.5381    -67.5288
                                                               04   054   -0.5110    -62.3447
                                                               05   055   -0.4838    -57.1607
                                                               06   056   -0.4566    -51.9766
                                                               07   057   -0.4294    -46.7925
                                                               08   058   -0.4022    -41.6085
                                                               09   059   -0.3750    -36.4244
                                                               10   060   -0.3479    -31.2403

07    0.8500   0.1516   28.669   45.609    0.07183  0.01342  0.50000
                                                              HBAR  MU     XMBAR     DELTA-PHI
                                                               01   061   -0.5190    -63.1348
                                                               02   062   -0.4973    -59.0203
                                                               03   063   -0.4757    -54.9058
                                                               04   064   -0.4540    -50.7913
                                                               05   065   -0.4324    -46.6768
                                                               06   066   -0.4107    -42.5623
                                                               07   067   -0.3890    -38.4478
                                                               08   068   -0.3674    -34.3333
                                                               09   069   -0.3457    -30.2188
                                                               10   070   -0.3240    -26.1043

08    0.9500   0.1061   26.069   42.912    0.11137  0.02216  0.50000
                                                              HBAR  MU     XMBAR     DELTA-PHI
                                                               01   071   -0.4413    -48.0297
                                                               02   072   -0.4269    -45.3008
                                                               03   073   -0.4124    -42.5719
                                                               04   074   -0.3980    -39.8430
                                                               05   075   -0.3835    -37.1142
                                                               06   076   -0.3691    -34.3853
                                                               07   077   -0.3546    -31.6564
                                                               08   078   -0.3402    -28.9275
                                                               09   079   -0.3257    -26.1986
                                                               10   080   -0.3113    -23.4697
```

Figure 25' AEROEXEC output (getxmb section 3, continued)

```
FORWARD ROTOR-INNER WAKE POINTS.  QUANTITY:  08
         NUMBER          R/R
           01           0.2000
           02           0.3500
           03           0.4500
           04           0.5500
           05           0.6500
           06           0.7500
           07           0.8500
           08           0.9500
```

Figure 26: AEROEXEC output (GETXMB section 4)

SUBROUTINE LESWP DEBUG PRINTOUT

N	BLADE STA.	MCA/D	CHORD/DIA	L.E. SWEEP	N	BLADE STA.	MCA/D	CHORD/DIA	L.E. SWEEP
1	0.100	0.0175	0.1747	-15.4217	2	0.300	-0.0101	0.1747	-17.9596
3	0.400	-0.0237	0.1897	-14.1844	4	0.500	-0.0224	0.2006	-0.2869
5	0.550	-0.0176	0.2026	13.7262	6	0.600	-0.0098	0.2015	23.1390
7	0.650	0.0010	0.1971	31.4503	8	0.700	0.0151	0.1900	38.2680
9	0.750	0.0322	0.1805	43.5563	10	0.800	0.0515	0.1678	46.5685
11	0.825	0.0616	0.1601	48.6969	12	0.850	0.0718	0.1516	49.6258
13	0.875	0.0820	0.1422	50.2498	14	0.900	0.0921	0.1319	50.9323
15	0.925	0.1018	0.1202	52.1766	16	0.950	0.1114	0.1061	53.4105
17	0.960	0.1151	0.0996	55.0169	18	0.970	0.1188	0.0924	56.0797
19	0.980	0.1224	0.0845	57.1878	20	0.990	0.1261	0.0759	58.0495
21	0.995	0.1279	0.0713	58.9631	22	1.000	0.1297	0.0665	59.2784

Figure 27: AEROEXEC output (GETXMB section 5, LESWP output)

```
**** TSO FOREGROUND HARDCOPY **** 09:50:11 92017
DSNAME=TSOG04E.UCAP.FIGS                          (FIG31    )


AFT ROTOR-INNER WAKE POINTS.  QUANTITY:  08
        NUMBER          R/R
          01           0.2000
          02           0.3500
          03           0.4500
          04           0.5500
          05           0.6500
          06           0.7500
          07           0.8500
          08           0.9500
```

Figure 28: AEROEXEC output (GETXMB section 7)

SUBROUTINE: CPMAP.

INDUCTION CALCULATION POINTS--REAR ROTOR ONTO FWD ROTOR

N	RADIUS	STREAMTUBE NO.	FLD CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3500
3	0.4500	2	0.4500
4	0.5500	3	0.5500
5	0.6500	4	0.6500
6	0.7500	4	0.7500
7	0.8500	4	0.8500
8	0.9500	4	0.9500

Figure 29A: AEROEXEC output (CPMAP, front rotor)

SUBROUTINE: CPMAP. DIAMETER RATIO: 1.0000

WAKE CALCULATION POINTS--FRONT ROTOR ONTO REAR ROTOR

N	RADIUS	STREAMTUBE NO.	WAKE CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3500
3	0.4500	2	0.4500
4	0.5500	3	0.5500
5	0.6500	4	0.6500
6	0.7500	4	0.7500
7	0.8500	4	0.8500
8	0.9500	4	0.9500

Figure 29B: AEROEXEC output (CPMAP, rear rotor)

```
PROPELLER LIFTING SURFACE PROGRAM :F271      AEROEXEC  EXECCASE      TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**********************************************************************************************************************************
 UCAP  FOR CR-2            INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

**********************************************************************************************************************************

LST PROGRAM AND VERSION F271M2.1    03 OCT90
TEMP, DEGF.                  56.2
RHO/RHO STD                0.9662
SPEED OF SOUND             1113.4
ADVANCE RATIO              1.4522
FLIGHT MACH NO.            0.2650
FLIGHT SPD KTS           174.8146
TIP ROT. MACH              0.5733
TIP SPD. FPS             638.2822
RPM                      5956.073
TIP HEL. MACH              0.6316
START BLENDING             0.9000
DIAMETER                   2.0467
NO. BLADES                      5
NO. INPT. STA.                 22
FREQ.OF UNST.                 0.0
NO. NODAL DIA.                  0
K-DOWN                     0.0250
K-START                    0.0100
INPUT STATIONS             0.1000     0.3000     0.4000     0.5000     0.5500     0.6000     0.6500     0.7000
                           0.7500     0.8000     0.8250     0.8500     0.8750     0.9000     0.9250     0.9500
                           0.9600     0.9700     0.9800     0.9900     0.9950     1.0000
B/D                        0.1746     0.1746     0.1897     0.2006     0.2026     0.2015     0.1971     0.1900
                           0.1805     0.1677     0.1601     0.1515     0.1421     0.1319     0.1202     0.1062
                           0.0996     0.0925     0.0846     0.0760     0.0715     0.0667
TOTAL TWIST               69.6773    69.6773    64.6812    59.6580    57.1517    54.7706    52.5466    50.4534
                          48.5225    46.8022    46.0226    45.2894    44.5923    43.9170    43.2569    42.5927
                          42.3166    42.0334    41.7455    41.4581    41.3180    41.1836
MCA/D                      0.0175    -0.0101    -0.0237    -0.0225    -0.0176    -0.0098     0.0010     0.0151
                           0.0322     0.0515     0.0616     0.07'9     0.0820     0.0921     0.1019     0.1114
                           0.1151     0.1188     0.1225     0.1261     0.1279     0.1297
FA /D                     -0.0020     0.0008    -0.0022    -0.0027    -0.0024    -0.0016     0.0000     0.0025
                           0.0057     0.0094     0.0113     0.0132     0.0152     0.0173     0.0195     0.0218
                           0.0227     0.0236     0.0245     0.0255     0.0259     0.0264
T/B                        0.2149     0.0995     0.0572     0.0440     0.0394     0.0353     0.0319     0.0289
                           0.0264     0.0243     0.0234     0.0226     0.0219     0.0213     0.0208     0.0204
                           0.0203     0.0202     0.0201     0.0201     0.0200     0.0200
CLD                        0.0324     0.0704     0.1067     0.1474     0.1652     0.1824     0.1986     0.2125
                           0.2243     0.2312     0.2326     0.2326     0.2314     0.2291     0.2257     0.2199
                           0.2166     0.2128     0.2086     0.2043     0.2022     0.2000
SWEEP                    -14.4320   -10.5796     0.2510    13.2020    18.6644    23.8473    28.8349    33.2224
                          35.9356    36.7154    36.4731    35.7786    34.7056    33.4078    31.9988    30.5831
                          30.1285    29.7313    29.3917    29.1096    28.9901    28.8795
```

Figure 30: AEROEXEC output (lifting surface solver)

LST CAMBER TABLE :F271 AEROEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

```
************************************************************************************************************************
 UCAP  FOR CR-2            INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

