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**AERONAUTICAL RESEARCH LABORATORY**  
**MELBOURNE, VICTORIA**

Aerodynamics Technical Memorandum 398

**A GUIDE TO INPUT AND OUTPUT FOR THE VORSBA  
COMPUTER PROGRAM(U)**

by

L.D. MacLaren

Approved for public release



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**SUMMARY**

The VORSBA computer program is used to calculate the incompressible vortex flow about slender wing configurations. Three programs have been written to enable the user (especially the beginner) to run VORSBA more efficiently. These include an input preprocessor, an output file handling program and a graphical output routine. A comprehensive set of examples is also given which can be used as a basis of solution for many problems that are likely to be encountered.



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## 1 INTRODUCTION

In 1986, the Aeronautical Research Laboratory (ARL) received from the National Aerospace Laboratory (NLR) in the Netherlands, a copy of the computer program VORSBA, which is used to calculate the incompressible vortex flow around slender wing configurations. VORSBA reduces three-dimensional vortex flow problems to a series of two-dimensional problems along a corresponding series of cross-flow planes. Theoretically the solution can be obtained at any cross-flow plane given the wing geometry and a suitable initial estimate for the vortex geometry. Both the wing and vortex sheet are defined using segments. The wing segments are modelled by doublet or source distributions and the vortex sheet segments are modelled by doublet distributions.

Because the problem is highly nonlinear, a second-order accurate panel method at each cross-flow plane is used. The resulting system of nonlinear equations is solved using Newton's method.

The method of data input for this program is via a formatted input file. Because this method is tedious and usually results in many unnecessary errors, an input preprocessor was written to improve the accuracy of the input process.

The printed output from a program run is very detailed and therefore finding the required information among the masses of data is difficult. NLR supplied a copy of their PLOT plotting routine which is used to present the output as a set of graphs but unfortunately, this was incompatible with the ARL ELXSI 6400 system. Therefore a new plotting routine was written incorporating the subroutines available in the DI3000 graphics library.

By using the input preprocessor and the new plotting routine, the use of the VORSBA program at ARL has been made much more efficient.

The User's Guide (Ref.1) for VORSBA provided some guidance as to how a problem should be solved and provided one example. A more comprehensive set of examples is provided in Section 5.

## 2 INPUT PROGRAMS

### 2.1 Input requirements

To execute the VORSBA program, the user must create a formatted input file that is appropriate for the case to be considered. The input file consists of a selection of 27 possible records with each record containing up to eleven variables. For most cases, not all of the 27 records are required, therefore the user must be careful that only the necessary records, in the correct order are included.

Creating a complicated input file by hand using the on-line editor is very tedious and usually results in errors occurring within the file. To minimize the

mistakes made when creating the input file, an input preprocessor was created.

The preprocessor VORSIN is a Fortran program that prompts the user to input a value for each variable and then writes the responses using the correct format to a data file called VORSBA.IN. The user is now not responsible for placing the data in the appropriate columns as the program does this automatically. More importantly, the program makes the decisions as to what records need to be specified and in what order, based on the values assigned to some of the earlier variables.

## 2.2 VORSIN – program description

The program has been written in modular form. It consists of a main program and a set of subroutines (one subroutine for each record).

The main program calls the record subroutines in an order that coincides with the NLR - VORSBA User's Guide (Ref.1). When each subroutine is called, its corresponding record number is written to the terminal screen so that the user (unfamiliar with the variables located on that record) may refer to the appropriate location in the user's manual.

A variable name is then displayed along with a short description. A complete list of the variables and their definitions are given in Appendix A. The user is prompted to input a response consistent with the given range and variable type. Some examples of these prompts are as follows :

### Example 1

```
*** Record 1 ***  
Identification label (ch*80)
```

- A string no longer than 80 characters is required.

### Example 2

```
*** Record 2 ***  
NSEG - Total number of segments.  
Enter NSEG (>=1) :
```

- The total number of segments must be greater than or equal to one and it must be input as an integer.

### Example 3

```
*** Record 9 ***  
REFB - Reference length.  
Enter REFB (0.0,>0.0) :
```

- The reference length is a real number and must be greater than zero. If input as zero, a default value of 1.0 will be assigned.

If the responses are not input in the required form, an error message will appear as well as a request for the variable to be input a second time. The error message will be invoked when :

1. A real number is input where the program is expecting an integer.
2. The input does not lie within the allowed range.
3. A string character is input where a number is required.

After all variables for the current record have been specified, the program will ask if there is anything on the record to be changed. A 'Y' or 'y' response means that the entire record must be redefined. Alternatively if the record is already correct a carriage return will allow the program to continue. The correct data will be stored in the locations as shown by the schematic input file in Appendix B. The program will then proceed to the next record.

Every variable on each record must have a value assigned to it. However, it is not always necessary for the user to provide all of these values. Some variables will be given a default value depending on the the data already defined. The user is informed of a defaulted parameter when its name and description appear on the display without the usual prompt as to its value. An example of this process occurs in record 12. When record 12 is used to describe a wing segment (ie. when  $IWS=0,1$ ), all vortex sheet segment type variables are defaulted to zero. Similarly when record 12 is used to describe a vortex sheet segment (ie. when  $IWS=2$ ), all wing segment type variables will be defaulted to zero.

This characteristic ensures that the user does not input more responses than are absolutely necessary, thus saving time and preventing errors in the VORSBA input file.

As the preprocessor is being run, labels will appear on the display at the points where a new station or segment is being defined. The label consists of a station number and/or a segment type and number and is used to remind the user what part of the problem is currently under consideration.

After all necessary records have been defined, the output from the preprocessor can be viewed by listing the file VORSBA.IN. If a mistake is noticed in VORSBA.IN at this stage, it is not necessary for the user to rerun VORSIN. It is simpler to alter the file using the EMACS editing facility available on the ARL ELXSI system.

Some VORSBA input files created using VORSIN including the example given by Hoeijmakers (Ref.2) are presented in Section 4.

### 3 OUTPUT PROGRAMS

#### 3.1 Output description

The output from the VORSBA program is written to two separate data files. One is a formatted file containing extensive details of the computation and the other is an unformatted file containing plotable data for every converged solution. The formatted file is so detailed that it can be difficult to find the required information among the many pages of computer output. It is therefore much easier to process the data stored on the plot file to obtain an immediate understanding of the solution by graphical means. A copy of the plotting routine (SPLOT) used at NLR was provided, but this was incompatible with the ARL ELXSI system, therefore another plotting routine was written.

The plotting program had to incorporate the following properties :

1. It must clearly define the axes and labels.
2. It must be simple to use.
3. The user must be able to produce multiple curve plots.

This was achieved by creating the Fortran programs, VCURVS and VGRAPH. The VCURVS program manipulates the data stored on the plot file into a form that is suitable for use by the plotting routine VGRAPH. This program incorporates many of the subroutines found in the D13000 graphics library.

#### 3.2 Data Storage

When the VORSBA program successfully completes a run, it places all of the plotting data for every converged solution onto VORSBA.FL99. The structure of this plot file is as follows :

Record 1 : NCURV - the number of curves in the plot.  
Record 2.1 : NPOINT - the number of points on the n-th curve.  
Record 2.2 : (X(I),I=1,NPOINT),(F(I),I=1,NPOINT)  
- data for curve F vs. X.

where records 2.1 and 2.2 are repeated for each of the NCURV curves of the plot.

An example of this form is shown below.

Example 4

```
2
4 0.0 1.0 2.0 3.0 0.0 1.0 2.0 3.0
3 1.0 2.0 3.0 0.0 1.0 2.0
1
3 0.0 1.0 2.0 2.0 1.0 0.0
```

This data indicates that the plot file contains 2 plots. The first plot has two curves, the first of which consists of four data points. All four x-ordinates follow and then their corresponding y-ordinates. The second curve of the first plot contains three data points. The next plot contains only one curve which has a total of three data points. When plotted, the above data would resemble Figures 1a and 1b.

Each time convergence is reached, a set of plot data as in Table.1 is written to VORSBA.FL99. Plots are identified by a plot number (PLOTNO). The definition of this number is illustrated in the following example.

Example 5 : Using the NLR example (Ref.2)

```
Number of wing segments : NSEGW = 1
Total number of segments : NSEG = 2
The first converged solution is required : CONV = 1
```

The general rule for finding the plot number is :

$$PLOTNO = (CONV - 1) * (NSEG + 2 * NSEGW + 2) + PLOTIND \quad (1)$$

To plot the component of velocity on the wing segment normal to ray vs. the normalized arc length then the required plot number would be calculated as follows :

$$\begin{aligned} PLOTIND &= NSEG + 2 * NSEGW + 1 \\ &= 2 + 2 * 1 + 1 \\ &= 5 \end{aligned}$$

$$\begin{aligned} PLOTNO &= (1 - 1) * (2 + 2 * 1 + 2) + 5 \\ &= 5 \end{aligned}$$



Table 1: Identification of plot data.