************************************************************************************************************************
```

CAMBER PLUS TWIST SURFACE ALONG STREAMLINES AS A FUNCTION OF RADIUS (<LOWER CASE R>/RTIP.

UNBAR TABLE FORMAT.

TABLE NO. 1. DEGREE 1.

	0.00000E+00	1.00000E-01	2.00000E-01	3.00000E-01	4.00000E-01	5.00000E-01	6.00000E-01	7.00000E-01	8.00000E-01
1.000E-01	6.90518E+01	6.94046E+01	6.96023E+01	6.97672E+01	6.99399E+01	7.01590E+01	7.04111E+01	7.07085E+01	7.09870E+01
3.000E-01	6.90518E+01	6.94046E+01	6.96023E+01	6.97672E+01	6.99399E+01	7.01590E+01	7.04111E+01	7.07085E+01	7.09870E+01
4.000E-01	6.29621E+01	6.37112E+01	6.40573E+01	6.43628E+01	6.46953E+01	6.50540E+01	6.54312E+01	6.58571E+01	6.61670E+01
5.000E-01	5.70681E+01	5.81944E+01	5.87658E+01	5.91470E+01	5.95075E+01	5.98713E+01	6.02632E+01	6.06830E+01	6.12603E+01
5.500E-01	5.42006E+01	5.56424E+01	5.62848E+01	5.66544E+01	5.69875E+01	5.73169E+01	5.76734E+01	5.80747E+01	5.85472E+01
6.000E-01	5.14046E+01	5.31170E+01	5.38347E+01	5.42261E+01	5.45747E+01	5.49158E+01	5.52804E+01	5.57168E+01	5.60257E+01
6.500E-01	4.87728E+01	5.06346E+01	5.14387E+01	5.18926E+01	5.22966E+01	5.26887E+01	5.31016E+01	5.35862E+01	5.39282E+01
7.000E-01	4.62946E+01	4.82883E+01	4.91796E+01	4.96997E+01	5.01608E+01	5.06031E+01	5.10654E+01	5.15738E+01	5.21137E+01
7.500E-01	4.40482E+01	4.61915E+01	4.71549E+01	4.77184E+01	4.82143E+01	4.86853E+01	4.91737E+01	4.97068E+01	5.02800E+01
8.000E-01	4.21437E+01	4.43751E+01	4.53919E+01	4.59859E+01	4.65032E+01	4.69898E+01	4.74859E+01	4.80368E+01	4.85209E+01
8.250E-01	4.13352E+01	4.35825E+01	4.46152E+01	4.52186E+01	4.57416E+01	4.62306E+01	4.67240E+01	4.72718E+01	4.77255E+01
8.500E-01	4.06100E+01	4.28622E+01	4.39014E+01	4.45074E+01	4.50302E+01	4.55172E+01	4.60054E+01	4.65430E+01	4.70095E+01
8.750E-01	3.99529E+01	4.21975E+01	4.32337E+01	4.38345E+01	4.43516E+01	4.48329E+01	4.53169E+01	4.58510E+01	4.63181E+01
9.000E-01	3.93470E+01	4.15640E+01	4.25894E+01	4.31797E+01	4.36858E+01	4.41591E+01	4.46418E+01	4.51794E+01	4.56582E+01
9.250E-01	3.87876E+01	4.09582E+01	4.19697E+01	4.25496E+01	4.30439E+01	4.35069E+01	4.39824E+01	4.45180E+01	4.49768E+01
9.500E-01	3.82565E+01	4.03832E+01	4.13771E+01	4.19449E+01	4.24264E+01	4.28723E+01	4.33209E+01	4.38253E+01	4.42611E+01
9.600E-01	3.80695E+01	4.01565E+01	4.11421E+01	4.17053E+01	4.21797E+01	4.26147E+01	4.30441E+01	4.35256E+01	4.39468E+01
9.700E-01	3.78954E+01	3.99279E+01	4.09038E+01	4.14616E+01	4.19278E+01	4.23502E+01	4.27588E+01	4.32147E+01	4.36145E+01
9.800E-01	3.76919E+01	3.97009E+01	4.06619E+01	4.12097E+01	4.16662E+01	4.20766E+01	4.24673E+01	4.29032E+01	4.32674E+01
9.900E-01	3.74585E+01	3.94739E+01	4.04150E+01	4.09480E+01	4.13943E+01	4.17955E+01	4.21759E+01	4.26004E+01	4.29567E+01
9.950E-01	3.73897E+01	3.93503E+01	4.02847E+01	4.08147E+01	4.12562E+01	4.16546E+01	4.20352E+01	4.24606E+01	4.27979E+01
1.000E+00	3.72915E+01	3.92323E+01	4.01576E+01	4.06817E+01	4.11193E+01	4.15170E+01	4.19010E+01	4.23309E+01	4.26722E+01

	9.00000E-01	1.00000E+00
1.000E-01	7.13028E+01	7.16871E+01
3.000E-01	7.13028E+01	7.16871E+01
4.000E-01	6.67261E+01	6.76942E+01
5.000E-01	6.20476E+01	6.30457E+01
5.500E-01	5.94657E+01	6.09645E+01
6.000E-01	5.70960E+01	5.92833E+01
6.500E-01	5.50825E+01	5.74297E+01
7.000E-01	5.32787E+01	5.52878E+01
7.500E-01	5.14970E+01	5.35782E+01
8.000E-01	4.98001E+01	5.22060E+01
8.250E-01	4.90107E+01	5.14861E+01
8.500E-01	4.82742E+01	5.06716E+01
8.750E-01	4.75660E+01	4.99209E+01
9.000E-01	4.68876E+01	4.91792E+01
9.250E-01	4.61887E+01	4.84768E+01
9.500E-01	4.54279E+01	4.76365E+01

Figure 31 : AEROEXEC output (lst camber table)

9.600E-01	4.50911E+01	4.72622E+01
9.700E-01	4.47352E+01	4.68776E+01
9.800E-01	4.43696E+01	4.65249E+01
9.900E-01	4.40262E+01	4.61135E+01
9.950E-01	4.38595E+01	4.59638E+01
1.000E+00	4.37141E+01	4.57673E+01

Figure 31 : AEROEXEC output (lst camber table, continued)

SUBROUTINE ANS0: K-INVERSE UNIT NAME: FWD000

I	MBAR	MU	R/R	TH+CAMB	THICKNESS	V-AXIAL	V-SWIRL	PI*X/J	CENTER BODY		
1	1	1	0.200	69.228	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	2.51045
1	2	2	0.200	69.503	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	2.78572
1	3	3	0.200	69.685	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	2.96705
1	4	4	0.200	69.854	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	3.13586
1	5	5	0.200	70.049	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	3.33173
1	6	6	0.200	70.285	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	3.56732
1	7	7	0.200	70.560	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	3.84209
1	8	8	0.200	70.848	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	4.13003
1	9	9	0.200	71.145	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	4.42716
1	10	10	0.200	71.495	0.0000	0.0000	0.0000	0.4303	0.0000	WMU:	4.77721
2	1	11	0.350	66.282	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	13.26380
2	2	12	0.350	66.694	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	13.67521
2	3	13	0.350	66.947	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	13.92878
2	4	14	0.350	67.191	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	14.17270
2	5	15	0.350	67.462	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	14.44344
2	6	16	0.350	67.764	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	14.74519
2	7	17	0.350	68.102	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	15.08334
2	8	18	0.350	68.430	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	15.41127
2	9	19	0.350	68.796	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	15.77710
2	10	20	0.350	69.353	0.0000	0.0000	0.0000	0.7531	0.0000	WMU:	16.33392
3	1	21	0.450	60.484	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	14.55850
3	2	22	0.450	61.182	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	15.25671
3	3	23	0.450	61.583	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	15.65774
3	4	24	0.450	61.928	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	16.00268
3	5	25	0.450	62.282	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	16.35656
3	6	26	0.450	62.655	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	16.72943
3	7	27	0.450	63.059	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	17.13312
3	8	28	0.450	63.492	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	17.56637
3	9	29	0.450	64.050	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	18.12476
3	10	30	0.450	64.878	0.0000	0.0000	0.0000	0.9682	0.0000	WMU:	18.95291
4	1	31	0.550	54.922	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	14.72212
4	2	32	0.550	55.964	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	15.76423
4	3	33	0.550	56.470	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	16.27025
4	4	34	0.550	56.821	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	16.62158
4	5	35	0.550	57.152	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	16.95279
4	6	36	0.550	57.495	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	17.29576
4	7	37	0.550	57.874	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	17.67469
4	8	38	0.550	58.311	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	18.11157
4	9	39	0.550	59.006	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	18.80706
4	10	40	0.550	60.215	0.0000	0.0000	0.0000	1.1834	0.0000	WMU:	20.01570
5	1	41	0.650	49.704	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	14.13747
5	2	42	0.650	51.037	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	15.47043
5	3	43	0.650	51.666	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	16.09940
5	4	44	0.650	52.095	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	16.52837
5	5	45	0.650	52.493	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	16.92644
5	6	46	0.650	52.895	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	17.32895
5	7	47	0.650	53.344	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	17.77770
5	8	48	0.650	53.757	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	18.19100
5	9	49	0.650	54.505	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	18.93913
5	10	50	0.650	56.256	0.0000	0.0000	0.0000	1.3986	0.0000	WMU:	20.68987
6	1	51	0.750	45.120	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	13.33342
6	2	52	0.750	46.673	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	14.88673
6	3	53	0.750	47.437	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	15.65019
6	4	54	0.750	47.966	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	16.17991
6	5	55	0.750	48.450	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	16.66337
6	6	56	0.750	48.930	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	17.14305
6	7	57	0.750	49.440	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	17.65377
6	8	58	0.750	49.993	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	18.20695

Figure 32 : AEROEXEC output (ANS0)

6	9	59	0.750	50.889	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	19.10207
6	10	60	0.750	52.538	0.0000	0.0000	0.0000	1.6137	0.0000	WMU:	20.75117
7	1	61	0.850	41.736	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	13.06657
7	2	62	0.850	43.382	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	14.71228
7	3	63	0.850	44.204	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	15.53487
7	4	64	0.850	44.769	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	16.09927
7	5	65	0.850	45.274	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	16.60419
7	6	66	0.850	45.761	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	17.09177
7	7	67	0.850	46.274	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	17.60468
7	8	68	0.850	46.776	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	18.10675
7	9	69	0.850	47.642	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	18.97234
7	10	70	0.850	49.473	0.0000	0.0000	0.0000	1.8289	0.0000	WMU:	20.80339
8	1	71	0.950	39.320	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	13.25036
8	2	72	0.950	40.880	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	14.81067
8	3	73	0.950	41.661	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	15.59152
8	4	74	0.950	42.186	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	16.11615
8	5	75	0.950	42.649	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	16.57983
8	6	76	0.950	43.097	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	17.02709
8	7	77	0.950	43.573	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	17.50361
8	8	78	0.950	44.043	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	17.97372
8	9	79	0.950	44.844	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	18.77498
8	10	80	0.950	46.532	0.0000	0.0000	0.0000	2.0440	0.0000	WMU:	20.46268

****

COEFFICIENT OF SOUND POWER = 0.000005 - SOUND POWER/ (RHO* RPS**3* DIAM**5)

****

Figure 32 : AEROEXEC output (ANS0, continued plus coeffiecient of sound power)

```
LSTDY: PERFORMANCE SUMMARY     AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**********************************************************************************************************************
UCAP  FOR CR-2           INPUT -- R252INPT.DATA
MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL

**********************************************************************************************************************
ITERATION NUMBER           1.
 PERFORMANCE WITHOUT VORTEX LIFT
 CP--FORWARD ROTOR      0.9202
 CT--FORWARD ROTOR      0.4716
 PERFORMANCE WITH VORTEX LIFT
 CP--FORWARD ROTOR      1.6138
 CT--FORWARD ROTOR      0.5772
```

Figure 33: AEROEXEC output (individual rotor performance summary)

```
VORTEX CALC. RESULTS (FWD ):  VTXOUT     AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

***************************************************************************************************************************
UCAP  FOR CR-2             INPUT -- R252INPT.DATA
MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL

***************************************************************************************************************************
RUNNING FWD  ROW : UAAP CALCULATION VERSION  4 : PERFORMANCE CALCULATION ON THE BLADE VERSION  0


 ***** OPERATING CONDITIONS ****

  FLIGHT  TIP ROT. ADVANCE    TEMP.  DENSITY
  MACH #   MACH #   RATIO     DEG F   RATIO
  ------  -------  -------   ------  -------

  0.2650   0.5702   1.4601    56.18   0.9662


           # CHORD-  # SPAN-
 # RADIAL    WISE     WISE
 STATIONS  STATIONS   MODES    MODOPT    NBOPT
 --------  --------   -----    ------    -----

    22        10        8        4         2
```

Figure 34: AEROEXEC output (vortex calculations: operating conditions)

BLADE GEOMETRY :	THETA 3/4	# BLADES	DIAMETER	SPINNER CUTOFF
	48.87	6.	2.047	0.2450

RADIAL STATION	CHORD/ DIAM	THICK/ CHORD	MID-CHORD COORDINATES XMC	YMC	ZMC	FACE ALINE	MID-CHORD ALINE	SWEEP	L. E. SWEEP	L. E. A.O.A.	ALPHA 3-D	INDUCED ANGLE	ADVANCE ANGLE	BLADE ANGLE
0.1000	0.1747	0.2149	0.2208	-0.0001	0.0017	-0.0019	0.0175	-14.42	-15.42	-9.59	-7.85	-17.23	77.86	70.00
0.3000	0.1747	0.0995	0.2998	-0.0122	-0.0162	0.0007	-0.0101	-10.59	-17.96	11.10	12.85	9.91	57.16	70.00
0.4000	0.1897	0.0572	0.3991	-0.0274	-0.0388	-0.0022	-0.0237	0.22	-14.18	12.52	15.72	11.47	49.28	65.00
0.5000	0.2006	0.0440	0.4992	-0.0291	-0.0346	-0.0028	-0.0224	13.18	-0.29	13.38	17.07	12.76	42.91	59.98
0.5500	0.2026	0.0394	0.5495	-0.0236	-0.0265	-0.0025	-0.0176	18.64	13.73	13.37	17.28	12.91	40.20	57.48
0.6000	0.2015	0.0353	0.5998	-0.0135	-0.0145	-0.0016	-0.0098	23.84	23.14	13.18	17.33	12.65	37.76	55.10
0.6500	0.1971	0.0319	0.6500	0.0016	0.0012	0.0000	0.0010	28.84	31.45	12.86	17.31	11.99	35.57	52.87
0.7000	0.1900	0.0289	0.6996	0.0223	0.0209	0.0025	0.0151	33.23	38.27	12.48	17.20	11.01	33.58	50.78
0.7500	0.1805	0.0264	0.7484	0.0485	0.0438	0.0058	0.0322	35.96	43.56	12.10	17.06	9.77	31.79	48.85
0.8000	0.1678	0.0243	0.7961	0.0793	0.0683	0.0096	0.0515	36.75	46.57	11.91	16.97	8.28	30.15	47.12
0.8250	0.1601	0.0234	0.8194	0.0959	0.0805	0.0115	0.0616	36.51	48.70	11.89	16.95	7.35	29.39	46.34
0.8500	0.1516	0.0226	0.8425	0.1128	0.0925	0.0134	0.0718	35.80	49.63	11.91	16.94	6.20	28.67	45.61
0.8750	0.1422	0.0219	0.8653	0.1299	0.1043	0.0155	0.0820	34.74	50.25	11.96	16.94	4.70	27.98	44.91
0.9000	0.1319	0.0213	0.8880	0.1467	0.1158	0.0176	0.0921	33.44	50.93	12.02	16.92	2.67	27.31	44.24
0.9250	0.1202	0.0208	0.9105	0.1633	0.1270	0.0199	0.1018	32.04	52.18	12.10	16.90	-0.09	26.68	43.58
0.9500	0.1061	0.0204	0.9329	0.1795	0.1378	0.0222	0.1114	30.65	53.41	12.19	16.84	-3.73	26.07	42.91
0.9600	0.0996	0.0203	0.9418	0.1858	0.1420	0.0231	0.1151	30.26	55.02	12.23	16.80	-5.35	25.83	42.64
0.9700	0.0924	0.0202	0.9508	0.1922	0.1461	0.0240	0.1188	29.89	56.08	12.26	16.75	-6.84	25.60	42.35
0.9800	0.0845	0.0201	0.9597	0.1984	0.1502	0.0250	0.1224	29.53	57.19	12.30	16.69	-7.70	25.37	42.06
0.9900	0.0759	0.0201	0.9686	0.2047	0.1542	0.0259	0.1261	29.19	58.05	12.35	16.63	-6.33	25.15	41.78
0.9950	0.0713	0.0200	0.9731	0.2078	0.1562	0.0264	0.1279	29.03	58.96	12.31	16.60	-3.04	25.04	41.64
1.0000	0.0665	0.0200	0.9775	0.2109	0.1582	0.0269	0.1297	28.88	59.28	12.37	16.57	0.00	24.93	41.50

Figure 35: AEROEXEC output (vortex calculations: elemental data)

COEFFICIENTS FROM POTENTIAL CALC.:

RADIAL STATION	DRAG CDLST	DRAG CDPOT	LIFT CLLST	LIFT CLPOT	L. E. K, MAG.	L. E. THRUST	RELATIVE MACH #	DESIGN CL
0.1000	0.0072	-0.0499	0.1696	0.1611	0.2393	0.0225	0.2711	0.0324
0.3000	0.0367	0.0684	0.4060	0.3913	0.1885	0.0140	0.3154	0.0704
0.4000	0.0512	0.1008	0.5235	0.4964	0.2564	0.0258	0.3496	0.1067
0.5000	0.0473	0.1224	0.5768	0.5406	0.2696	0.0285	0.3892	0.1474
0.5500	0.0414	0.1266	0.5907	0.5525	0.2758	0.0299	0.4106	0.1652
0.6000	0.0389	0.1263	0.6012	0.5628	0.2902	0.0331	0.4327	0.1824
0.6500	0.0428	0.1217	0.6101	0.5728	0.3140	0.0387	0.4556	0.1986
0.7000	0.0479	0.1132	0.6170	0.5820	0.3449	0.0467	0.4791	0.2125
0.7500	0.0514	0.1018	0.6234	0.5914	0.3809	0.0570	0.5031	0.2243
0.8000	0.0522	0.0880	0.6334	0.6048	0.4254	0.0711	0.5275	0.2312
0.8250	0.0518	0.0792	0.6399	0.6134	0.4533	0.0807	0.5399	0.2326
0.8500	0.0506	0.0677	0.6465	0.6226	0.4869	0.0931	0.5524	0.2326
0.8750	0.0478	0.0518	0.6507	0.6306	0.5276	0.1093	0.5649	0.2314
0.9000	0.0420	0.0296	0.6483	0.6336	0.5759	0.1302	0.5775	0.2291
0.9250	0.0303	-0.0010	0.6344	0.6271	0.6312	0.1564	0.5902	0.2257
0.9500	0.0229	-0.0392	0.5990	0.6014	0.6861	0.1849	0.6030	0.2199
0.9600	0.0194	-0.0543	0.5736	0.5800	0.7013	0.1932	0.6081	0.2166
0.9700	0.0143	-0.0655	0.5362	0.5459	0.7038	0.1945	0.6133	0.2128
0.9800	0.0098	-0.0660	0.4774	0.4882	0.6770	0.1800	0.6184	0.2086
0.9900	0.0052	-0.0421	0.3732	0.3800	0.5757	0.1301	0.6236	0.2043
0.9950	0.0043	-0.0149	0.2793	0.2809	0.4507	0.0798	0.6262	0.2022
1.0000	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.6288	0.2000

Figure 36: AEROEXEC output (vortex calculations: coefficients from potential calculation)

PERFORMANCE CALCULATIONS - LIFT COEFFICIENTS

**** NOTE THAT VORTEX LIFT COMPONENTS ARE NOT PRESENTED AS PERPENDICULAR TO THE LOCAL ADVANCE ANGLE ****

RADIAL STATION	POT. LIFT	L. E. VORTEX	TIP VORTEX	AUGMENTED VORTEX	TOTAL LIFT
0.1000	0.1611	0.0000	0.0000	0.0000	0.1611
0.3000	0.3913	0.0000	0.0000	0.0000	0.3913
0.4000	0.4964	0.0000	0.0000	0.0000	0.4964
0.5000	0.5406	0.0000	0.0000	0.0000	0.5406
0.5500	0.5525	0.0307	0.0000	0.0000	0.5755
0.6000	0.5628	0.0360	0.0000	0.0000	0.5903
0.6500	0.5728	0.0454	0.0000	0.0000	0.6084
0.7000	0.5820	0.0595	0.0000	0.0000	0.6299
0.7500	0.5914	0.0786	0.0000	0.0000	0.6563
0.8000	0.6048	0.1034	0.0000	0.0000	0.6912
0.8250	0.6134	0.1222	0.0000	0.0000	0.7164
0.8500	0.6226	0.1437	0.0000	0.0000	0.7440
0.8750	0.6306	0.1710	0.0000	0.0000	0.7752
0.9000	0.6336	0.2066	0.0000	0.0000	0.8086
0.9250	0.6271	0.2551	0.0000	0.0000	0.8437
0.9500	0.6014	0.3102	0.0000	0.6492	1.4869
0.9600	0.5800	0.3369	0.5751	1.0885	2.4609
0.9700	0.5459	0.3486	0.9143	1.2978	2.9635
0.9800	0.4882	0.3321	0.9829	1.2401	2.9037
0.9900	0.3800	0.2459	0.7174	0.8486	2.0929
0.9950	0.2809	0.1547	0.4260	0.4927	1.2955
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

INCREMENTAL LIFTS AND DRAGS

RADIAL STATION	POT. LIFT	POT + LE VORT	POT + SE VORT	POT + AUGVORT	TOTAL LIFT	POT. DRAG	POT + LE VORT	POT + SE VORT	POT + AUGVORT	TOTAL DRAG
0.1000	0.1611	0.1611	0.1611	0.1611	0.1611	-0.0499	-0.0499	-0.0499	-0.0499	-0.0427
0.3000	0.3913	0.3913	0.3913	0.3913	0.3913	0.0684	0.0684	0.0684	0.0684	0.1050
0.4000	0.4964	0.4964	0.4964	0.4964	0.4964	0.1008	0.1008	0.1008	0.1008	0.1520
0.5000	0.5406	0.5406	0.5406	0.5406	0.5406	0.1224	0.1224	0.1224	0.1224	0.1697
0.5500	0.5525	0.5755	0.5525	0.5525	0.5755	0.1266	0.1628	0.1266	0.1266	0.2043
0.6000	0.5628	0.5903	0.5628	0.5628	0.5903	0.1263	0.1667	0.1263	0.1263	0.2056
0.6500	0.5728	0.6084	0.5728	0.5728	0.6084	0.1217	0.1695	0.1217	0.1217	0.2123
0.7000	0.5820	0.6299	0.5820	0.5820	0.6299	0.1132	0.1717	0.1132	0.1132	0.2196
0.7500	0.5914	0.6563	0.5914	0.5914	0.6563	0.1018	0.1740	0.1018	0.1018	0.2254
0.8000	0.6048	0.6912	0.6048	0.6048	0.6912	0.0880	0.1788	0.0880	0.0880	0.2310
0.8250	0.6134	0.7164	0.6134	0.6134	0.7164	0.0792	0.1833	0.0792	0.0792	0.2351
0.8500	0.6226	0.7440	0.6226	0.6226	0.7440	0.0677	0.1884	0.0677	0.0677	0.2390
0.8750	0.6306	0.7752	0.6306	0.6306	0.7752	0.0518	0.1942	0.0518	0.0518	0.2420
0.9000	0.6336	0.8086	0.6336	0.6336	0.8086	0.0296	0.2000	0.0296	0.0296	0.2420
0.9250	0.6271	0.8437	0.6271	0.6271	0.8437	-0.0010	0.2055	-0.0010	-0.0010	0.2358
0.9500	0.6014	0.8655	0.6014	1.2228	1.4869	-0.0392	0.2070	-0.0392	0.1489	0.4180
0.9600	0.5800	0.8684	1.1306	1.6220	2.4609	-0.0543	0.2058	0.1119	0.2603	0.7061
0.9700	0.5459	0.8452	1.4214	1.7886	2.9635	-0.0655	0.1986	0.1980	0.3086	0.8505
0.9800	0.4882	0.7744	1.4297	1.6761	2.9037	-0.0660	0.1806	0.2163	0.2902	0.8289
0.9900	0.3800	0.5924	1.0674	1.1931	2.0929	-0.0421	0.1376	0.1632	0.2007	0.5909
0.9950	0.2809	0.4151	0.6892	0.7531	1.2955	-0.0149	0.0960	0.1068	0.1258	0.3627
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0054

Figure 37: AEROEXEC output (vortex calculations: lift coefficients and incremental lifts and drags)

PERFORMANCE SUMMARY

ELEMENTAL PERFORMANCE

RADIAL * STATION	POTENTIAL DCP/DX	DCT/DX	* DETA/DX	POT+LEAD EDGE VORTEX * DCP/DX	DCT/DX	DETA/DX	POT+SIDE EDGE VORTEX * DCP/DX	DCT/DX	DETA/DX	POT+AUGMENTED VORTEX * DCP/DX	DCT/DX	DETA/DX	DCP/DX	TOTAL DCT/DX	* DETA/DX
0.1000	0.0270	0.0483	2.6158	0.0270	0.0483	2.6158	0.0270	0.0483	2.6158	0.0270	0.0483	2.6158	0.0273	0.0442	2.3687
0.3000	0.2728	0.1225	0.6555	0.2728	0.1225	0.6555	0.2728	0.1225	0.6555	0.2728	0.1225	0.6555	0.2877	0.0981	0.4979
0.4000	0.5864	0.2613	0.6505	0.5864	0.2613	0.6505	0.5864	0.2613	0.6505	0.5864	0.2613	0.6505	0.6307	0.2203	0.5100
0.5000	0.9949	0.4326	0.6349	0.9949	0.4326	0.6349	0.9949	0.4326	0.6349	0.9949	0.4326	0.6349	1.0702	0.3881	0.5294
0.5500	1.2182	0.5292	0.6342	1.3324	0.5202	0.5700	1.2182	0.5292	0.6342	1.2182	0.5292	0.6342	1.4174	0.4786	0.4930
0.6000	1.4393	0.6315	0.6406	1.5973	0.6263	0.5725	1.4393	0.6315	0.6406	1.4393	0.6315	0.6406	1.6968	0.5854	0.5037
0.6500	1.6437	0.7361	0.6539	1.8707	0.7382	0.5762	1.6437	0.7361	0.6539	1.6437	0.7361	0.6539	2.0030	0.6919	0.5044
0.7000	1.8178	0.8386	0.6735	2.1465	0.8537	0.5807	1.8178	0.8386	0.6735	1.8178	0.8386	0.6735	2.3209	0.8011	0.5040
0.7500	1.9510	0.9342	0.6991	2.4195	0.9699	0.5853	1.9510	0.9342	0.6991	1.9510	0.9342	0.6991	2.6335	0.9136	0.5065
0.8000	2.0301	1.0180	0.7322	2.6822	1.0799	0.5879	2.0301	1.0180	0.7322	2.0301	1.0180	0.7322	2.9232	1.0242	0.5116
0.8250	2.0386	1.0534	0.7545	2.8169	1.1354	0.5885	2.0386	1.0534	0.7545	2.0386	1.0534	0.7545	3.0656	1.0814	0.5150
0.8500	2.0138	1.0821	0.7846	2.9371	1.1844	0.5888	2.0138	1.0821	0.7846	2.0138	1.0821	0.7846	3.1865	1.1333	0.5193
0.8750	1.9399	1.1003	0.8281	3.0391	1.2261	0.5891	1.9399	1.1003	0.8281	1.9399	1.1003	0.8281	3.2789	1.1798	0.5254
0.9000	1.7954	1.1006	0.8951	3.1079	1.2554	0.5898	1.7954	1.1006	0.8951	1.7954	1.1006	0.8951	3.3192	1.2169	0.5353
0.9250	1.5554	1.0695	1.0040	3.1167	1.2618	0.5911	1.5554	1.0695	1.0040	1.5554	1.0695	1.0040	3.2670	1.2359	0.5523
0.9500	1.2013	0.9797	1.1908	2.9701	1.2065	0.5931	1.2013	0.9797	1.1908	3.5196	1.8153	0.7531	5.3964	2.0243	0.5477
0.9600	1.0310	0.9151	1.2960	2.8507	1.1603	0.5943	3.0013	1.6247	0.7904	4.7598	2.2580	0.6927	8.6380	3.1986	0.5407
0.9700	0.8525	0.8237	1.4108	2.6245	1.0703	0.5954	3.8226	1.8929	0.7230	5.0683	2.3413	0.6745	9.8726	3.6473	0.5394
0.9800	0.6779	0.6909	1.4881	2.2434	0.9160	0.5962	3.6621	1.7650	0.7037	4.4430	2.0461	0.6724	9.0328	3.3391	0.5397
0.9900	0.5158	0.4866	1.3774	1.5734	0.6424	0.5961	2.5143	1.2058	0.7003	2.8797	1.3374	0.6781	5.9555	2.2095	0.5417
0.9950	0.4195	0.3322	1.1562	1.0456	0.4272	0.5966	1.5463	0.7377	0.6966	1.7227	0.8011	0.6790	3.4909	1.2993	0.5435
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5253	0.0000	0.0000	0.0000	0.0183	-0.0027	-0.2158

Figure 38: AEROEXEC output (vortex calculations: performance summary)

```
LSTDY: PERFORMANCE SUMMARY     AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

*****************************************************************************************************************************
 UCAP  FOR CR-2          INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

*****************************************************************************************************************************
ITERATION NUMBER           1.
 PERFORMANCE WITHOUT VORTEX LIFT
 CP--FORWARD ROTOR      0.9202
 CT--FORWARD ROTOR      0.4716
 PERFORMANCE WITH VORTEX LIFT
 CP--FORWARD ROTOR      1.6138
 CT--FORWARD ROTOR      0.5772
```

Figure 39: AEROEXEC output (Individual rotor performance summary)

```
SUBROUTINE:  INTFRS.  GEOMETRY DATA
                       NUMBER OF RADIAL STATIONS:    22
                       INTEGRATION MESH SIZE DENOMINATOR:   10

INDEX  R/RTIP   CHD/D    ZMC     DCPDZ    DCTDZ        INDEX  R/RTIP   CHD/D    ZMC     DCPDZ    DCTDZ
  1    0.100    0.175   +0.002   +0.044   +0.027    |   +2    +0.300   +0.175   -0.016   +0.098   +0.288
  3    0.400    0.190   -0.039   +0.220   +0.631    |   +4    +0.500   +0.201   -0.035   +0.388   +1.070
  5    0.550    0.203   -0.026   +0.479   +1.417    |   +6    +0.600   +0.201   -0.015   +0.585   +1.697
  7    0.650    0.197   +0.001   +0.692   +2.003    |   +8    +0.700   +0.190   +0.021   +0.801   +2.321
  9    0.750    0.181   +0.044   +0.914   +2.634    |  +10    +0.800   +0.168   +0.068   +1.024   +2.923
 11    0.825    0.160   +0.080   +1.081   +3.066    |  +12    +0.850   +0.152   +0.093   +1.133   +3.187
 13    0.875    0.142   +0.104   +1.180   +3.279    |  +14    +0.900   +0.132   +0.116   +1.217   +3.319
 15    0.925    0.120   +0.127   +1.236   +3.267    |  +16    +0.950   +0.106   +0.138   +2.024   +5.396
 17    0.960    0.100   +0.142   +3.199   +8.638    |  +18    +0.970   +0.092   +0.146   +3.647   +9.873
 19    0.980    0.085   +0.150   +3.339   +9.033    |  +20    +0.990   +0.076   +0.154   +2.209   +5.955
 21    0.995    0.071   +0.156   +1.299   +3.491    |  +22    +1.000   +0.067   +0.158   -0.003   +0.018