PLOTIND	DESCRIPTION
1	Cross flow plane geometry of wing and vortex sheet segments.
2	Singularity distribution vs. normalized arc length on segment 1.
3	Singularity distribution vs. normalized arc length on segment 2.
.	.
NSEG+1	Singularity distribution vs. normalized arc length on segment NSEG.
NSEG+2	Pressure distribution on wing segments.
NSEG+3	Component of velocity on first wing segment normal to ray vs. normalized arc length.
NSEG+4	Component of velocity on first wing segment along ray vs. normalized arc length.
.	.
NSEG+2NSEGW+1	Component of velocity on NSEGW-th wing segment normal to ray vs. normalized arc length.
NSEG+2NSEGW+2	Component of velocity on NSEGW-th wing segment along ray vs. normalized arc length.

To plot the pressure distribution, the plot number would be :

$$\begin{aligned} PLOTIND &= NSEG + 2 \\ &= 2 + 2 \\ &= 4 \end{aligned}$$

$$\begin{aligned} PLOTNO &= (1 - 1) * (2 + 2 * 1 + 2) + 4 \\ &= 4 \end{aligned}$$

The process of determining the correct plot number has been made simpler with the addition of another data output file to the VORSBA program. Using the plot data stored on VORSBA.FL99, a formatted data file called VORSBA.FL90 has been created.

Every time a converged solution is reached, the current streamwise position, angles of attack/sideslip and the number of panels on wing and vortex sheet segments are recorded in a formatted form on VORSBA.FL90. This is followed by the plot data for the converged solution with each set of data given a separate label and corresponding plot number.

The contents of this file may be inspected after the completion of a run to obtain the plot numbers of the data sets to be plotted.

Now the VCURVS program can be run to select the appropriate data sets from the file VORSBA.FL99 and to place this data on separate files ready for plotting.

### 3.3 File handling program - VCURVS

Upon supplying the required plot number, VCURVS will read through (from the beginning) all of the data on VORSBA.FL99 until it has reached the specified set. This data set will be written onto another file in the following format.

```
Record 1 : NCURV
Record 2 : NPOINT
Record 3 : X(1) F(1)
Record 4 : X(2) F(2)
.
.
.
Record 2+NPOINT : X(NPOINT) F(NPOINT)
```

Table 2: Available storage files.

INPUT	FILE NAME	TAPE NO.	MAJOR USE
1	VORGEOM	51	Vortex geometry plots
2	VORDBLT	52	Doublet distributions
3	VORPRES	53	Pressure distributions
4	VORVELN	54	Velocity normal to ray
5	VORVELP	55	Velocity parallel to ray
6	-	-	To be specified by the user

#### Example 6

Consider the data used in example 4. If plot number two was specified when running program VCURVS, the data would be read from VORSBA.FL99 and written to another file as follows.

```

1
3
0.0 2.0
1.0 1.0
2.0 0.0
    
```

#### 3.3.1 Running VCURVS

1. There may be more than one data set on VORSBA.FL99 that the user requires for plotting. The first prompt asks for the number of plots that are to be read from the data file.
2. The next input identifies the name and number of the new file where the data is to be stored. The available inputs are given in table 2. If, for example a '1' is input, then tape number fifty-one will be opened and given the name 'VORGEOM'. If the number '6' is input then the user will be prompted to input a tape name and number other than those that appear in Table.2.
3. The required plot number is the next thing to be input. This set of data will be read from VORSBA.FL99 and stored on the file created with the previous input.
4. A useful feature of this program is the ability to place more than one set of data on the same file. After the data from VORSBA.FL99 has been stored

on the appropriate plotting file(s), the VORSBA program may be run again for a different case and its results may be added to the data already saved on the selected VCURVS file(s) or it may overwrite the existing data.

An add/overwrite prompt is given where the user must decide on the necessary action.

When there are many plots to be made from a single VORSBA run, steps two, three and four should be repeated until the total number of plots is reached.

### 3.3.2 A VCURVS tutorial

Using the example input file given in Ref.2, VORSBA can be run and the plot file VORSBA.FL99 generated. The example is a unit aspect-ratio delta wing at an angle of attack of  $\alpha = 20^\circ$ .

Because there is only one station, one combination of angle of attack sideslip and no automatic sheet extensions to be considered, there will only be one converged solution appearing on VORSBA.FL99 (ie. CONV = 1).

Suppose a plot of the singularity distributions on both the wing and vortex sheet segments is required. The following inputs will compile a file containing data in the correct format for plotting.

```
:run VCURVS
2   - the number of data sets to be plotted is 2.
2   - store the data for curve no. 1 on tape52 - VORDBLT.
2   - the required plot no. is 2.
2   - this is to be the first set of data on tape52 (- overwrite).
2   - store the data for the second curve on tape52 also.
3   - the required plot no. is 3.
1   - this data is to be added to the existing data on tape52.
```

A summary will appear at the end of the run listing the files that have been used for data storage. This information should be noted for later reference.

### 3.4 Plotting routine – VGRAPH

VGRAPH will plot the data stored on the files created by VCURVS. The prompts are usually self explanatory with all yes/no type questions to be answered with the usual y/n response. The inputs required are for format control, such as bold lettering, grid lines etc. as well as scaling parameters and character string labels.

### 3.4.1 A VGRAPH tutorial

Continuing on from the VCURVS tutorial, the program VGRAPH will now be used to obtain plotted output from the previously created data file called VORDBLT. The plot is to have the following characteristics.

1. It must have a series of grid lines drawn over it.
2. The lettering must be in bold type.
3. A marker must be drawn at every data point.
4. Each line on the plot must have a different linestyle.
5. A legend should be included to identify each curve.

To obtain a graph to meet these requirements, the following inputs should be used.

<code>:run VGRAPH</code>	
<code>VORDBLT</code>	- the file name where the data is stored.
<code>y</code>	- bold lettering is a requirement.
<code>y</code>	- the curves are to be drawn with lines and marks.
<code>y</code>	- variable linestyle is required.
<code>y</code>	- a grid is required.
<code>100</code>	- a good length for the X-axis would be 100mm as the X-ordinates vary from 0.0 to 1.0
<code>0.,1.</code>	- X-axis will extend from 0.0 to 1.0
<code>.2</code>	- make the space between major tick marks 0.2
<code>3</code>	- try 3 major tick marks between majors.
<code>100</code>	- for a square plot, make the Y-axis 100mm long also. The Y-ordinates vary from 1.342 to 1.745
<code>1.3,1.8</code>	- Y-axis will extend from 1.3 to 1.8
<code>.1</code>	- make the space between major tick marks 0.1
<code>1</code>	- try 1 minor tick mark between majors.
<code>SINGULARITY DIST.</code>	- type in any title.
<code>NLR - Example</code>	- type in any note.
<code>y/s</code>	- horizontal axis label.
<code>Rho</code>	- vertical axis label.
<code>y</code>	- a legend is also required.
<code>wing seg.</code>	- a short comment for curve no. 1
<code>vort.seg.</code>	- a short comment for curve no. 2

The finished plot is stored on a metafile called METADAT. This can be viewed on a graphics terminal screer or a hard copy can be obtained using a

plotter. It is a good idea to change the name of the METADAT file so that there is a permanent record to refer to at a later stage if the need arises. For example :

```
:rename metadat graph1
```

The following inputs should be used to view the plot.

Graphics Terminal Screen (say VT24C).

```
:metrans.240  
M> s mf 1 graph1  
M> d p 1
```

The plot will then be drawn on the screen. To exit from plot mode, enter :

```
<CR>  
M> q
```

Hard copy on the zeta8 plotter.

```
:plot.zt8 graph1 picno=1 frame=210,280
```

- the frame=210,280 command corresponds to the frame size used in the program. This plot size has been designed to fit on an A4 page.

The finished plot (hardcopy) is shown on Figure 2.

The NLR example set of plots shown on Figures 3a - 3f have also been generated using VCURVS and VGRAPH.

The VGRAPH program is not limited to plotting the results from VORSBA only. It can be used to plot any data file that has been formatted in the correct manner.

## 4 ERROR HANDLING

When running the VORSBA program, it is possible that the user may have an error occur. These may be due to incorrect input of some variables when using VORSIN or when altering one or two variables using the on-line editor and a previously created input file.