          ROTOR:  FWD
          ADVANCE RATIO:    1.460
            MACH NUMBER:    0.265
NUMBER OF OUTPUT RADII:      8 USED OF  10 ALLOWED
NUMBER OF AXIAL POINTS:     10 PER OUTPUT RADIUS.
   INDEX     RADIUS    AXIAL LOCATION      VX-BODY    VX-POT.    VX-2DARY
     1        0.200
                         1         0.373      0.000      0.028      -0.005
                         2         0.406      0.000      0.028      -0.005
                         3         0.438      0.000      0.028      -0.005
                         4         0.471      0.000      0.028      -0.005
                         5         0.504      0.000      0.028      -0.005
                         6         0.537      0.000      0.028      -0.005
                         7         0.569      0.000      0.028      -0.005
                         8         0.602      0.000      0.028      -0.005
                         9         0.635      0.000      0.028      -0.005
                        10         0.668      0.000      0.028      -0.005
     2        0.350
                         1         0.335      0.000      0.050      -0.010
                         2         0.369      0.000      0.050      -0.010
                         3         0.402      0.000      0.050      -0.010
                         4         0.436      0.000      0.050      -0.010
                         5         0.469      0.000      0.050      -0.010
                         6         0.503      0.000      0.050      -0.010
                         7         0.537      0.000      0.050      -0.010
                         8         0.570      0.000      0.050      -0.010
                         9         0.604      0.000      0.050      -0.010
                        10         0.637      0.000      0.050      -0.010
     3        0.450
                         1         0.322      0.000      0.080      -0.012
                         2         0.357      0.000      0.080      -0.012
                         3         0.391      0.000      0.080      -0.012
                         4         0.426      0.000      0.080      -0.012
                         5         0.460      0.000      0.080      -0.012
                         6         0.495      0.000      0.080      -0.012
                         7         0.529      0.000      0.080      -0.012
                         8         0.564      0.000      0.080      -0.012
                         9         0.598      0.000      0.080      -0.012
                        10         0.633      0.000      0.080      -0.012
     4        0.550
                         1         0.334      0.000      0.106      -0.010
                         2         0.368      0.000      0.106      -0.010
```

Figure 40 : AEROEXEC output (steady interference velocity field calculation)

		3	0.403	0.000	0.106	-0.010
		4	0.437	0.000	0.106	-0.010
		5	0.471	0.000	0.106	-0.010
		6	0.505	0.000	0.106	-0.010
		7	0.539	0.000	0.106	-0.010
		8	0.573	0.000	0.106	-0.010
		9	0.607	0.000	0.106	-0.010
		10	0.641	0.000	0.106	-0.010
5	0.650					
		1	0.374	0.000	0.110	-0.010
		2	0.406	0.000	0.110	-0.010
		3	0.437	0.000	0.110	-0.010
		4	0.468	0.000	0.110	-0.010
		5	0.500	0.000	0.110	-0.010
		6	0.531	0.000	0.110	-0.010
		7	0.562	0.000	0.110	-0.010
		8	0.593	0.000	0.110	-0.010
		9	0.625	0.000	0.110	-0.010
		10	0.656	0.000	0.110	-0.010
6	0.750					
		1	0.436	0.000	0.113	-0.008
		2	0.463	0.000	0.113	-0.008
		3	0.490	0.000	0.113	-0.008
		4	0.517	0.000	0.113	-0.008
		5	0.544	0.000	0.113	-0.008
		6	0.571	0.000	0.113	-0.008
		7	0.598	0.000	0.113	-0.008
		8	0.625	0.000	0.113	-0.008
		9	0.652	0.000	0.113	-0.008
		10	0.679	0.000	0.113	-0.008
7	0.850					
		1	0.509	0.000	0.116	-0.006
		2	0.530	0.000	0.116	-0.006
		3	0.552	0.000	0.116	-0.006
		4	0.573	0.000	0.116	-0.006
		5	0.595	0.000	0.116	-0.006
		6	0.617	0.000	0.116	-0.006
		7	0.638	0.000	0.116	-0.006
		8	0.660	0.000	0.116	-0.006
		9	0.681	0.000	0.116	-0.006
		10	0.703	0.000	0.116	-0.006
8	0.950					
		1	0.586	0.000	0.118	-0.005
		2	0.600	0.000	0.118	-0.005
		3	0.615	0.000	0.118	-0.005
		4	0.629	0.000	0.118	-0.005
		5	0.643	0.000	0.118	-0.005
		6	0.658	0.000	0.118	-0.005
		7	0.672	0.000	0.118	-0.005
		8	0.687	0.000	0.118	-0.005
		9	0.701	0.000	0.118	-0.005
		10	0.715	0.000	0.118	-0.005

INDEX	RADIUS	CHORD/D	ZMC	DCTDZ	DCPDZ
1	0.200	0.1747	-0.0073	+0.071	+0.157

MBAR	MU	X/PCA	X/C/2	RX	V/AXIAL	V/SWIRL
1	01	+0.373	+2.369	+1.000	-0.168	+0.366
2	02	+0.406	+2.573	+1.000	-0.154	+0.366
3	03	+0.438	+2.777	+1.000	-0.141	+0.366
4	04	+0.471	+2.981	+1.000	-0.130	+0.366
5	05	+0.504	+3.185	+1.000	-0.120	+0.366
6	06	+0.537	+3.390	+1.000	-0.110	+0.366

Figure 40 : AEROEXEC output (steady interference velocity field calculation, continued)

						7	07	+0.569	+3.594	+1.000	-0.101	+0.366
						8	08	+0.602	+3.798	+1.000	-0.093	+0.366
						9	09	+0.635	+4.002	+1.000	-0.086	+0.366
2	0.350	0.1822	-0.0275	+0.159	+0.459	10	10	+0.668	+4.206	+1.000	-0.078	+0.366
						1	11	+0.335	+2.492	+1.000	-0.105	+0.343
						2	12	+0.369	+2.722	+1.000	-0.094	+0.343
						3	13	+0.402	+2.953	+1.000	-0.083	+0.343
						4	14	+0.436	+3.184	+1.000	-0.074	+0.343
						5	15	+0.469	+3.415	+1.000	-0.065	+0.343
						6	16	+0.503	+3.645	+1.000	-0.056	+0.343
						7	17	+0.537	+3.876	+1.000	-0.049	+0.343
						8	18	+0.570	+4.107	+1.000	-0.041	+0.343
						9	19	+0.604	+4.337	+1.000	-0.034	+0.343
3	0.450	0.1951	-0.0367	+0.304	+0.850	10	20	+0.637	+4.568	+1.000	-0.027	+0.343
						1	21	+0.322	+2.560	+1.000	-0.013	+0.374
						2	22	+0.357	+2.807	+1.000	-0.004	+0.374
						3	23	+0.391	+3.053	+1.000	+0.004	+0.374
						4	24	+0.426	+3.299	+1.000	+0.012	+0.374
						5	25	+0.460	+3.545	+1.000	+0.020	+0.374
						6	26	+0.495	+3.791	+1.000	+0.027	+0.374
						7	27	+0.529	+4.037	+1.000	+0.034	+0.374
						8	28	+0.564	+4.284	+1.000	+0.040	+0.374
						9	29	+0.598	+4.530	+1.000	+0.047	+0.374
4	0.550	0.2026	-0.0265	+0.479	+1.417	10	30	+0.633	+4.776	+1.000	+0.053	+0.374
						1	31	+0.334	+2.760	+1.000	+0.072	+0.406
						2	32	+0.360	+3.020	+1.000	+0.079	+0.406
						3	33	+0.403	+3.281	+1.000	+0.085	+0.406
						4	34	+0.437	+3.541	+1.000	+0.092	+0.406
						5	35	+0.471	+3.801	+1.000	+0.098	+0.406
						6	36	+0.505	+4.062	+1.000	+0.104	+0.406
						7	37	+0.539	+4.322	+1.000	+0.110	+0.406
						8	38	+0.573	+4.583	+1.000	+0.116	+0.406
						9	39	+0.607	+4.843	+1.000	+0.121	+0.406
5	0.650	0.1971	0.0012	+0.692	+2.003	10	40	+0.641	+5.103	+1.000	+0.126	+0.406
						1	41	+0.374	+3.256	+1.000	+0.157	+0.410
						2	42	+0.406	+3.529	+1.000	+0.162	+0.410
						3	43	+0.437	+3.802	+1.000	+0.168	+0.410
						4	44	+0.468	+4.075	+1.000	+0.173	+0.410
						5	45	+0.500	+4.348	+1.000	+0.177	+0.410
						6	46	+0.531	+4.621	+1.000	+0.182	+0.410
						7	47	+0.562	+4.894	+1.000	+0.187	+0.410
						8	48	+0.593	+5.167	+1.000	+0.191	+0.410
						9	49	+0.625	+5.440	+1.000	+0.195	+0.410
6	0.750	0.1805	0.0438	+0.914	+2.634	10	50	+0.656	+5.713	+1.000	+0.199	+0.410
						1	51	+0.436	+4.123	+1.000	+0.230	+0.403
						2	52	+0.463	+4.407	+1.000	+0.234	+0.403
						3	53	+0.490	+4.692	+1.000	+0.238	+0.403
						4	54	+0.517	+4.976	+1.000	+0.241	+0.403
						5	55	+0.544	+5.261	+1.000	+0.245	+0.403
						6	56	+0.571	+5.545	+1.000	+0.248	+0.403
						7	57	+0.598	+5.829	+1.000	+0.252	+0.403
						8	58	+0.625	+6.114	+1.000	+0.255	+0.403
						9	59	+0.652	+6.398	+1.000	+0.258	+0.403
7	0.850	0.1516	0.0925	+1.133	+3.187	10	60	+0.679	+6.683	+1.000	+0.261	+0.403

Figure 40 AEROEXEC output (steady interference velocity field calculation, continued)

						1	61	+0.509	+5.726	+1.000	+0.291	+0.378
						2	62	+0.530	+6.022	+1.000	+0.293	+0.378
						3	63	+0.552	+6.318	+1.000	+0.295	+0.378
						4	64	+0.573	+6.614	+1.000	+0.298	+0.378
						5	65	+0.595	+6.911	+1.000	+0.300	+0.378
						6	66	+0.617	+7.207	+1.000	+0.302	+0.378
						7	67	+0.638	+7.503	+1.000	+0.304	+0.378
						8	68	+0.660	+7.799	+1.000	+0.306	+0.378
						9	69	+0.681	+8.095	+1.000	+0.308	+0.378
						10	70	+0.703	+8.391	+1.000	+0.309	+0.378
8	0.950	0.1061	0.1378	+2.024	+5.396							
						1	71	+0.586	+9.610	+1.000	+0.551	+0.511
						2	72	+0.600	+9.918	+1.000	+0.552	+0.511
						3	73	+0.615	+10.226	+1.000	+0.553	+0.511
						4	74	+0.629	+10.534	+1.000	+0.554	+0.511
						5	75	+0.643	+10.842	+1.000	+0.555	+0.511
						6	76	+0.658	+11.150	+1.000	+0.556	+0.511
						7	77	+0.672	+11.458	+1.000	+0.557	+0.511
						8	78	+0.687	+11.766	+1.000	+0.558	+0.511
						9	79	+0.701	+12.075	+1.000	+0.559	+0.511
						10	80	+0.715	+12.383	+1.000	+0.560	+0.511

Figure 40 : AEROEXEC output (steady interference velocity field calculation, continued)

```
PASS  1 OF 21; TOL:   1.000E-02             AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

****************************************************************************************************
 UCAP  FOR CR-2             INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

****************************************************************************************************

              RATIOS (REAR ROTOR DIVIDED BY FORWARD ROTOR)
               DIAMETER RATIO:         1.0000
               ANGULAR VELOCITY:       1.0054
               TIP SPEED:              1.0054

               ROTOR-ROTOR SPACING:    0.2570 (DIVIDED BY FRONT ROTOR DIAMETER.)
```

COEFFICIENT	FORWARD	AFT	TOTAL
PERFORMANCE SUMMARY WITHOUT VORTEX LOADING.			
ADVANCE RATIO	1.46	1.45	
POWER	0.920	0.877	1.81
THRUST	0.472	0.468	0.945
TORQUE	0.146	0.140	0.288
EFFICIENCY	0.748	0.776	0.762
ROLLING MOMENT			0.540E-02

RATIO	FORWARD/TOTAL	AFT/TOTAL	AFT/FORWARD
TIP SPEED			1.01
DIAMETER			1.00
ANGULAR SPEED			1.01
AREA	0.500	0.500	1.00
POWER	0.508	0.492	0.968
THRUST	0.499	0.501	1.01
TORQUE	0.509	0.491	0.963

Figure 41 : AEROEXEC output (PRTPRF: counter-rotation performance summary)

PERFORMANCE SUMMARY INCLUDING VORTEX LOADING.

ADVANCE RATIO	1.46	1.45	
POWER	1.61	1.46	3.09
THRUST	0.577	0.511	1.09
TORQUE	0.257	0.232	0.491
EFFICIENCY	0.522	0.510	0.516
ROLLING MOMENT			0.226E-01

RATIO	FORWARD/TOTAL	AFT/TOTAL	AFT/FORWARD
TIP SPEED			1.01
DIAMETER			1.00
ANGULAR SPEED			1.01
AREA	0.500	0.500	1.00
POWER	0.522	0.478	0.917
THRUST	0.528	0.472	0.900
TORQUE	0.523	0.477	0.912

Figure 41 : AEROEXEC output (PRTPRF: counter-rotation performance summary, continued)

```
SBR:  ADJUST.   FORWARD ROTOR DATA     AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

****************************************************************************************************************************
 UCAP  FOR CR-2           INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

****************************************************************************************************************************

SUBROUTINE ADJUST

NUMBER OF SPANWISE MODES:    8
NUMBER OF CHORDWISE PANELS 10
 STATION     V-AXIAL
 1   0.200    1.2628
                          M    MU    POTENTIAL 2D-ARY    OTHER ROTOR
                          1    1     0.0284     -0.0055     0.1922
                          2    2     0.0284     -0.0055     0.2007
                          3    3     0.0284     -0.0055     0.2098
                          4    4     0.0284     -0.0055     0.2196
                          5    5     0.0284     -0.0055     0.2301
                          6    6     0.0284     -0.0055     0.2415
                          7    7     0.0284     -0.0055     0.2540
                          8    8     0.0284     -0.0055     0.2677
                          9    9     0.0284     -0.0055     0.2829
                         10   10     0.0284     -0.0055     0.2999
 2   0.350    1.2354
                          M    MU    POTENTIAL 2D-ARY    OTHER ROTOR
                          1   11     0.0498     -0.0095     0.1559
                          2   12     0.0498     -0.0095     0.1630
                          3   13     0.0498     -0.0095     0.1705
                          4   14     0.0498     -0.0095     0.1786
                          5   15     0.0498     -0.0095     0.1873
                          6   16     0.0498     -0.0095     0.1968
                          7   17     0.0498     -0.0095     0.2070
                          8   18     0.0498     -0.0095     0.2183
                          9   19     0.0498     -0.0095     0.2306
                         10   20     0.0498     -0.0095     0.2442
 3   0.450    1.2406
                          M    MU    POTENTIAL 2D-ARY    OTHER ROTOR
                          1   21     0.0803     -0.0118     0.1380
                          2   22     0.0803     -0.0118     0.1442
                          3   23     0.0803     -0.0118     0.1509
                          4   24     0.0803     -0.0118     0.1580
                          5   25     0.0803     -0.0118     0.1656
                          6   26     0.0803     -0.0118     0.1738
                          7   27     0.0803     -0.0118     0.1826
                          8   28     0.0803     -0.0118     0.1922
                          9   29     0.0803     -0.0118     0.2027
                         10   30     0.0803     -0.0118     0.2141
 4   0.550    1.2493
                          M    MU    POTENTIAL 2D-ARY    OTHER ROTOR
                          1   31     0.1062     -0.0101     0.1251
                          2   32     0.1062     -0.0101     0.1304
```

Figure 42 : AEROEXEC output (ADJUST)