The most common errors that occur are :

1. Fortran stop statement 0. This is usually due to the inexact specification of variables such as NP where NP must be identical to the sum of the panels per segment at each cross-flow plane. To find the cause of such an error, a search through the VORSBA.OUT file for the string - ERROR is suggested. An explanation of the error should be displayed.
2. End of file reached while reading. This is due to the incorrect number of records given on the input file. To help in determining which records the program is expecting to read, the VORSBA.FL80 file was added to the VORSBA program. Whenever VORSBA comes to read a record from the input file, it will write the number of that record and the data read at that point onto VORSBA.FL80. This can be used as a check to make sure that the correct piece of data is being read at the correct time.
3. Divergent calculation. There will be no error message for this problem. The program will behave as though a solution has been reached but upon examination of the end of the VORSBA.OUT file, it will be noted that the usual summary of CPU seconds spent in each subroutine does not appear. If this occurs, search through the program for the string - DIVERGED to find out exactly how far the program did get and then make the appropriate adjustments to the input file (eg. smaller step sizes).

To make sure that convergence has been reached after a run, it is suggested that the user either search through the VORSBA.OUT file for the string - REACHED or search through the VORSBA.FL90 file for the string - GEOMETRY. The number of times these strings appear is directly proportional to the number times that the program has converged on a solution.

## 5 EXAMPLES

The following set of examples have been prepared to provide a broader understanding of the VORSBA program. For each case, a short description of the problem is given and the subsequent input files are shown in Appendix C.

### 5.1 NLR - Example

Unit aspect-ratio delta wing : Angle of attack,  $\alpha = 20^\circ$   
: Angle of sideslip,  $\beta = 0^\circ$   
: Vortex sheet length, BSL = 0.6

The input file was created using the VORSIN preprocessor and the data supplied by Hoijmakers (Ref.2). A reproduction of the file is supplied in Appendix C.1 along with the corresponding record numbers on the left hand side. The vortex geometry plot resulting from this input data is shown in Figure 4.

### 5.2 Vortex Sheet Extension

The vortex geometry plot obtained from the NLR example is for a free vortex sheet of limited length. However, the fact that the computation did converge for this simple case allows a more detailed calculation to be performed. The results from the simple case will be used as input in an attempt to extend the length of the free vortex sheet. A new input file needs to be compiled which will take a form similar to the previous one but incorporating the following changes.

IDENT - Identification label should be changed.  
NEXT = 1 - Number of vortex sheets to be extended is 1.  
NEXP = 25 - Vortex sheet segment extension is to be tried 25 times.  
M = 22 - Maximum number of input points per segment + 1.  
As there will be a maximum of 20 panels used on one segment as input (ie. wing segment), there will be 21 points on that segment.  
 $\Rightarrow M = 21 + 1 = 22$   
IINP = 0 - Initial geometry and singularity distribution data will be read from TAPE3.  
IEXT = 1 - Free vortex sheet segment will be extended by additional panels.



**DSMIN** = 0.05 - Minimum extension of free vortex sheet segment is  
 DSMIN \* BSL.  
 ⇒ Min. extension is  $0.05 * 0.6 = 0.03$   
**DSMAX** = 0.10 - Maximum extension of free vortex sheet segment is  
 DSMAX \* BSL.  
 ⇒ Max. extension is  $0.10 * 0.6 = 0.06$

The final input file is shown in Appendix C.2.

Because IINP=0, the solution from the simple case (stored now in an unformatted form on VORSBA.FL2) must be used as input (read from VORSBA.FL3). Therefore the following commands must be performed before the VORSBA program is rerun.

```
:COPY VORSBA.FL2 VORSBA.FL3
```

Also as a precautionary measure, the data on VORSBA.FL2 should be saved on a backup file in case the calculation does not converge and a complete restart is required. For example,

```
:COPY VORSBA.FL2 VORS.EX1
```

It will then be possible to perform a restart by copying VORS.EX1 to VORSBA.FL3.

The new input file can be run with VORSBA and the resulting vortex geometry plot is shown in Figure 5.

### 5.3 Multiple angle of attack

Using the results from the vortex sheet extension, the solutions for a set of different angles of attack can be calculated. An input file is to be created using VORSIN which will be similar to the previous example but with the following differences.

**IDENT** - Identification label  
**NEXT** = 0 - No vortex sheet segments will be extended by additional panels.  
**NA** = 6 - There are 6 different angle of attack/sideslip combinations to be considered.  
**NEXP** = 0 - No vortex sheet segment extensions will be attempted.  
**NP** = 57 - Total number of panels used in the computation at this station is identical to those on input.  
 $NP = NPV + NPW = 37 + 20 = 57$   
**M** = 39 - As there is a max. of 37 panels on the vortex sheet segment (ie. 38 points),  $M = 38 + 1 = 39$ .  
**NPS** = 37 - On the vortex sheet segment, there are 37 panels.

**ISL = 0** - Length of free vortex sheet segment at present station is equal to the length of the geometry on input.  
**IEXT = 0** - Free vortex sheet segment is not to be extended by additional panels.  
**ALFA = 20, 22, 24, 26, 28, 30**  
 - Six angles of attack are specified. Note that the step in  $\alpha$  is relatively small. Larger step sizes result in the program not being able to converge on a solution. eg.  $\Delta\alpha = 5^\circ$

The input file is shown in Appendix C.3.

As stated earlier, when using the solution from a previous example as a starting point, the contents of VORSBA.FL2 should be copied to VORSBA.FL3 and also to a backup file.

```

: COPY VORSBA.FL2 VORSBA.FL3
: COPY VORSBA.FL2 VORS.EX2

```

After running the current input file, a vortex geometry plot showing all specified angles of attack should resemble Figure 6.

#### 5.4 Stepping Downstream

The results from the automatic sheet extension performed earlier can be used as a starting point for calculating the vortex geometry at a station further downstream. As advised earlier, the solution for the extended sheet should have been stored on the backup file VORS.EX2. This should now be copied to the file, VORSBA.FL3 so that VORSBA can use this as an initial estimate.

```

: COPY VORS.EX2 VORSBA.FL3

```

The required input file for marching downstream is similar to the one used when varying the angle of attack. Instead of specifying 6 angles of attack for the calculation, the new input file will specify 6 streamwise stations. The following changes must be made to the existing input file.

**IDENT** - Unit aspect delta wing (six stations)  
**NMAR=6** - Calculate the solution at 6 streamwise stations.  
**NA=1** - Only one angle of attack / sideslip combination will be considered.  
**ISL=1** - Length of free vortex sheet segment used in computation is BSL.  
**BSL=2.0** - Exact length of vortex sheet is unknown so use 2.0 as an approximation.

When considering a multi-station problem, each of the stations must be defined by a small set of records. For the given case, another five stations must be defined in the same fashion as the following example for station number two.

NPREC=1 - Present station has different panelling to the preceding station.  
NPO=57 - No. of panels on preceding station.  
IINP=3 - This is a defaulted value. (no need to specify)  
IINPO=3 - This is a defaulted value. (no need to specify)  
X=4.1 - Present station.  
XO=4.0 - Preceding station.  
NI=3 - No. of input points to define present wing segment is 3.  
IEDGE=0 - No specification of first derivative.  
Y(1)=0.0000 Z(1)=0.0000 - The initial input points that define  
Y(2)=0.5125 Z(2)=0.0000 the present wing segment.  
Y(3)=1.0250 Z(3)=0.0000  
SCALE=1.025 - Scaling factor is 4.1 4.0=1.025 . This scales the results  
from the preceding station to get the first guess  
at the present station.

The input file is shown in Appendix C.4.

The results obtained when running this input file are shown in Figure 7. When trying to march downstream with a reasonably well defined vortex shape, it is very difficult to get the solution to converge if the step size along the wing in the longitudinal direction is too large. This is the reason for choosing very small step sizes with a large number of steps in the above example. If simple vortex geometry is used, as in the initial NLR example case, then much larger step sizes would be possible. The maximum step size that allows convergence of the solution depends on the problem under consideration and therefore must be found by trial and error.

## 5.5 Yawed case

When the effect of sideslip is to be investigated using the VORSBA program, the entire wing geometry must be specified on input (as well as initial estimates for all vortex sheets involved) as the problem can no longer be assumed symmetrical. The suggested method to use when confronted with a problem such as this is almost identical to the problems discussed previously. The approach is as follows.

1. Define the wing geometry using twice the number of wing segments normally used for the symmetrical case. Each wing segment should have a mirror image of itself about the line  $Y = 0.0$ .
2. Consider the wing with zero sideslip first. Use simple vortex sheets as initial estimates and these should have a mirror image of themselves about the wing centreline.
3. When a converged solution is reached, the results (written in binary form and stored on VORSBA.FL2) can be copied to VORSBA.FL3 which can then be used to restart with a new input file.
4. The vortex sheet can now be extended to the required length.
5. COPY VORSBA.FL2 VORSBA.FL3
6. The wing can now be subjected to a range of angles of attack/sideslip. The step size in  $\alpha$  and  $\beta$  should be kept to around  $2^\circ$  for a good chance of convergence.

It is difficult to have all of these processes done using the one input file even though it is theoretically possible to do so. The above steps were implemented when finding the solution due to sideslip for the wing used in the earlier examples. The input files are given in Appendices C.5, C.6, and C.7, and the graphical output is shown in Figures 8, 9, and 10 respectively.

A plot of the pressure distribution due to various sideslip angles is also given on Figure 11 as a matter of interest.

## 5.6 Altering wing cross-section

In the examples so far, the only wing to be analysed has been a flat plate unit aspect-ratio delta wing. The VORSBA program is not limited to flat plates. It can find a solution for any cross-section as long as it remains *slender*. The exact definition of slender is a bit vague but one would assume that a reasonable definition would be a wing whose thickness:span ratio does not exceed about 0.25 .

A delta wing with triangular shaped cross-section with a flat lower surface was used as an example. The wing geometry was defined using two straight wing segments joined at the tip at an angle of  $15^\circ$  . The initial estimate for the vortex sheet geometry consisted of a single panel extending vertically from the wing tip to a length of  $BSL=0.05$  . The initial position of the vortex core was placed at  $y/s=0.7$  and  $z/s=0.45$  . This quickly converged to a solution which was then used to extend the vortex sheet to the required length.

The two input files used in this process are shown in Appendices C.8 and C.9.

When plotted over the flat plate geometry results (see Fig.12), it is seen that the vortex for the triangular wing is shifted up and flattens out more than the flat plate vortex. This corresponds with what would be expected in practice.

## 6 CONCLUDING REMARKS

By using the input preprocessor VORSIN and the output programs VCURVS and VGRAPH, the overall use of VORSBA at ARL has been made more efficient. The graphical output is easily read and makes data analysis simpler. The automatic calculations available in the program (such as sheet extensions etc.) have been demonstrated by several examples. The examples given provide a good basis on which to create new input files that solve larger and more complex problems.

## ACKNOWLEDGEMENTS

The author of this report would like to thank Dr. David Thompson for providing the project and for his help in interpreting the original VORSBA User's Guide. The assistance given by Mr. Ashley Arney in the computing area is also gratefully noted.

## REFERENCES

1. HOEIJMAKERS, H.W.M.  
User's guide for computer program VORSBA  
NLR Memorandum AT-85-015 U, 1985
2. HOEIJMAKERS, H.W.M.  
An approximate method for computing the flow about slender configurations  
with vortex flow separation.  
Part II : Description of computer program VORSBA  
NLR TR 86011 U, 1986

## A Input variable descriptions

Variable	Rec. nos.	Description
ALFA	27	Angle of attack (degrees).
BETA	27	Angle of sideslip (degrees).
BSL	13	Arc length used in computation.
BSLO	13	Arc length to which free-vortex sheet at preceding station is cut before repanelling.
DSMAX	13	Maximum extension of free-vortex sheet segment in fractions of total arc length of sheet.
DSMIN	13	Minimum extension of free-vortex sheet segment in fractions of total arc length of sheet.
EPSQ	4	Entrainment factor.
IABUTN	12	Edge-N abutment indicator of segments.
IABUT1	12	Edge-1 abutment indicator of segments.
IAIC	2	Geometric symmetry parameter.
IDENT	1	Identification label.
IDIST	12	Panel scheme type.
IEDGE	14a&b	Derivative specification.
IEDGE0	21a&b	Derivative specification.
IENTR	4	Entrainment type.
IEXT	12	Free-vortex sheet extension option.
IFLOW	12	External flow wetting parameter.
IFORC	12	Is wing segment to be included in the computation of forces and moments.
IGEOM	12	Is initial data wing geometry saved.
IINP	10	Present station initial data storage parameter.
IINPO	10	Preceding station initial data storage parameter.
ISL	12	How is free-vortex sheet segment length to be defined.
ISLO	12	Description of free-vortex sheet length at preceding station.
ITER	3	Maximum number of Newton iterations allowed per case.
IWS	12	Segment type.
I2D	2	Not implemented in this version.
M	7	Maximum number of input points per segment + 1.
NA	3	Number of angle of attack/sideslip configurations to be considered.

Variable	Rec. nos.	Description
NEXP	3	Number of times a vortex sheet extension is to be tried.
NEXT	2	Number of vortex sheet segments that will be extended by one or more panels.
NFIELD	7	Number of field points at which velocity and pressure is to be calculated.
NI	14a&b	Number of input points for the geometry of the segment at the present station.
NIO	21a&b	Number of input points for the geometry of the segment at the preceding station.
NMAR	3	Number of streamwise stations.
NP	7	Total number of panels used in the computation at this cross-flow plane.
NPAR	7	Number of partitions in AIC-matrix.
NPARG	7	Number of partitions in gradient matrix.
NPO	8	Total number of panels on preceding station.
NPREC	8	Panelling scheme.
NPS	12	Number of panels on segment.
NSEG	2	Total number of segments per station.
NSEGW	2	Total number of wing segments per station.
NSWTCH	5	Calculation method : Analytic Expansion procedure or Gauss numerical integration.
Q	16	Initial source strength of vortex core.
QO	23	Source strength of vortex core.
RA	20	Radius of circle with centre at XM.
REFB	9	Reference length used to non-dimensionalise the cross plane coordinates.
REFL	5	Reference length used for near-field cut-off.
RFAC	18	Factor used to compute initial singularity distribution as $RFAC \cdot \pi$ .
RFACO	25	Factor used to compute the singularity distribution as $RFACO \cdot \pi$ .
RI	17a&b	Value of initial singularity distribution on free- vortex sheet segment.



Variable	Rec. nos.	Description
SCALE	13	Factor used to scale solution at preceding station to obtain initial solution at present station.
T	19	Value of normalised arc length at each panel-edge point.
TNORM	5	Criterion used to determine far-field of a panel.
TOLC	6	Convergence criterium.
TOLD	6	Divergence criterium.
X	11	X-Coordinate of present station.
XM	20	Position of centre of circle in terms of T.
XMOM	9	X-Coordinate of moment reference point.
XO	11	X-Coordinate of preceding station.
Y	15a&b 22a&b	Value of Y-coordinate at each input point on each segment.
YFD	26	Y-Coordinate of field point.
YMOM	9	Y-Coordinate of moment reference point.
YV	16	Y-Coordinate of initial vortex position.
YVO	23	Y-Coordinate of vortex position.
Z	15a&b 22a&b	Value of Z-coordinate at each input point on each segment.
ZFD	26	Z-Coordinate of field point
ZMOM	9	Z-Coordinate of moment reference point
ZV	16	Z-Coordinate of initial vortex position.
ZVO	23	z-Coordinate of vortex position.

## B Schematic input file

	5	10	15	20	25	30	35	40	45	50	55
1	IDENT										
2	NSEG	NSEGW	IAIC	NEXT	I2D						
3	NMAR	NA	NEXP	ITEP							
4	IENTR		EPSQ								
5	NSWTCH		TNORM		REFL						
6	TOLC		TOLF								
7	NP	M	NPAR	NPARC	NFIELD						
8	NPREC	NPO									
9	REFB		XMOM		YMOM	ZMOM					
10	IINP	IINPO									
11	X		XC								
12	IWS	IABUTJ	IABUTN	NPS	IDIST	ISL	ISLO	IEXT	IFLOW	IFORC	IGEOM
13	BSL		BSLO		DSMIN	DSMAX		SCALE			
14	NI	IEDGE									
15	Y(1)		Z(1)								
16	Y(NI)		Z(NI)								
17	YV		ZV		Q						
	RI(1)										
	RI(NI+1)										
18	RFAC										
19	T(1)		T(2)	T(3)		T(NPS+1)					
20	XM		RA								
21	NIO	IEDGEO									
22	Y(1)		Z(1)								
	Y(NIO)		Z(NIO)								
23	YVO		ZVC		QO						
24	RI(1)										
	RI(NIO+1)										
25	RFACO										
26	YFD		ZFD								
27	ALFA		BETA								