```
                         3   33   0.1062     -0.0101      0.1359
                         4   34   0.1062     -0.0101      0.1419
                         5   35   0.1062     -0.0101      0.1482
                         6   36   0.1062     -0.0101      0.1549
                         7   37   0.1062     -0.0101      0.1620
                         8   38   0.1062     -0.0101      0.1696
                         9   39   0.1062     -0.0101      0.1778
                        10   40   0.1062     -0.0101      0.1866
 5   0.650    1.2361
                         M   MU   POTENTIAL  2D-ARY     OTHER ROTOR
                         1   41   0.1096     -0.0096      0.1154
                         2   42   0.1096     -0.0096      0.1195
                         3   43   0.1096     -0.0096      0.1238
                         4   44   0.1096     -0.0096      0.1283
                         5   45   0.1096     -0.0096      0.1329
                         6   46   0.1096     -0.0096      0.1378
                         7   47   0.1096     -0.0096      0.1429
                         8   48   0.1096     -0.0096      0.1482
                         9   49   0.1096     -0.0096      0.1537
                        10   50   0.1096     -0.0096      0.1594
 6   0.750    1.2250
                         M   MU   POTENTIAL  2D-ARY     OTHER ROTOR
                         1   51   0.1130     -0.0075      0.1064
                         2   52   0.1130     -0.0075      0.1092
                         3   53   0.1130     -0.0075      0.1121
                         4   54   0.1130     -0.0075      0.1150
                         5   55   0.1130     -0.0075      0.1180
                         6   56   0.1130     -0.0075      0.1210
                         7   57   0.1130     -0.0075      0.1240
                         8   58   0.1130     -0.0075      0.1271
                         9   59   0.1130     -0.0075      0.1301
                        10   60   0.1130     -0.0075      0.1332
 7   0.850    1.2116
                         M   MU   POTENTIAL  2D-ARY     OTHER ROTOR
                         1   61   0.1159     -0.0063      0.0956
                         2   62   0.1159     -0.0063      0.0971
                         3   63   0.1159     -0.0063      0.0986
                         4   64   0.1159     -0.0063      0.1001
                         5   65   0.1159     -0.0063      0.1015
                         6   66   0.1159     -0.0063      0.1029
                         7   67   0.1159     -0.0063      0.1042
                         8   68   0.1159     -0.0063      0.1055
                         9   69   0.1159     -0.0063      0.1067
                        10   70   0.1159     -0.0063      0.1078
 8   0.950    1.1966
                         M   MU   POTENTIAL  2D-ARY     OTHER ROTOR
                         1   71   0.1179     -0.0048      0.0820
                         2   72   0.1179     -0.0048      0.0825
                         3   73   0.1179     -0.0048      0.0829
                         4   74   0.1179     -0.0048      0.0832
                         5   75   0.1179     -0.0048      0.0836
                         6   76   0.1179     -0.0048      0.0838
                         7   77   0.1179     -0.0048      0.0841
                         8   78   0.1179     -0.0048      0.0843
                         9   79   0.1179     -0.0048      0.0844
                        10   80   0.1179     -0.0048      0.0845

NUMBER OF GEOMETRY STATIONS:   22
      NUMBER OF STREAMLINES:    5
```

Figure 42 : AEROEXEC output (ADJUST, continued)

	RADIUS	S.L. ANGLE
1	0.100	0.000
2	0.300	4.163
3	0.400	3.124
4	0.500	2.486
5	0.550	2.084
6	0.600	1.782
7	0.650	1.503
8	0.700	1.246
9	0.750	1.012
10	0.800	0.792
11	0.825	0.687
12	0.850	0.584
13	0.875	0.485
14	0.900	0.391
15	0.925	0.300
16	0.950	0.208
17	0.960	0.169
18	0.970	0.127
19	0.980	0.087
20	0.990	0.050
21	0.995	0.034
22	1.000	0.020

NUMBER OF STREAMLINES:

1	0.245	0.371	0.3143	0.242	4.015	1.2420	0.0000	0.3009
2	0.371	0.497	0.4383	0.342	2.849	1.2400	0.0000	0.4242
3	0.497	0.623	0.5631	0.442	2.005	1.2476	0.0000	0.5513
4	0.623	1.000	0.8329	1.924	0.654	1.2139	0.0000	2.3354

Figure 42 : AEROEXEC output (ADJUST, continued)

```
AFT ROTOR DATA     AEROEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4

**********************************************************************************************************
 UCAP  FOR CR-2            INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

**********************************************************************************************************

SUBROUTINE ADJUST

NUMBER OF SPANWISE MODES:    8
NUMBER OF CHORDWISE PANELS 10
 STATION     V-AXIAL
 1   0.200    0.9978
                        M    MU   POTENTIAL  2D-ARY    OTHER ROTOR
                        1    1    0.0563     0.0000    -0.1676
                        2    2    0.0563     0.0000    -0.1536
                        3    3    0.0563     0.0000    -0.1411
                        4    4    0.0563     0.0000    -0.1299
                        5    5    0.0563     0.0000    -0.1196
                        6    6    0.0563     0.0000    -0.1102
                        7    7    0.0563     0.0000    -0.1015
                        8    8    0.0563     0.0000    -0.0933
                        9    9    0.0563     0.0000    -0.0856
                       10   10    0.0563     0.0000    -0.0784
 2   0.350    1.0071
                        M    MU   POTENTIAL  2D-ARY    OTHER ROTOR
                        1   11    0.0986     0.0000    -0.1051
                        2   12    0.0986     0.0000    -0.0939
                        3   13    0.0986     0.0000    -0.0834
                        4   14    0.0986     0.0000    -0.0738
                        5   15    0.0986     0.0000    -0.0648
                        6   16    0.0986     0.0000    -0.0564
                        7   17    0.0986     0.0000    -0.0485
                        8   18    0.0986     0.0000    -0.0411
                        9   19    0.0986     0.0000    -0.0341
                       10   20    0.0986     0.0000    -0.0274
 3   0.450    1.0129
                        M    MU   POTENTIAL  2D-ARY    OTHER ROTOR
                        1   21    0.1258    -0.0495    -0.0129
                        2   22    0.1258    -0.0495    -0.0044
                        3   23    0.1258    -0.0495     0.0039
                        4   24    0.1258    -0.0495     0.0119
                        5   25    0.1258    -0.0495     0.0195
                        6   26    0.1258    -0.0495     0.0268
                        7   27    0.1258    -0.0495     0.0338
                        8   28    0.1258    -0.0495     0.0404
                        9   29    0.1258    -0.0495     0.0468
                       10   30    0.1258    -0.0495     0.0529
 4   0.550    1.0241
                        M    MU   POTENTIAL  2D-ARY    OTHER ROTOR
                        1   31    0.1394    -0.0247     0.0724
                        2   32    0.1394    -0.0247     0.0789
```

Figure 42 : AEROEXEC output (ADJUST, continued)

```
                         3   33   0.1394    -0.0247     0.0855
                         4   34   0.1394    -0.0247     0.0918
                         5   35   0.1394    -0.0247     0.0981
                         6   36   0.1394    -0.0247     0.1041
                         7   37   0.1394    -0.0247     0.1099
                         8   38   0.1394    -0.0247     0.1155
                         9   39   0.1394    -0.0247     0.1209
                        10   40   0.1394    -0.0247     0.1261
  5   0.650    1.0314
                         M   MU   POTENTIAL 2D-ARY    OTHER ROTOR
                         1   41   0.1337    -0.0195     0.1570
                         2   42   0.1337    -0.0195     0.1624
                         3   43   0.1337    -0.0195     0.1676
                         4   44   0.1337    -0.0195     0.1726
                         5   45   0.1337    -0.0195     0.1775
                         6   46   0.1337    -0.0195     0.1822
                         7   47   0.1337    -0.0195     0.1867
                         8   48   0.1337    -0.0195     0.1911
                         9   49   0.1337    -0.0195     0.1954
                        10   50   0.1337    -0.0195     0.1995
  6   0.750    1.0375
                         M   MU   POTENTIAL 2D-ARY    OTHER ROTOR
                         1   51   0.1289    -0.0141     0.2300
                         2   52   0.1289    -0.0141     0.2340
                         3   53   0.1289    -0.0141     0.2378
                         4   54   0.1289    -0.0141     0.2415
                         5   55   0.1289    -0.0141     0.2450
                         6   56   0.1289    -0.0141     0.2484
                         7   57   0.1289    -0.0141     0.2516
                         8   58   0.1289    -0.0141     0.2548
                         9   59   0.1289    -0.0141     0.2578
                        10   60   0.1289    -0.0141     0.2607
  7   0.850    1.0424
                         M   MU   POTENTIAL 2D-ARY    OTHER ROTOR
                         1   61   0.1241    -0.0097     0.2908
                         2   62   0.1241    -0.0097     0.2931
                         3   63   0.1241    -0.0097     0.2954
                         4   64   0.1241    -0.0097     0.2976
                         5   65   0.1241    -0.0097     0.2997
                         6   66   0.1241    -0.0097     0.3018
                         7   67   0.1241    -0.0097     0.3038
                         8   68   0.1241    -0.0097     0.3057
                         9   69   0.1241    -0.0097     0.3076
                        10   70   0.1241    -0.0097     0.3095
  8   0.950    1.0673
                         M   MU   POTENTIAL 2D-ARY    OTHER ROTOR
                         1   71   0.1189    -0.0058     0.5514
                         2   72   0.1189    -0.0058     0.5524
                         3   73   0.1189    -0.0058     0.5534
                         4   74   0.1189    -0.0058     0.5544
                         5   75   0.1189    -0.0058     0.5554
                         6   76   0.1189    -0.0058     0.5563
                         7   77   0.1189    -0.0058     0.5573
                         8   78   0.1189    -0.0058     0.5582
                         9   79   0.1189    -0.0058     0.5592
                        10   80   0.1189    -0.0058     0.5601

NUMBER OF GEOMETRY STATIONS:   22
       NUMBER OF STREAMLINES:    5
```

Figure 42 : AEROEXEC output (ADJUST, continued)

	RADIUS	S.L. ANGLE
1	0.100	0.000
2	0.300	4.163
3	0.400	3.124
4	0.500	2.406
5	0.550	2.084
6	0.600	1.782
7	0.650	1.503
8	0.700	1.246
9	0.750	1.012
10	0.800	0.792
11	0.825	0.687
12	0.850	0.584
13	0.875	0.485
14	0.900	0.391
15	0.925	0.300
16	0.950	0.208
17	0.960	0.169
18	0.970	0.127
19	0.980	0.087
20	0.990	0.050
21	0.995	0.034
22	1.000	0.020

NUMBER OF STREAMLINES:

1	0.245	0.371	0.3143	0.242	4.015	1.0049	0.0000	0.2434
2	0.371	0.497	0.4383	0.342	2.849	1.0122	0.0000	0.3463
3	0.497	0.623	0.5631	0.442	2.005	1.0250	0.0000	0.4529
4	0.623	1.000	0.8329	1.924	0.654	1.0416	0.0000	2.0039

STREAMLINES BEFORE AND AFTER ADJUSTMENT

	FORWARD ROTOR		AFT ROTOR	
N	OLD	NEW	OLD	NEW
1	0.2450	0.2450	0.2450	0.2450
2	0.3708	0.3499	0.3708	0.3947
3	0.4967	0.4597	0.4967	0.5381
4	0.6225	0.5717	0.6225	0.6789
5	1.0000	0.9232	1.0000	1.0839

Figure 42 : AEROEXEC output (ADJUST, continued)

SUBROUTINE: CPMAP.

INDUCTION CALCULATION POINTS--REAR ROTOR ONTO FWD ROTOR

N	RADIUS	STREAMTUBE NO.	FLD CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3949
3	0.4500	2	0.5254
4	0.5500	3	0.6516
5	0.6500	3	0.7773
6	0.7500	4	0.8843
7	0.8500	4	0.9995
8	0.9500	4	1.1147

Figure 43: AEROEXEC output (CPMAP, rear rotor onto front rotor)

SUBROUTINE: CPMAP. DIAMETER RATIO: 1.0000

WAKE CALCULATION POINTS--FRONT ROTOR ONTO REAR ROTOR

N	RADIUS	STREAMTUBE NO.	WAKE CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3186
3	0.4500	2	0.3922
4	0.5500	3	0.4692
5	0.6500	3	0.5487
6	0.7500	4	0.6334
7	0.8500	4	0.7202
8	0.9500	4	0.8070

Figure 44: AEROEXEC output (CPMAP, front rotor onto rear rotor)

```
PROPELLER EFFICIENCY PROGRAM     :INTFR2     AEROEXEC  EXECCASE     TIME:  17:J0:20 DATE:   1/15/92 UCAP --- NASA    4

****************************************************************************************************
 UCAP  FOR CR-2              INPUT -- R252INPT.DATA
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

****************************************************************************************************
WMU VECTOR:  FRONT ROTOR ONTO REAR
                        STEADY TERM.
   STATION               PHI       SIGMA1    SIGMA2    SIGMA1/SIGMA2    TWIST
    1    0.2000        66.7165   1.088659  1.089587     0.999148       69 6773