## C Input files

### C.1 NLR - Example case.

```
1 | UNIT-ASPECT DELTA WING (NLR - Example)
2 | 2 1 1 0 0
3 | 1 1 0 0
4 | 0 .00000
5 | 0 .45000 1.00000
6 | .00000 10.00000
7 | 32 6 4 5 0
8 | 0 0
9 | 1.00000 .00000 .00000 .00000
10 | 2 4
11 | 4.00000 .00000
12 | 0 1 -2 20 2 0 0 0 2 1 0
13 | .0000 .0000 .0000 .0000 .0000
14a | 3 0
15a | .00000 .00000
15a | .50000 .00000
15a | 1.00000 .00000
18 | .50000
12 | 2 1 0 12 2 1 0 0 2 0 0
13 | .6000 .0000 .0000 .0000 .0000
14. | 5 0
15b | 1.00000 .00000
15b | 1.05700 .07628
15b | 1.06600 .21400
15b | 1.01000 .40400
15b | .87900 .55300
16 | .65000 .35000 .00000
18 | .50000
27 | 20.00000 .00000
```

## C.2 Extension of the vortex sheet.

1	UNIT-ASPECT DELTA WING (automatic sheet extension)										
2	2	1	1	1	0						
3	1	1	25	0							
4	0	.00000									
5	0	.45000	1.00000								
6	.00000	10.00000									
7	32	22	4	5	0						
8	0	0									
9	1.00000	.00000	.00000	.00000	.00000						
10	0	4									
11	4.00000	.00000									
12	0	1	-2	20	2	0	0	0	2	1	0
13	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
12	2	1	0	12	2	1	0	1	2	0	0
13	.60000	.00000	.00000	.05000	.10000	.00000	.00000	.00000	.00000	.00000	.00000
27	20.00000	.00000									

### C.3 Varying angle of attack

1		UNIT-ASPECT DELTA WING (multi angle of attack)										
2		2	1	1	0	0						
3		1	6	0	0							
4		0	.00000									
5		0	.45000	1.00000								
6		.00000	10.00000									
7		57	39	4	5	0						
8		0	0									
9		1.00000	.00000	.00000	.00000	.00000						
10		0	4									
11		4.00000	.00000									
12		0	1	-2	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
12		2	1	0	37	2	0	0	0	2	0	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
27		20.00000	.00000									
27		22.00000	.00000									
27		24.00000	.00000									
27		26.00000	.00000									
27		28.00000	.00000									
27		30.00000	.00000									

### C.4 Solution at a downstream station

1	UNIT-ASPECT DELTA WING (six station)										
2	2	1	1	0	0						
3	6	1	0	0							
4	0	.00000									
5	0	.45000	1.00000								
6	.00000	10.00000									
7	57	39	4	5	0						
8	0	0									
9	1.00000	.00000	.00000	.00000	.00000						
10	0	4									
11	4.00000	.00000									
12	0	1	-2	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
12	2	1	0	37	2	1	0	0	2	0	0
13	2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
27	20.00000	.00000									
7	57	39	4	5	0						
8	1	57									
9	1.00000	.00000	.00000	.00000	.00000	.00000					
11	4.10000	4.00000									
12	0	1	-2	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a	3	0									
15a	.00000	.00000									
15a	.51250	.00000									
15a	1.02500	.00000									
12	2	1	0	37	2	1	0	0	2	0	0
13	2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0250		
7	57	39	4	5	0						
8	1	57									
9	1.00000	.00000	.00000	.00000	.00000	.00000					
11	4.20000	4.10000									
12	0	1	-2	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a	3	0									
15a	.00000	.00000									
15a	.52500	.00000									
15a	1.05000	.00000									
12	2	1	0	37	2	1	0	0	2	0	0
13	2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0244		

7		57	39	4	5	0						
8		1	57									
9		1.00000	.00000	.00000	.00000	.00000						
11		4.30000	4.20000									
12		0	1	-2	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a		3	0									
15a		.00000	.00000									
15a		.53750	.00000									
15a		1.07500	.00000									
12		2	1	0	37	2	1	0	0	2	0	0
13		2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0238		
7		57	39	4	5	0						
8		1	57									
9		1.00000	.00000	.00000	.00000	.00000						
11		4.40000	4.30000									
12		0	1	-2	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a		3	0									
15a		.00000	.00000									
15a		.55000	.00000									
15a		1.10000	.00000									
12		2	1	0	37	2	1	0	0	2	0	0
13		2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0233		
7		57	39	4	5	0						
8		1	57									
9		1.00000	.00000	.00000	.00000	.00000						
11		4.50000	4.40000									
12		0	1	-2	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a		3	0									
15a		.00000	.00000									
15a		.56250	.00000									
15a		1.12500	.00000									
12		2	1	0	37	2	1	0	0	2	0	0
13		2.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0227		

### C.5 Full wing geometry assuming no symmetry

1		UNIT-ASPECT DELTA WING (full geometry - initial guess)										
2		4	2	0	0	0						
3		1	1	0	0							
4		0	.00000									
5		0	.45000	1.00000								
6		.00000	10.00000									
7		64	6	4	5	0						
8		0	0									
9		1.00000	.00000	.00000	.00000	.00000						
10		2	4									
11		4.00000	.00000									
12		0	-4	2	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a		3	0									
15a		-1.00000	.00000									
15a		-.50000	.00000									
15a		.00000	.00000									
18		.50000										
12		0	-1	-3	20	2	0	0	0	2	1	0
13		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14a		3	0									
15a		.00000	.00000									
15a		.50000	.00000									
15a		1.00000	.00000									
18		.50000										
12		2	2	0	12	2	1	0	0	2	0	0
13		.6000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14b		5	0									
15b		1.00000	.00000									
15b		1.05700	.07628									
15b		1.06600	.21400									
15b		1.01000	.40400									
15b		.87900	.55300									
16		.65000	.35000	.00000								
18		.50000										
12		2	1	0	12	2	1	0	0	2	0	0
13		.6000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
14b		5	0									
15b		-1.00000	.00000									
15b		-1.05700	.07628									



15b		-1.06600	.21400	
15b		-1.01000	.40400	
15b		-.87900	.55300	
16		-.65000	.35000	.00000
18		-.50000		
27		20.00000	.00000	

### C.6 Extension of vortex sheets (entire wing)

1	UNIT-ASPECT DELTA WING (full geometry - sheet extension)										
2	4	2	0	2	0						
3	1	1	25	0							
4	0	.00000									
5	0	.45000	1.00000								
6	.00000	10.00000									
7	64	22	4	5	0						
8	0	0									
9	1.00000	.00000	.00000	.00000	.00000						
10	0	4									
11	4.00000	.00000									
12	0	-4	2	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
12	0	-1	-3	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
12	2	2	0	12	2	1	0	1	2	0	0
13	.6000	.0000	.0500	.1000	.0000						
12	2	1	0	12	2	1	0	1	2	0	0
13	.6000	.0000	.0500	.1000	.0000						
27	20.00000	.00000									

### C.7 Varying angle of sideslip

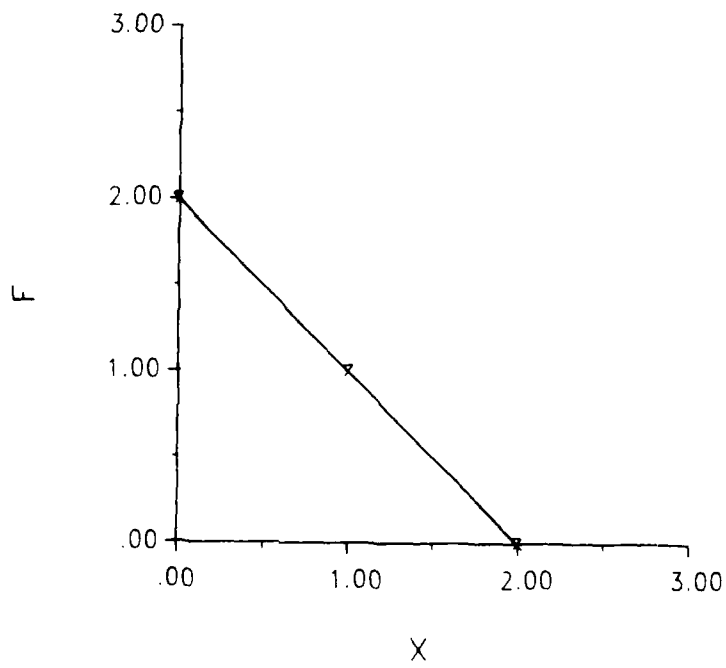
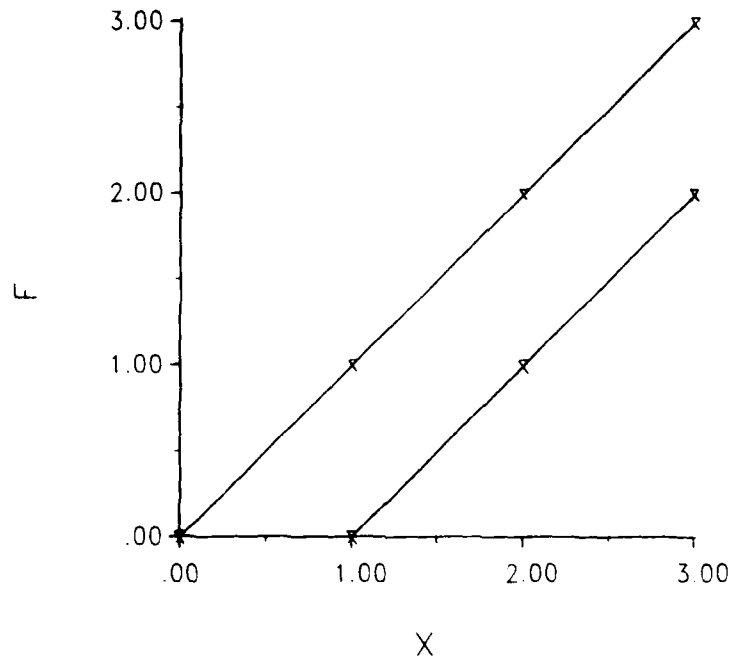
1	UNIT-ASPECT DELTA WING (full geometry - varying sideslip)										
2	4	2	0	0	0						
3	1	7	0	0							
4	0	.00000									
5	0	.45000	1.00000								
6	.00000	10.00000									
7	104	34	4	5	0						
8	0	0									
9	1.00000	.00000	.00000	.00000	.00000						
10	0	4									
11	4.00000	.00000									
12	0	-4	2	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
12	0	-1	-3	20	2	0	0	0	2	1	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
12	2	2	0	32	2	0	0	0	2	0	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
12	2	1	0	32	2	0	0	0	2	0	0
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
27	20.00000	.00000									
27	20.00000	2.50000									
27	20.00000	5.00000									
27	20.00000	7.50000									
27	20.00000	10.00000									
27	20.00000	12.50000									
27	20.00000	15.00000									

### C.8 Triangular cross section- initial guess

1	UNIT-ASPECT DELTA WING (triangular cross-section)									
2	3	2	1	0	0					
3	1	1	0	0						
4	0	.00000								
5	0	.45000	1.00000							
6	.00000	10.00000								
7	41	4	4	5	0					
8	0	0								
9	1.00000	.00000	.00000	.00000	.00000					
10	2	4								
11	4.00000	.00000								
12	1	1	0	20	2	0	0	0	0	1
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
14a	3	0								
15a	.00000	.26795								
15a	.50000	.13397								
15a	1.00000	.00000								
18	.50000									
12	0	2	-3	20	2	0	0	0	1	1
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
14a	3	0								
15a	.00000	.00000								
15a	.50000	.00000								
15a	1.00000	.00000								
18	.50000									
12	2	2	0	1	2	1	0	0	2	0
13	.0500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
14b	2	0								
15b	1.00000	.00000								
15b	1.00000	.05000								
16	.70000	.45000	.00000							
18	.50000									
27	20.00000	.00000								

C.9 Triangular cross-section - vortex extension

1	UNIT-ASPECT DELTA WING (automatic sheet extension)									
2	3	2	1	1	0					
3	1	1	35	0						
4	0	.00000								
5	0	.45000	1.00000							
6	.00000	10.00000								
7	41	22	4	5	0					
8	0	0								
9	1.00000	.00000	.00000	.00000	.00000					
10	0	4								
11	4.00000	.00000								
12	1	1	0	20	2	0	0	0	0	1
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	0	2	-3	20	2	0	0	0	1	1
13	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	2	2	0	1	2	1	0	1	2	0
13	.0500	.0000	.5000	1.0000	.0000	.0000	.0000	.0000	.0000	.0000
27	20.00000	.00000								



Figures 1(a) & (b). Plotted data from example 4.

SINGULARITY DIST.  
NLR - Example

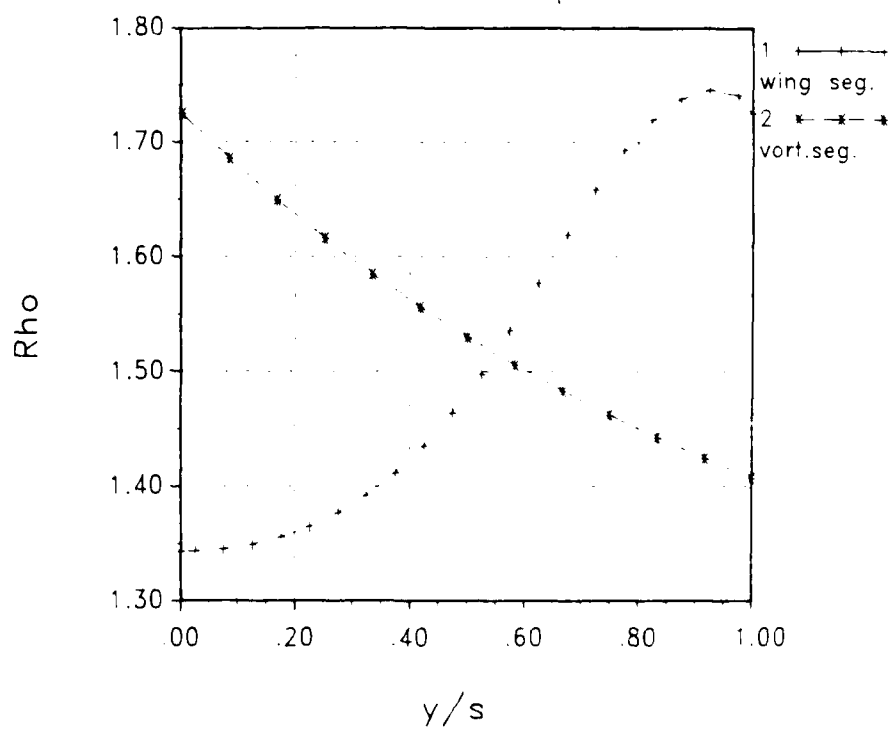
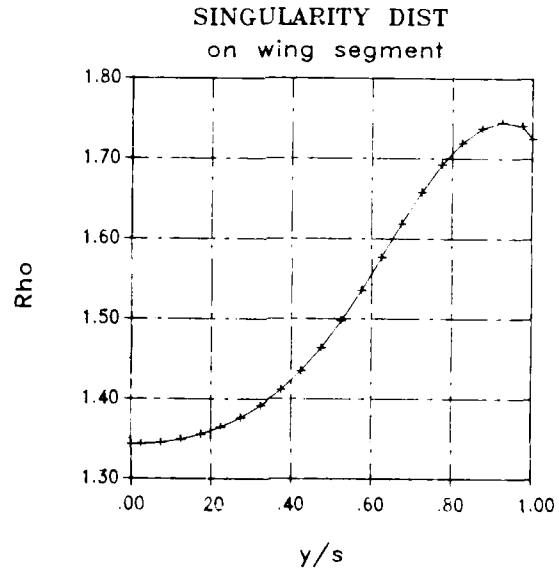
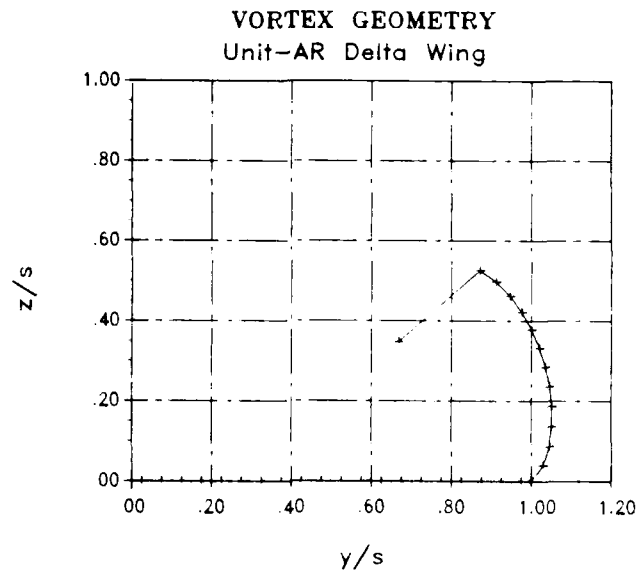
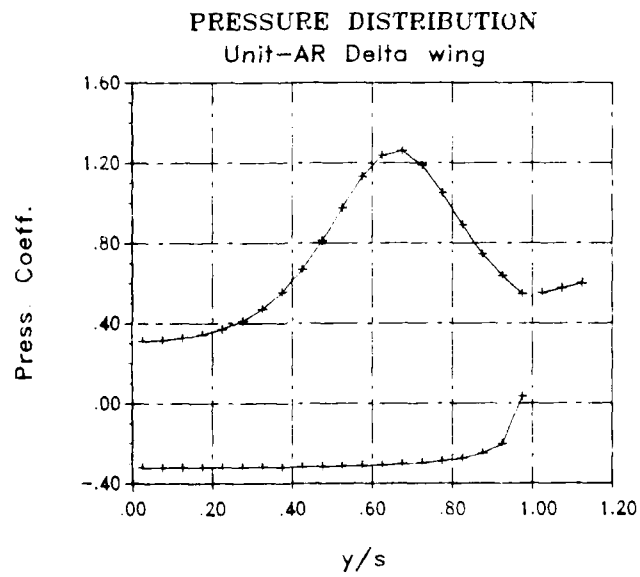
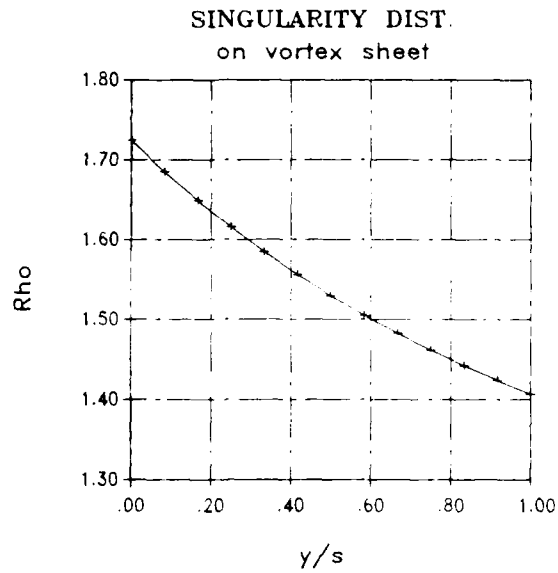