MBAR  XMBAR    MU   WMU(STEADY)    DOWNWASH       CHORDWISE       VISCOUS WAKE   AXIAL    SWIRL
 01   +0.373   01     4.68365     -0.509608       0.430217        0.178157E-01  +1.5839  +0.6327
 02   +0.406   02     6.91450     -0.464361       0.325639        0.132434E-01  +1.4705  +0.5500
 03   +0.438   03     8.89787     -0.424132       0.232661        0.127336E-01  +1.3697  +0.4765
 04   +0.471   04    10.6347      -0.388096       0.151222        0.122764E-01  +1.2814  +0.4121
 05   +0.504   05    12.1674      -0.357793       0.793344E-01    0.118638E-01  +1.2034  +0.3553
 06   +0.537   06    13.4858      -0.331025       0.174664E-01    0.114891E-01  +1.1363  +0.3064
 07   +0.569   07    14.5530      -0.309323      -0.326903E-01    0.111472E-01  +1.0820  +0.2668
 08   +0.602   08    15.4246      -0.291574      -0.737140E-01    0.108336E-01  +1.0376  +0.2344
 09   +0.635   09    16.1469      -0.276843      -0.107760        0.105447E-01  +1.0008  +0.2075
 10   +0.668   10    16.7492      -0.264537      -0.136202        0.102774E-01  +0.9700  +0.1851
WMU VECTOR:  FRONT ROTOR ONTO REAR
                        STEADY TERM.
   STATION               PHI       SIGMA1    SIGMA2    SIGMA1/SIGMA2    TWIST
    2    0.3500        55.8089   1.208944  1.254313     0.963830       67.1792

MBAR  XMBAR    MU   WMU(STEADY)    DOWNWASH       CHORDWISE       VISCOUS WAKE   AXIAL    SWIRL
 01   +0.335   11    10.7102      -0.728094       0.297911        0.565164E-01  +1.6088  +0.7576
 02   +0.369   12    12.9875      -0.664718       0.205130        0.540376E-01  +1.4985  +0.6471
 03   +0.402   13    14.9010      -0.611337       0.126981        0.518471E-01  +1.4057  +0.5540
 04   +0.436   14    16.5417      -0.565472       0.598353E-01    0.498956E-01  +1.3260  +0.4741
 05   +0.469   15    17.9321      -0.526487       0.276171E-02    0.481441E-01  +1.2583  +0.4063
 06   +0.503   16    19.0453      -0.495052      -0.432588E-01    0.465615E-01  +1.2039  +0.3517
 07   +0.537   17    19.9466      -0.469409      -0.807994E-01    0.451231E-01  +1.1596  +0.3072
 08   +0.570   18    20.6579      -0.448951      -0.110749        0.438084E-01  +1.1244  +0.2719
 09   +0.604   19    21.1988      -0.433138      -0.133899        0.426010E-01  +1.0974  +0.2447
 10   +0.637   20    21.6091      -0.420902      -0.151812        0.414873E-01  +1.0766  +0.2238
WMU VECTOR:  FRONT ROTOR ONTO REAR
                        STEADY TERM.
   STATION               PHI       SIGMA1    SIGMA2    SIGMA1/SIGMA2    TWIST
    3    0.4500        49.8363   1.308548  1.395600     0.937624       62.1696

MBAR  XMBAR    MU   WMU(STEADY)    DOWNWASH       CHORDWISE       VISCOUS WAKE   AXIAL    SWIRL
 01   +0.322   21    19.9842      -0.688377       0.147074        0.270095      +1.3500  +0.4347
 02   +0.357   22    21.8562      -0.624173       0.714124E-01    0.257965      +1.2600  +0.3385
 03   +0.391   23    23.3066      -0.572768       0.108345E-01    0.247281      +1.1887  +0.2621
 04   +0.426   24    24.4400      -0.531121      -0.382446E-01    0.237789      +1.1316  +0.2009
 05   +0.460   25    25.3158      -0.497435      -0.779424E-01    0.229290      +1.0860  +0.1520
 06   +0.495   26    25.9715      -0.470535      -0.109642        0.221626      +1.0503  +0.1136
 07   +0.529   27    26.4467      -0.449232      -0.134747        0.214671      +1.0227  +0.0838
 08   +0.564   28    26.7681      -0.432701      -0.154228        0.208324      +1.0020  +0.0614
 09   +0.598   29    26.9098      -0.421510      -0.167416        0.202504      +0.9892  +0.0474
 10   +0.633   30    26.9317      -0.414016      -0.176247        0.197140      +0.9817  +0.0391
```

Figure 45 : AEROEXEC output (steady WMU vector calculation)

WMU VECTOR: FRONT ROTOR ONTO REAR
STEADY TERM.

STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST
4	0.5500	44.2483	1.433139	1.554253	0.922076	57.1517

MBAR	XMBAR	MU	WMU(STEADY)	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.334	31	20.4785	-0.502200	-0.674949E-01	0.226663	+1.1545	+0.1070
02	+0.368	32	21.6051	-0.461004	-0.107407	0.216815	+1.1040	+0.0534
03	+0.403	33	22.2582	-0.433219	-0.134326	0.208109	+1.0714	+0.0189
04	+0.437	34	22.7200	-0.411483	-0.155384	0.200352	+1.0465	-0.0073
05	+0.471	35	23.0747	-0.393477	-0.172829	0.193387	+1.0263	-0.0285
06	+0.505	36	23.1896	-0.382378	-0.183582	0.187090	+1.0153	-0.0399
07	+0.539	37	23.1928	-0.374835	-0.190890	0.181364	+1.0088	-0.0465
08	+0.573	38	23.1142	-0.369986	-0.195587	0.176127	+1.0057	-0.0495
09	+0.607	39	22.8652	-0.369981	-0.195592	0.171315	+1.0090	-0.0455
10	+0.641	40	22.5437	-0.372284	-0.193362	0.166874	+1.0153	-0.0384

WMU VECTOR: FRONT ROTOR ONTO REAR
STEADY TERM.

STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST
5	0.6500	39.5681	1.569870	1.725487	0.909813	52.5466

MBAR	XMBAR	MU	WMU(STEADY)	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.374	41	19.9334	-0.255360	-0.237413	0.135008	+0.9591	-0.1705
02	+0.406	42	19.6339	-0.256166	-0.236751	0.130692	+0.9634	-0.1648
03	+0.437	43	19.4208	-0.255531	-0.237272	0.126103	+0.9655	-0.1616
04	+0.468	44	19.0392	-0.259583	-0.233942	0.121958	+0.9734	-0.1523
05	+0.500	45	18.6713	-0.263781	-0.230493	0.118191	+0.9812	-0.1432
06	+0.531	46	18.3813	-0.266489	-0.228267	0.114749	+0.9869	-0.1364
07	+0.562	47	17.9382	-0.273299	-0.222670	0.111586	+0.9978	-0.1243
08	+0.593	48	17.2960	-0.285291	-0.212814	0.108673	+1.0151	-0.1052
09	+0.625	49	16.6315	-0.298102	-0.202285	0.105973	+1.0334	-0.0853
10	+0.656	50	16.0688	-0.308666	-0.193603	0.103464	+1.0487	-0.0685

WMU VECTOR: FRONT ROTOR ONTO REAR
STEADY TERM.

STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST
6	0.7500	35.5371	1.720490	1.905913	0.902712	48.5225

MBAR	XMBAR	MU	WMU(STEADY)	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.436	51	15.0272	-0.818745E-01	-0.291221	0.940696E-02	+0.8919	-0.2335
02	+0.463	52	14.2691	-0.996201E-01	-0.278615	0.912445E-02	+0.9138	-0.2111
03	+0.490	53	13.5146	-0.117311	-0.266047	0.886[illegible]6E-02	+0.9357	-0.1888
04	+0.517	54	12.7419	-0.135461	-0.253153	0.862750E-02	+0.9581	-0.1660
05	+0.544	55	11.7914	-0.157876	-0.237229	0.844739E-02	+0.9857	-0.1379
06	+0.571	56	10.8810	-0.179353	-0.221972	0.820318E-02	+1.0122	-0.1109
07	+0.598	57	10.1254	-0.197155	-0.209325	0.801307E-02	+1.0341	-0.0886
08	+0.625	58	9.35935	-0.215220	-0.196492	0.783551E-02	+1.0564	-0.0659
09	+0.652	59	8.68820	-0.231034	-0.185258	0.766919E-02	+1.0759	-0.0461
10	+0.679	60	8.10004	-0.244880	-0.175422	0.751298E-02	+1.0929	-0.0287

WMU VECTOR: FRONT ROTOR ONTO REAR
STEADY TERM.

STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST
7	0.8500	32.1434	1.879557	2.093157	0.897953	45.2894

MBAR	XMBAR	MU	WMU(STEADY)	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.509	61	12.9006	-0.251277E-01	-0.252679	0.982295E-02	+0.8816	-0.2413
02	+0.530	62	11.6296	-0.547228E-01	-0.234183	0.960674E-02	+0.9166	-0.2074
03	+0.552	63	10.5897	-0.789094E-01	-0.219068	0.940413E-02	+0.9453	-0.1797
04	+0.573	64	9.65131	-0.100723	-0.205435	0.921374E-02	+0.9711	-0.1547
05	+0.595	65	8.75049	-0.121669	-0.192345	0.903441E-02	+0.9959	-0.1307
06	+0.617	66	8.05849	-0.137722	-0.182312	0.886510E-02	+1.0149	-0.1122

Figure 45 : AEROEXEC output (steady WMU vector calculation, continued)

07	+0.638	67	7.43804	-0.152106	-0.173323	0.870494E-02	+1.0319	-0.0957
08	+0.660	68	6.72663	-0.160635	-0.162993	0.855311E-02	+1.0515	-0.0767
09	+0.681	69	6.04487	-0.184478	-0.153092	0.849694E-02	+1.0703	-0.0586
10	+0.703	70	5.55129	-0.195908	-0.145949	0.827179E-02	+1.0838	-0.0454

WMU VECTOR: FRONT ROTOR ONTO REAR
STEADY TERM.

STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST
8	0.9500	29.2876	2.044179	2.285543	0.894395	42.5927

MBAR	XMBAR	MU	WMU(STEADY)	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.586	71	7.76135	-0.573701E-01	-0.168252	0.987998E-02	+0.9629	-0.1496
02	+0.600	72	7.21802	-0.698231E-01	-0.161305	0.974601E-02	+0.9772	-0.1365
03	+0.615	73	6.64858	-0.828877E-01	-0.154017	0.961734E-02	+0.9922	-0.1227
04	+0.629	74	6.00784	-0.976118E-01	-0.145803	0.949361E-02	+1.0092	-0.1071
05	+0.643	75	5.43048	-0.110871	-0.138406	0.937453E-02	+1.0244	-0.0932
06	+0.658	76	5.04148	-0.119765	-0.133444	0.925981E-02	+1.0346	-0.0837
07	+0.672	77	4.74665	-0.126480	-0.129699	0.914919E-02	+1.0424	-0.0766
08	+0.687	78	4.40312	-0.134328	-0.125320	0.904243E-02	+1.0514	-0.0683
09	+0.701	79	4.02114	-0.143073	-0.120442	0.893932E-02	+1.0615	-0.0591
10	+0.715	80	3.67044	-0.151096	-0.115966	0.883964E-02	+1.0707	-0.0506

Figure 45 : AEROEXEC output (steady WMU vector calculation, continued)

```
UNSTEADY:  FRONT ROTOR ON REAR ROTOR
         HARMONIC OF BLADE PASS FREQUENCY:    1
                        NUMBER OF BLADES:    6
             HARMONIC OF SHAFT FREQUENCY:    6
                                Q-ORDER:  12.0326385

WMU VECTOR:
 STATION  WAKE PNT     PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
1    0.200    0.200    +66.717  +1.0887  +1.0896     +0.9991     +69.677
                            MBAR  MU   XMBAR     DPHI            WMU                 DOWNWASH             CHORDWISE        VISCOUS WAKE
                               1  01    0.373     0.549  (  0.496,  -0.933)  ( -0.011,   0.006)  (  0.034,  -0.032)   0.013
                               2  02    0.406     0.681  (  0.019,  -0.799)  ( -0.010,   0.012)  (  0.007,  -0.025)   0.013
                               3  03    0.438     0.812  ( -0.063,  -0.873)  ( -0.005,   0.019)  ( -0.004,  -0.015)   0.012
                               4  04    0.471     0.943  ( -0.059,  -0.959)  (  0.006,   0.024)  ( -0.008,  -0.005)   0.012
                               5  05    0.504     1.074  (  0.235,  -1.153)  (  0.018,   0.024)  ( -0.009,   0.005)   0.011
                               6  06    0.537     1.205  (  0.549,  -0.962)  (  0.029,   0.019)  ( -0.008,   0.005)   0.011
                               7  07    0.569     1.336  (  0.639,  -0.820)  (  0.037,   0.011)  ( -0.005,   0.001)   0.011
                               8  08    0.602     1.467  (  0.927,  -0.849)  (  0.043,  -0.002)  ( -0.003,  -0.002)   0.010
                               9  09    0.635     1.599  (  1.064,  -0.291)  (  0.035,  -0.008)  ( -0.001,  -0.004)   0.010
                              10  10    0.668     1.730  ( -0.250,   0.652)  (  0.019,   0.018)  ( -0.001,  -0.004)   0.010
WMU VECTOR:
 STATION  WAKE PNT     PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
2    0.350    0.316    +55.809  +1.2089  +1.2543     +0.9638     +67.179
                            MBAR  MU   XMBAR     DPHI            WMU                 DOWNWASH             CHORDWISE        VISCOUS WAKE
                               1  11    0.335     0.484  (  1.996,  -7.026)  ( -0.062,   0.021)  (  0.170,  -0.151)   0.052
                               2  12    0.369     0.597  (  1.311,  -5.418)  ( -0.061,   0.058)  (  0.065,  -0.156)   0.049
                               3  13    0.402     0.710  (  0.977,  -4.365)  ( -0.041,   0.104)  ( -0.002,  -0.128)   0.047
                               4  14    0.436     0.822  (  0.504,  -3.666)  (  0.008,   0.149)  ( -0.040,  -0.090)   0.044
                               5  15    0.469     0.935  ( -0.269,  -3.327)  (  0.091,   0.177)  ( -0.057,  -0.055)   0.042
                               6  16    0.503     1.047  ( -1.682,  -3.710)  (  0.207,   0.165)  ( -0.058,  -0.027)   0.040
                               7  17    0.537     1.160  ( -3.425,  -5.683)  (  0.344,   0.085)  ( -0.050,  -0.006)   0.039
                               8  18    0.570     1.273  ( -4.547,  -9.844)  (  0.470,  -0.089)  ( -0.039,   0.008)   0.037
                               9  19    0.604     1.385  ( -3.638, -16.303)  (  0.530,  -0.372)  ( -0.027,   0.016)   0.036
                              10  20    0.637     1.498  (  0.881, -24.457)  (  0.447,  -0.754)  ( -0.015,   0.019)   0.034
WMU VECTOR:
 STATION  WAKE PNT     PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
3    0.450    0.392    +49.836  +1.3085  +1.3956     +0.9376     +62.170
                            MBAR  MU   XMBAR     DPHI            WMU                 DOWNWASH             CHORDWISE        VISCOUS WAKE
                               1  21    0.322     0.447  ( -7.997, -16.333)  ( -0.100,   0.040)  (  0.222,  -0.381)   0.181
                               2  22    0.357     0.562  ( -2.709, -16.113)  ( -0.099,   0.103)  (  0.076,  -0.344)   0.163
                               3  23    0.391     0.677  (  2.354, -14.238)  ( -0.060,   0.172)  ( -0.027,  -0.281)   0.147
                               4  24    0.426     0.792  (  5.930, -10.399)  (  0.028,   0.237)  ( -0.091,  -0.207)   0.134
                               5  25    0.460     0.906  (  6.739,  -5.688)  (  0.169,   0.268)  ( -0.122,  -0.134)   0.122
                               6  26    0.495     1.021  (  4.448,  -1.864)  (  0.358,   0.229)  ( -0.128,  -0.069)   0.111
                               7  27    0.529     1.136  ( -0.239,  -0.826)  (  0.568,   0.074)  ( -0.116,  -0.018)   0.101
                               8  28    0.564     1.251  ( -5.547,  -3.929)  (  0.737,  -0.236)  ( -0.093,   0.018)   0.092
                               9  29    0.598     1.365  ( -9.257, -11.629)  (  0.764,  -0.723)  ( -0.066,   0.039)   0.084
                              10  30    0.633     1.480  ( -8.865, -23.534)  (  0.514,  -1.347)  ( -0.039,   0.048)   0.077
WMU VECTOR:
 STATION  WAKE PNT     PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
```

Figure 46 : AEROEXEC output (unsteady WMU vector calculation)