Figure 2. Results from VCURVS/VGRAPH tutorial.

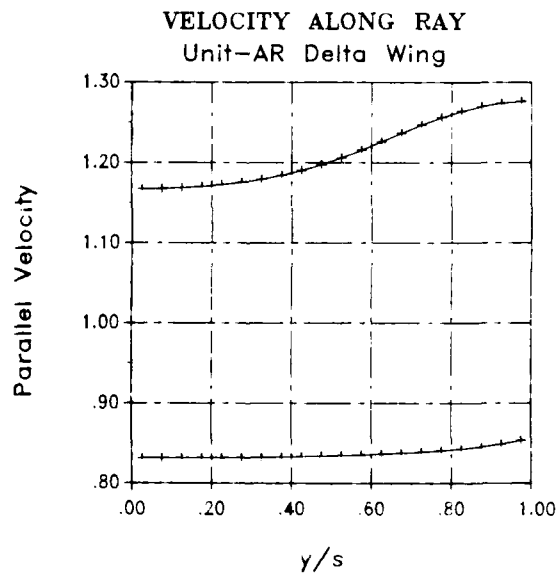
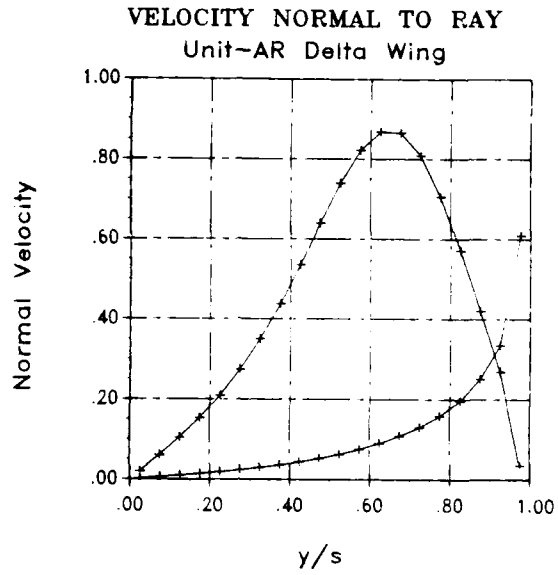


Figures 3(a) & (b). Plotted results from the NLR example case.





Figures 3(c) & (d) Plotted results from the NLR example case.



Figures 3(e) & (f). Plotted results from the NLR example case.

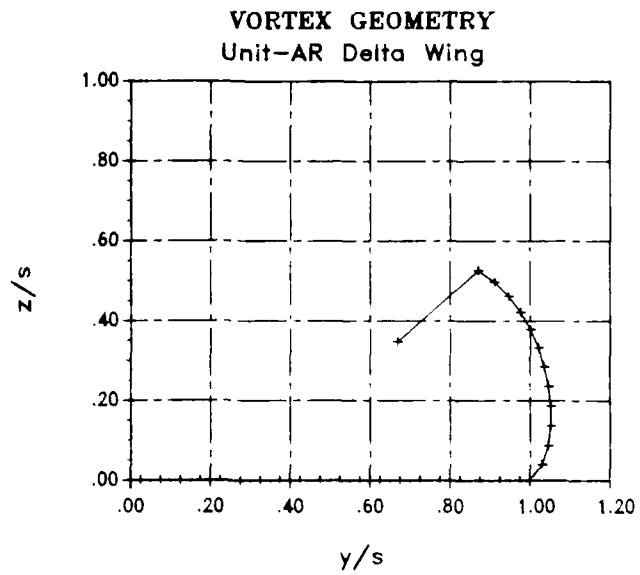


Figure 4. NLR example geometry plot.

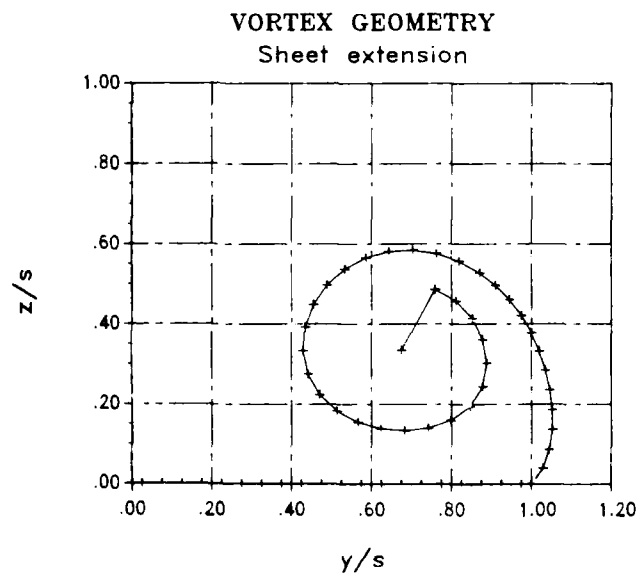


Figure 5. Free vortex sheet extension.

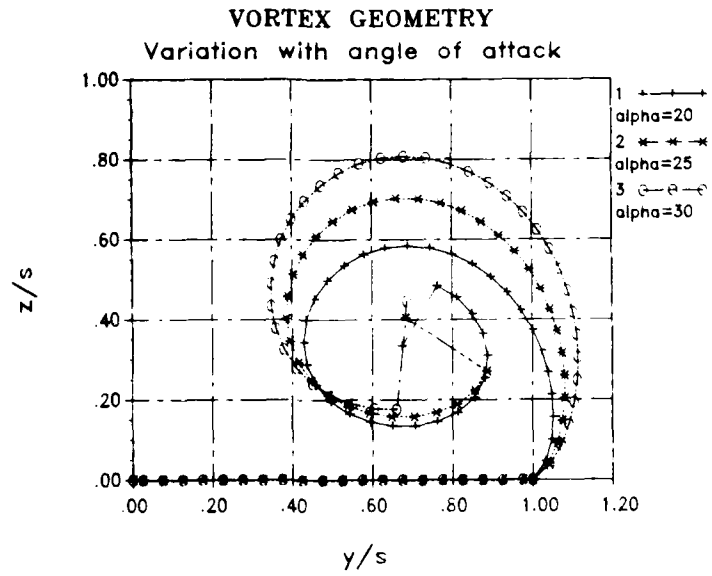


Figure 6. Effect of varying angle of attack.