```
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
4   0.550   0.477   +44.240  +1.4331  +1.5543     +0.9221      +57.152
                              MBAR  MU   XMBAR    DPHI              WMU                   DOWNWASH                  CHORDWISE         VISCOUS WAKE
                                1   31   0.334    0.496   (   5.510, -35.425)  (  -0.135,    0.096)  (   0.401,  -0.677)   0.150
                                2   32   0.368    0.610   (  13.698, -26.713)  (  -0.106,    0.105)  (   0.141,  -0.616)   0.144
                                3   33   0.403    0.723   (  18.348, -17.153)  (  -0.024,    0.275)  (  -0.042,  -0.507)   0.132
                                4   34   0.437    0.836   (  19.091,  -7.913)  (   0.122,    0.341)  (  -0.160,  -0.375)   0.121
                                5   35   0.471    0.949   (  16.523,  -5.214)  (   0.320,    0.339)  (  -0.221,  -0.242)   0.111
                                6   36   0.505    1.063   (  11.126,   5.117)  (   0.563,    0.221)  (  -0.234,  -0.123)   0.102
                                7   37   0.539    1.176   (   3.984,   6.732)  (   0.799,   -0.051)  (  -0.213,  -0.029)   0.094
                                8   38   0.573    1.289   (  -2.941,   3.968)  (   0.938,   -0.504)  (  -0.171,   0.036)   0.087
                                9   39   0.607    1.402   (  -7.506,  -3.041)  (   0.862,   -1.131)  (  -0.121,   0.074)   0.080
                               10   40   0.641    1.516   (  -7.666, -12.977)  (   0.422,   -1.854)  (  -0.069,   0.089)   0.074
WMU VECTOR:
 STATION  WAKE PNT    PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
5   0.650   0.562   +39.568  +1.5699  +1.7255     +0.9098      +52.547
                              MBAR  MU   XMBAR    DPHI              WMU                   DOWNWASH                  CHORDWISE         VISCOUS WAKE
                                1   41   0.374    0.642   (  39.297, -29.592)  (  -0.101,    0.226)  (   0.309,  -0.931)   0.104
                                2   42   0.406    0.746   (  39.099, -13.462)  (  -0.011,    0.308)  (   0.021,  -0.801)   0.098
                                3   43   0.437    0.851   (  34.925,  -0.857)  (   0.132,    0.362)  (  -0.184,  -0.627)   0.091
                                4   44   0.468    0.955   (  28.430,   8.445)  (   0.322,    0.358)  (  -0.305,  -0.438)   0.086
                                5   45   0.500    1.059   (  20.496,  14.556)  (   0.543,    0.267)  (  -0.351,  -0.261)   0.081
                                6   46   0.531    1.163   (  12.063,  17.442)  (   0.760,    0.058)  (  -0.344,  -0.111)   0.076
                                7   47   0.562    1.267   (   3.994,  17.165)  (   0.917,   -0.286)  (  -0.300,   0.004)   0.072
                                8   48   0.593    1.372   (  -2.515,  13.733)  (   0.945,   -0.763)  (  -0.230,   0.080)   0.068
                                9   49   0.625    1.476   (  -6.327,   8.550)  (   0.745,   -1.339)  (  -0.154,   0.122)   0.065
                               10   50   0.656    1.580   (  -7.399,   2.945)  (   0.255,   -1.941)  (  -0.087,   0.136)   0.061
WMU VECTOR:
 STATION  WAKE PNT    PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
6   0.750   0.651   +35.537  +1.7205  +1.9059     +0.9027      +48.523
                              MBAR  MU   XMBAR    DPHI              WMU                   DOWNWASH                  CHORDWISE         VISCOUS WAKE
                                1   51   0.436    0.859   (  47.211,  14.079)  (   0.103,    0.336)  (  -0.127,  -0.911)   0.009
                                2   52   0.463    0.949   (  36.036,  21.543)  (   0.243,    0.340)  (  -0.318,  -0.701)   0.009
                                3   53   0.490    1.040   (  25.661,  25.512)  (   0.402,    0.293)  (  -0.425,  -0.488)   0.009
                                4   54   0.517    1.130   (  16.437,  27.018)  (   0.562,    0.181)  (  -0.464,  -0.292)   0.008
                                5   55   0.544    1.220   (   8.162,  26.409)  (   0.702,   -0.006)  (  -0.441,  -0.126)   0.008
                                6   56   0.571    1.310   (   1.447,  24.290)  (   0.794,   -0.267)  (  -0.381,   0.002)   0.008
                                7   57   0.598    1.400   (  -3.764,  21.661)  (   0.804,   -0.596)  (  -0.307,   0.094)   0.008
                                8   58   0.625    1.490   (  -7.851,  18.729)  (   0.697,   -0.969)  (  -0.225,   0.150)   0.008
                                9   59   0.652    1.580   ( -11.031,  15.712)  (   0.442,   -1.353)  (  -0.145,   0.176)   0.007
                               10   60   0.679    1.670   ( -13.796,  12.692)  (   0.020,   -1.699)  (  -0.075,   0.178)   0.007
WMU VECTOR:
 STATION  WAKE PNT    PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
7   0.850   0.740   +32.143  +1.8796  +2.0932     +0.8980      +45.289
                              MBAR  MU   XMBAR    DPHI              WMU                   DOWNWASH                  CHORDWISE         VISCOUS WAKE
                                1   61   0.509    1.116   (  16.520,  35.930)  (   0.372,    0.200)  (  -0.495,  -0.480)   0.009
                                2   62   0.530    1.187   (   8.452,  34.451)  (   0.461,    0.116)  (  -0.511,  -0.307)   0.009
                                3   63   0.552    1.259   (   1.854,  32.203)  (   0.534,    0.001)  (  -0.495,  -0.155)   0.009
                                4   64   0.573    1.330   (  -3.671,  29.383)  (   0.581,   -0.143)  (  -0.451,  -0.031)   0.009
                                5   65   0.595    1.401   (  -8.234,  26.240)  (   0.596,   -0.311)  (  -0.389,   0.066)   0.009
                                6   66   0.617    1.473   ( -11.980,  22.894)  (   0.566,   -0.496)  (  -0.317,   0.136)   0.008
                                7   67   0.638    1.544   ( -15.082,  19.445)  (   0.486,   -0.689)  (  -0.241,   0.181)   0.008
                                8   68   0.660    1.616   ( -17.638,  15.924)  (   0.350,   -0.875)  (  -0.168,   0.204)   0.008
                                9   69   0.681    1.687   ( -19.756,  12.309)  (   0.157,   -1.040)  (  -0.101,   0.209)   0.008
                               10   70   0.703    1.759   ( -21.493,   8.545)  (  -0.092,   -1.169)  (  -0.043,   0.199)   0.008
WMU VECTOR:
 STATION  WAKE PNT    PHI     SIGMA1   SIGMA2  SIGMA1/SIGMA2   TWIST
```

Figure 46 : AEROEXEC output (unsteady WMU vector calculation, continued)

```
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)
8   0.950   0.829    +29.288  +2.0442  +2.2855     +0.8944     +42.593
                               MBAR  MU   XMBAR      DPHI              WMU                    DOWNWASH                  CHORDWISE          VISCOUS WAKE
                                 1   71   0.586      1.378   ( -10.220,  26.297)  (  0.383,  -0.102)  (  -0.444,  -0.010)   0.009
                                 2   72   0.600      1.425   ( -12.594,  23.610)  (  0.304,  -0.169)  (  -0.403,   0.057)   0.009
                                 3   73   0.615      1.472   ( -14.594,  20.879)  (  0.375,  -0.239)  (  -0.356,   0.111)   0.009
                                 4   74   0.629      1.520   ( -16.202,  18.111)  (  0.353,  -0.310)  (  -0.305,   0.153)   0.009
                                 5   75   0.643      1.567   ( -17.448,  15.366)  (  0.320,  -0.379)  (  -0.252,   0.183)   0.009
                                 6   76   0.658      1.614   ( -18.453,  12.681)  (  0.273,  -0.446)  (  -0.200,   0.204)   0.009
                                 7   77   0.672      1.662   ( -19.242,  10.022)  (  0.216,  -0.507)  (  -0.152,   0.215)   0.009
                                 8   78   0.687      1.709   ( -19.781,   7.355)  (  0.147,  -0.560)  (  -0.106,   0.218)   0.009
                                 9   79   0.701      1.757   ( -20.057,   4.698)  (  0.068,  -0.604)  (  -0.064,   0.215)   0.008
                                10   80   0.715      1.804   ( -20.074,   2.047)  ( -0.018,  -0.637)  (  -0.027,   0.205)   0.008
```

Figure 46 : AEROEXEC output (unsteady WMU vector calculation, continued)

```
NOISE CALCULATION OUTPUT        : NOZOUT     NOIZEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    6

*******************************************************************************************************************
UCAP  FOR CR-2              INPUT -- R252INPT.DATA
MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*******************************************************************************************************************

NOISE PROGRAM EXECUTION TIME

CPU TIME AT START  =  726.941 SEC

CPU TIME AT END    =  733.660 SEC

   NET TIME        =    6.719 SEC

OBSERVER LOCATIONS

    DIRECTIVITY POINTS AT ALTITUDE OR SIDELINE DISTANCE,     6.120     FT.

DISTANCE FORWARD OF PLANE OF ROTATION (RETARDED) RE FRONT ROTOR
   6.360       4.645        2.573       0.4170      -1.447      -4.112      -8.773

DISTANCE FORWARD OF PLANE OF ROTATION (VISUAL) RE FRONT ROTOR
   4.021       2.609        0.8137      -1.209      -3.114      -6.066      -11.61

RADIATION ANGLE FROM FLIGHT DIRECTION - DEGREES RE FRONT ROTOR
   43.90       52.80        67.20       86.10       103.3       123.9       145.1

VISUAL RADIATION ANGLE - DEGREES RE FRONT ROTOR
   56.69       66.91        82.43       101.2       117.0       134.7       152.2

FRONT ROTOR AZIMUTHAL OBSERVER ANGLE IS  90.0 DEGREES

REAR ROTOR POSITIONS OFFSET FROM FRONT ROTOR OBSERVER POSITIONS BY     0.2570 * FRONT RADIUS

DISTANCE FORWARD OF PLANE OF ROTATION (RETARDED) RE REAR ROTOR
   7.014       5.276        3.166       0.9590      -0.9464     -3.651      -8.340

DISTANCE FORWARD OF PLANE OF ROTATION (VISUAL) RE REAR ROTOR
   4.547       3.135        1.340       -0.6826     -2.580      -5.540      -11.08

RADIATION ANGLE FROM FLIGHT DIRECTION - DEGREES RE REAR ROTOR
   41.11       49.23        62.45       81.09       98.79       120.8       143.7

VISUAL RADIATION ANGLE - DEGREES RE REAR ROTOR
   53.39       62.88        77.65       96.36       112.9       132.2       151.1

REAR ROTOR AZIMUTHAL OBSERVER ANGLE IS  90.0 DEGREES


AMBIENT ATMOSPHERIC CONDITIONS

 TEMPERATURE          =      56.18
 PRESSURE / SEA LEVEL =     0.9598
 LOCAL SPEED OF SOUND =    1113.36 FEET PER SECOND
```

Figure 47:NOIZEXEC output (observer position summary)

```
FRONT ROTOR OPERATING CONDITIONS

   0.2650 FLIGHT MACH NUMBER,     0.5702 TIP ROTATIONAL MACH NUMBER,     0.6288 TIP RELATIVE MACH NUMBER,
   2.1516 MT / MX,     592.37 BPF,     2.0467 FOOT DIAMETER
```

```
REAR ROTOR OPERATING CONDITIONS

   0.2650 FLIGHT MACH NUMBER,     0.5733 TIP ROTATIONAL MACH NUMBER,     0.6316 TIP RELATIVE MACH NUMBER,
   2.1633 MT / MX,     496.33 BPF,     2.0467 FOOT DIAMETER
```

Figure 48:NOIZEXEC output (front and rear rotor operating conditions)