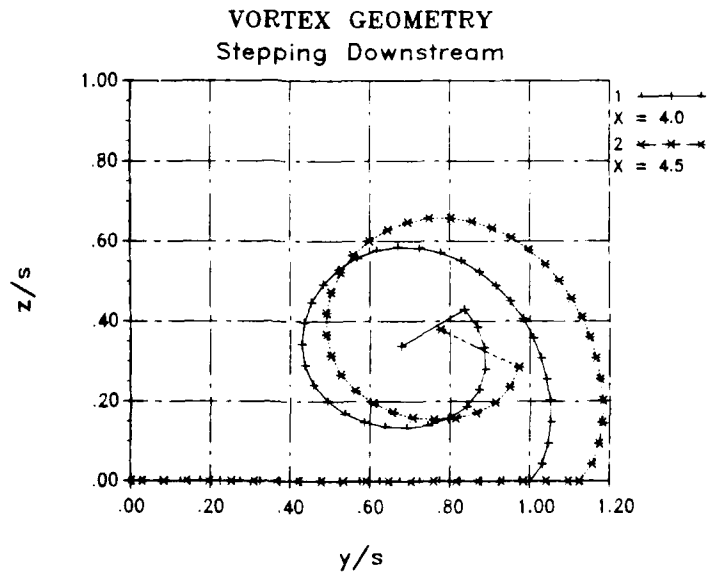


Figure 7. Multiple streamwise stations.

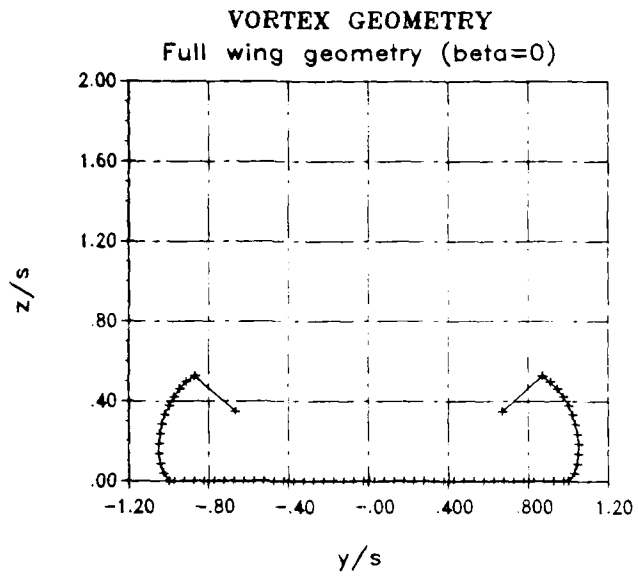


Figure 8. Full wing geometry with no assumed symmetry.

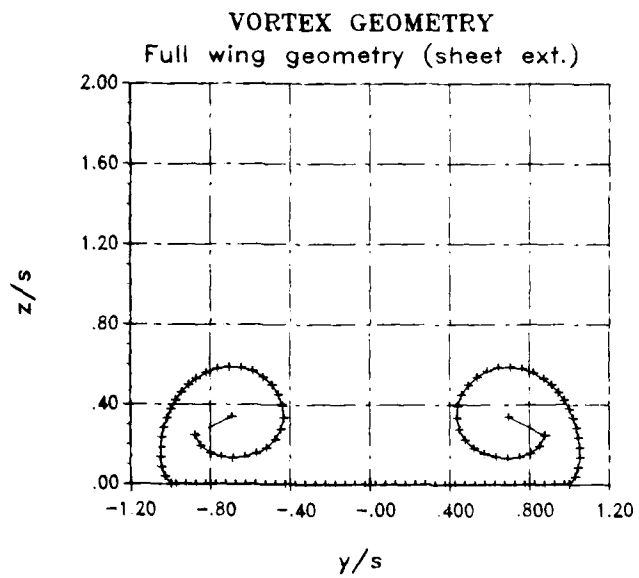


Figure 9. Free vortex sheet extension (no assumed symmetry).

VORTEX GEOMETRY  
Variation with sideslip

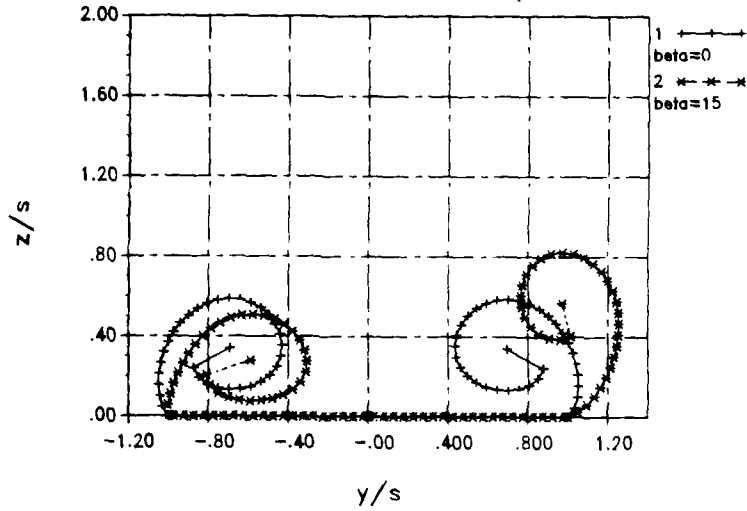


Figure 10. Effect of varying angle of sideslip.

PRESSURE DISTRIBUTION  
Variation with sideslip

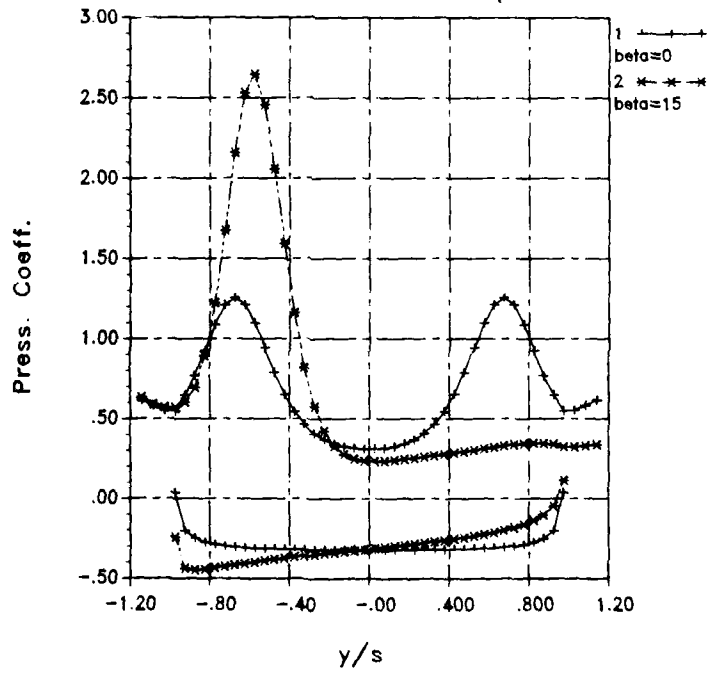


Figure 11. Pressure variation with sideslip angle.

VORTEX GEOMETRY  
Variation with wing cross-sect.

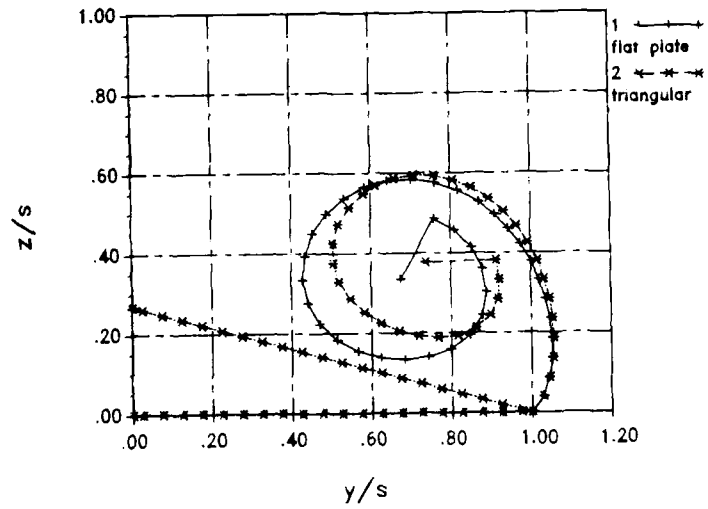


Figure 12. Effect of altering wing cross-sectional geometry.

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16. ABSTRACT The Vorsba computer program is used to calculate the incompressible vortex flow about slender wing configurations. Three programs have been written to enable the user (especially the beginner) to run VORSBA more efficiently. These include an input preprocessor, an output file handling program and a graphical output routine. A comprehensive set of examples is also given which can be used as a basis of solution for many problems that are likely to be encountered.			

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