```
PRINT FRONT & REAR ROTOR HARMS : NOZOUZ     NOIZEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA     4
*******************************************************************************************************************
UCAP  FOR CR-2             INPUT -- R252INPT.DATA
MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*******************************************************************************************************************


RESULTS AT OBSERVER POSITION  1 : VISUAL COORDINATES     RETARDED COORDINATES
                                   X POSITION ANGLE        X POSITION ANGLE
                    FRONT ROTOR :      4.02   56.69          6.36    43.90
                     REAR ROTOR :      4.55   53.39          7.01    41.11

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  1 TIMES BLADE PASSING FREQUENCY

RADIATION     M        K                            FRONT ROTOR                                                     REAR ROTOR
  FREQ     COUNTER  COUNTER     DB       PHASE    P REAL .  P IMAG     RMS PA          DB       PHASE     P REAL    P IMAG      RMS PA
 688.42       2       -1      -65.8       0.8    0.0000    0.0000    0.0000

       ** FRONT ROTOR **
       * STEADY  NOISE *
 592.37       1        0       99.7     101.2   -0.3760    1.8963    1.9332         102.9      295.6     1.2027   -2.5050     2.7787
       STEADY THICKNESS        92.2     162.5   -0.7775    0.2445    0.8150
             QUADRUPOLE      -200.0       0.0    0.0000    0.0000    0.0000
         RADIAL LOADING      -200.0       0.0    0.0000    0.0000    0.0000
          TOTAL NOISE         101.7     118.3   -1.1535    2.1408    2.4318


       ** REAR  ROTOR **
       * STEADY  NOISE *
 496.33       0        1      118.4     202.7  -15.3091   -6.4173   16.5997          84.3      332.2     0.3647   -0.1919     0.4122
       STEADY THICKNESS                                                            85.8      323.5     0.3125   -0.2312     0.3887
             QUADRUPOLE                                                          -200.0        0.0     0.0000    0.0000     0.0000
         RADIAL LOADING                                                          -200.0        0.0     0.0000    0.0000     0.0000
    TOTAL STEADY NOISE                                                             92.0      328.0     0.6772   -0.4232     0.7986

 400.29      -1        2                                                         -134.0       54.6     0.0000    0.0000     0.0000
 304.24      -2        3                                                         -200.0        0.0     0.0000    0.0000     0.0000

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  2 TIMES BLADE PASSING FREQUENCY

RADIATION     M        K                            FRONT ROTOR                                                     REAR ROTOR
  FREQ     COUNTER  COUNTER     DB       PHASE    P REAL    P IMAG     RMS PA          DB       PHASE     P REAL    P IMAG      RMS PA
1280.79       3       -1      -70.3     301.3    0.0000    0.0000    0.0000

       ** FRONT ROTOR **
       * STEADY  NOISE *
1184.75       2        0       63.4     340.5    0.0289   -0.0059    0.0295          47.9      252.9    -0.0015   -0.0048     0.0050
       STEADY THICKNESS        62.9     104.8   -0.0071    0.0270    0.0279
             QUADRUPOLE      -200.0       0.0    0.0000    0.0000    0.0000
         RADIAL LOADING      -200.0       0.0    0.0000    0.0000    0.0000
          TOTAL NOISE          63.6      44.0    0.0218    0.0211    0.0303

1088.70       1        1      148.9     170.6 -549.2166   91.3227  556.7573         151.6      293.6   305.2954 -700.2676   763.9241

       ** REAR  ROTOR **
       * STEADY  NOISE *
 992.66       0        2                                                           47.1       99.7    -0.0008    0.0045     0.0046
       STEADY THICKNESS                                                            60.9      137.7    -0.0163    0.0149     0.0221
             QUADRUPOLE                                                          -200.0        0.0     0.0000    0.0000     0.0000
         RADIAL LOADING                                                          -200.0        0.0     0.0000    0.0000     0.0000
    TOTAL STEADY NOISE                                                             62.2      131.5    -0.0171    0.0193     0.0258

 896.62      -1        3                                                         -123.0      243.6     0.0000    0.0000     0.0000
 800.57      -2        4                                                         -200.0        0.0     0.0000    0.0000     0.0000
```

Figure 49: NOIZEXEC output (summary of noise results, by directivity)

```
PRINT TOTAL NOISE SUMMATION    : NOZOU3      NOIZEXEC  EXECCASE     TIME:  17:00:20 DATE:   1/15/92 UCAP --- NASA    4
*******************************************************************************************************************
UCAP  FOR CR-2               INPUT -- R252INPT.DATA
MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR  BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL

*******************************************************************************************************************
```

```
**** SUMMATION OF FRONT AND REAR NOISE HARMONICS ****
RESULTS AT OBSERVER POSITION  1 : VISUAL COORDINATES     RETARDED COORDINATES
                                  X POSITION ANGLE        X POSITION ANGLE
                  FRONT ROTOR :      4.02   56.49            6.36   43.98
                   REAR ROTOR :      4.55   53.39            7.01   41.11


CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  1 TIMES BLADE PASSING FREQUENCY

RADIATION  FREQUENCY            DB      PHASE    P REAL     P IMAG     RMS PA
  688.42                      -65.8       0.8    0.0000     0.0000     0.0000
  592.37                       85.3     277.7    0.0492    -0.3642     0.3675
  496.33                      118.1     205.1  -14.6318    -6.8404    16.1518
  400.29                     -134.0      54.6    0.0000     0.0000     0.0000


CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  2 TIMES BLADE PASSING FREQUENCY

RADIATION  FREQUENCY            DB      PHASE    P REAL     P IMAG     RMS PA
 1280.79                      -78.3     301.3    0.0000     0.0000     0.0000
 1184.75                       62.3      38.8    0.0203     0.0163     0.0261
 1088.70                      150.3     248.2 -243.9211  -608.9448   655.9812
  992.66                       62.2     131.5   -0.0171     0.0193     0.0258
  896.62                     -123.0     243.6    0.0000     0.0000     0.0000


CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  3 TIMES BLADE PASSING FREQUENCY

RADIATION  FREQUENCY            DB      PHASE    P REAL     P IMAG     RMS PA
 1873.16                     -100.2     243.9    0.0000     0.0000     0.0000
 1777.12                       27.5      92.9    0.0000     0.0005     0.0005
 1681.07                      155.3     316.4  844.7412  -804.5437  1166.5669
 1585.03                      141.9     186.0 -247.1802   -26.1392   248.4789
 1488.99                       36.7     311.3    0.0009    -0.0010     0.0014
 1392.94                     -134.7      78.5    0.0000     0.0000     0.0000


CALCULATED NOISE FOR HARMONICS IN THE RANGE OF  4 TIMES BLADE PASSING FREQUENCY

RADIATION  FREQUENCY            DB      PHASE    P REAL     P IMAG     RMS PA
 2465.53                     -125.2     190.4    0.0070     0.0000     0.0000
 2369.49                        9.3      45.2    0.0000     0.0000     0.0001
 2273.45                      131.6     223.3  -55.0670   -51.8259    75.6194
 2177.40                      141.4     102.4  -50.1917   228.9375   234.3749
 2081.36                      136.7      30.5  117.7966    69.4187   136.7296
 1985.32                       11.7     133.9   -0.0001     0.0001     0.0001
 1889.27                     -152.6     278.6    0.0000     0.0000     0.0000
```

Figure 50:NOIZEXEC output (summary of noise results at each frequency)

```
      PROGRAM QWMUGEN

      REAL RWMU(20,20), IWMU(20,20)

      INTEGER TYPE

C     #(@) THIS WILL CALCULATE QWMU FOR LSTPARMS 351 TO 550
C     TYPE IS 1 FOR SEARS LIFT RESPONSE FOR SINUSOIDAL GUST
C     IT IS ASSUMED THE FOLLOWING INFORMATION ARE KNOWN:
C     NCP     NUMBER OF CHORDWISE PANELS. LSTPARMS
C     NSM     NUMBER OF RADIAL STATIONS. LSTPARMS
C     BD      CHORD/DIAMETER RATIO AT NSM STATIONS (BLADEGEO)
C     ZAR     LOCATION OF THE RADIAL STATIONS (LSTPARMS 101-110)
C     J       ADVANCE RATIO

      REAL J, BD(10), ZAR(10)


      WRITE(*,*)' ENTER ADVANCE RATIO'
      READ(*,*) J

      WRITE(*,*)' ENTER NUMBER OF CHORDWISE PANELS'
      READ(*,*) NCP

      WRITE(*,*)' ENTER NUMBER OF RADIAL STATIONS'
      READ(*,*) NSM
      WRITE(*,*)' ENTER ',NSM,' RADIAL STATIONS--ASCENDING ORDER'
      READ(*,*) (ZAR(I),I=1,NSM)
      WRITE(*,*)' ENTER ',NSM,' VALUES OF CHORD/DIAMETER'
      READ(*,*) (BD(I),I=1,NSM)
      WRITE(*,*) ' ENTER Q'
      READ(*,*) Q
      WRITE(*,*)' ENTER GUST VELOCITY, DIVIDED BY ROTOR TIP SPEED'
      READ(*,*) WZERO
      DO N=1,NSM
         SIGMA=3.14159/J
         DO M=1,NCP
            XN=-0.5+(FLOAT(M)-0.5)/FLOAT(NCP)
            RWMU(M,N)=WZERO*COS(2.0*Q*BD(N)*XN/SIGMA)
            IWMU(M,N)=WZERO*SIN(2.0*Q*BD(N)*XN/SIGMA)
         ENDDO
      ENDDO
      WRITE(*,1010)351,((RWMU(M,N),IWMU(M,N),M=1,NCP),N=1,NSM)
1010  FORMAT(I3,(T5,6(F9.4,1X)))
      STOP
      END
```

Figure 51
Listing of sample program to generate QWMU vector for simusoidal gust

```
C      @(#) CRPBLK.F 1.1.1@(#)
C      90/08/15
C      16:47:12

C     @(#) BLOCK DATA FOR COMMON/CRPP01/
C     PURPOSE:  BLOCK DATA FOR COMMON/CRPP01/
C     MODIFIED TO MAKE DEFAULT VALUE OF CRPTOL 0.01

      BLOCK DATA CRPBLK

C--BLOCK DATA FOR CRPPRM

C--COMMON BLOCK FOR CRPPARMS

      REAL AFTHRM,     COUNT,      CRPBUG,     CRPTOL,     FWDHRM,
     $     RATIO,      ROW,        SPACE,      SWITCH
C
      COMMON/CRPP01/CRPBUG,     SWITCH,     SPACE,      COUNT,
     $              CRPTOL,     FWDHRM,     AFTHRM,     ROW,
     $              RATIO
C
C     CRPBUG:  DEBUG SWITCH.  0:  NO DEBUG PRINTOUT
C                             1:  ECHO INPUT
C
C     SWITCH:  CRP/SRP SWITCH.  0:  SINGLE ROTATION (DEFAULT)
C                               1:  COUNTER ROTATION
C
C     SPACE:   DISTANCE BETWEEN BLADE PITCH CHANGE AXES, DIVIDED BY
C              FRONT ROTOR DIAMETER.
C
C     RATIO:   REAR DIAMETER DIVIDED BY FORWARD DIAMETER
C
C     COUNT:   MAXIMUM NUMBER OF FRONT/REAR ITERATIONS.  DEFAULT IS 0,
C              WHICH IS ONE TRIP THROUGH.
C
C     CRPTOL:  MINIMUM VALUE OF THE CONVERGENCE MONITOR REQUIRED TO
C              START ANOTHER ITERATION.  IF THIS IS <= 0, IT WILL BE
C              SET TO 1.0E+4
C
C     ROW:     ROW SELECTOR SWITCH:  SET INTERNALLY ONLY!
C              <1.5:  FRONT ROW
C              >1.5:  REAR ROW
C
C    FWDHRM:  HIGHEST FORWARD ROW WAKE HARMONIC TO USE FOR EXCITATION
C             OF REAR ROTOR.  NOTE THAT THE FORWARD ROTOR WAKE IS
C             STEADY WHEN VIEWED FROM A POINT MOVING WITH THE FRONT
C             ROTOR.  THE HARMONICS ARE HARMONICS IN SPACE ONLY.
C             THOSE HARMONICS > 0 WILL APPEAR UNSTEADY TO THE REAR
C             ROTOR IN THE SAME WAY BUMPS ON A ROAD CAUSE TIME VARYING
C             FORCES ON AN AUTOMOBILE MOVING DOWN THE ROAD.
C
C    AFTHRM:  HIGHEST REAR ROW POTENTIAL FIELD HARMONIC TO USE FOR
C             EXCIT ATION OF THE FORWARD ROTOR.  NOTE THAT THE REAR
C             ROTOR POTENTIAL FIELD IS, LIKE THE WAKE, STEADY ONLY
C             WHEN VIEWED FROM A POINT MOVING WITH THE REAR ROTOR.  IT
C             IS ALSO NOT HOMOGENOUS.
C
      DATA AFTHRM/0.0/, COUNT/0.0/, CRPBUG/1.0/,
     $     CRPTOL/1.0E-2/, FWDHRM/0.0/, SPACE/-1.0/,
     $     SWITCH/0.0/
C
      END
```

Figure 52
Listing of CRPBLK with changed default valve for CRP tolerance CRPTOL

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13. ABSTRACT *(Maximum 200 words)*

This is the user's manual for UCAP (Unified Counter-rotation Aeroacoustics Program), the counter-rotation derivative of the UAAP (Unified Aero-Acoustic Program). The purpose of this program is to predict steady and unsteady airloading on the blades and the noise produced by a counter-rotation Prop-Fan. The aerodynamic method is based on linear potential theory with corrections for non-linearity associated with axial flux induction, vortex lift on the blades, and rotor-to-rotor interference. The theory for acoustics and the theory for individual blade loading and wakes are derived in *Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise*, Volume 1 (NASA CR-4329). This user's manual also includes a brief explanation of the theory used for the modelling of counter-rotation.

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