

THE SOARING EDGE

SAILPLANE DESIGN PROGRAM Version 5.0

Software for Performance Analysis of Radio-Controlled Sailplanes

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INTRODUCTION

The Sailplane Design Program Version 5.0 (SDP) for the IBM-PC can be used to predict the performance of radio-controlled sailplanes. Using SDP, the designer can easily compare aerodynamic performance of different sailplane designs and produce output in both numerical and graphical form. Here are some of the program's features:

- The analysis results for up to 5 designs may be compared simultaneously.
- Data for up to 100 sailplane designs and 100 airfoils may be saved on one disk.

- A drawing of the sailplane may be produced on either the screen or printer.
- A plot of the airfoil data may be produced on either the screen or printer.
- Sailplane and airfoil data can be entered and edited from one screen, using a highlighted cursor controlled with the arrow keys.
- Units can be toggled between English and Metric with one keystroke.

System Requirements

- IBM-PC, XT, AT, PS/2, and most compatible computers.
- PC-DOS or MS-DOS version 2.0 or later.
- At least 256K of free memory is required.
- Monochrome or Color Monitor.
- Hercules, CGA, EGA, or VGA graphics card (Optional).
- Epson or compatible 9 or 24 pin printer (Optional).

Program Description

All programs and support files are provided on one 3-1/2 inch double sided, high density (1.44 Mb) floppy disk. The data files on the distribution disk are listed below:

SDP50.EXE - The main program that performs the sailplane and airfoil data entry, design analysis, and data output.

AIRFOIL.EXE – A program for entering and manipulating airfoil data from the Selig, Donovan, and Fraser airfoil data published in Soartech 8⁽¹⁾.

DATA45.EXE – A program that creates blank data disks to store both design data and airfoil data. Can be used either with a floppy disk or hard disk.

DESIGN 1-10.DAT – Starter sailplane design files for the following sailplanes: Aquila, Camano 100, Drifter II, Frisky II, Olympic II, Paragon, Sagitta 600, Sagitta 900, Sailaire, and Windsong.

DESIGN.LST – ASCII list file containing names for each design file.

AIRFOIL 1-20.DAT – Starter airfoil data files for the following airfoils: Eppler 214^(T), Clark-Y^(T), Eppler 205^(T), Wortmann FX 60-126^(T), Selig S-4233-136^(T), MB 253515^(T), Eppler 193^(T), Eppler 211^(T), Quabeck HQ 2.5/9^(T), Quabeck HQ 1.5/9^(T), Eppler 387^(T), Eppler 374^(T), Quabeck HQ 2.5/9^(T) Flapped, Quabeck HQ 2.5/9^(T) Flapped, Quabeck HQ 1.5/9^(T) Flapped, Quabeck HQ 1.5/9^(T) Flapped, Eppler 214^(M), Eppler 205^(M), Selig S-2091-101-83^(T), and Selig S-3091-095-84^(T).

Note: ^(T) = Theoretical data, ^(M)=Measured data.

AIRFOIL.LST – ASCII list file containing names for each airfoil file.

A Word about Sailplane Design

It is important for the sailplane designer to realize that any type of aircraft design involves compromise. This software package is designed to offer one means of comparison of different sailplane designs. With this idea in mind, some important preliminary considerations must be addressed before using this program, such as:

- What type of flying will the sailplane be doing? (AMA thermal duration contests, F3B, slope racing, cross-country, slope combat, Sunday afternoon sport flying, etc.)
- What limitations govern the geometry of the sailplane? (Contest rules, transportation requirements, structural considerations, flying characteristics, visibility requirements, cost, availability of materials, etc.)
- What are the performance priorities for the design? (High L/D ratio, low sink rate, spot landing ability, high launch/zoom capability, good maneuverability, stability for ease of flying, adaptability to varying weather conditions, etc.)

These are just a few considerations. Keep in mind that the aerodynamic performance of a sailplane is only one consideration in the design process, and that the most successful designs are the result of careful compromises between the areas of structures, aerodynamics, transportability, size constraints, etc.

There are several good articles and books that deal with sailplane design. For more information, see the Appendices and References at the end of this manual. Good luck!

GETTING STARTED

The distribution disk is not copy protected. You should copy all programs and data files to a "working" disk and use the distribution disk as a backup.

Making a backup copy of the program disk

You will need a formatted 3-1/2 inch high-density (1.44MB) diskette. Be sure the diskette is blank!

Insert the distribution diskette into the A floppy drive and type:

```
C:\diskcopy a: a:      <ENTER>
```

Follow the prompts, exchanging the distribution diskette and the working copy as needed. When everything is finished, label the backup diskette and put the original diskette in a safe place.

Making data disks

These instructions are for creating individual data disks. If you want to store your design and airfoil data on the same disk as the program, go to the next section titled Installing SDP.

Put the working disk in drive A and from the DOS prompt type:

```
C:\a:                  <ENTER>
A:\data45              <ENTER>
```

A title screen will appear with the copyright message and a name and address of whom to call in case of any problems. Press any key to display the main menu. Move the highlight bar with the <UP> and <DOWN> arrow keys, followed by <ENTER> to activate a menu selection.

Now, select the appropriate destination for the data files to be placed. Any disk drive may be selected. Note that not specifying a destination drive will cause the blank data disk files to be placed on

the current working disk drive. After specifying the destination for the files, select Make Data Disk for Current Disk Drive from the main menu.

WARNING: Be careful not to overwrite an existing data disk, especially when data is stored in a hard disk directory, as recovering a lost data disk header file is difficult!

If you have selected floppy drive A as the destination for the data files, remove the working disk first and place a newly formatted disk in its place.

The program will put the necessary data files on the blank disk in drive A. Data disks will eventually get full, so it would be a good idea to make several disks at once, label them accordingly, and store them in a safe place.

When finished, select Exit Program to quit.

Installing SDP

First, create a sub-directory called SDP50 from the DOS prompt. Type the commands:

```
C:\cd\                 <ENTER>
C:\md sdp50            <ENTER>
```

These commands will create the sub-directory. Now, put the working copy of the program disk in drive A and copy all program files into the sub-directory by using the commands:

```
C:\cd\sdp50            <ENTER>
C:\SDP50\copy a:*. *   <ENTER>
```

Running SDP

The first thing to do is run GRAPHICS.COM from DOS. GRAPHICS.COM is a program that allows screen printouts to be made from a high-resolution video screen on a printer. It is a DOS program that is included in your operating system. Please see your DOS manual for any options that may be needed for the particular

printer being used. To run GRAPHICS.COM, type the following at the DOS prompt:

```
C:\graphics      <ENTER>
```

If the program is not in the path or cannot be found, please refer to your DOS manual for more information. The Sailplane Design Program does not require GRAPHICS.COM to run, but without it, cannot make high resolution screen prints of graphics screens.

If you are using Windows 95/98, you shouldn't need to run GRAPHICS.COM, as Windows will handle all of the printing tasks.

After completing the starting procedures outlined above, the program can be run with the following commands:

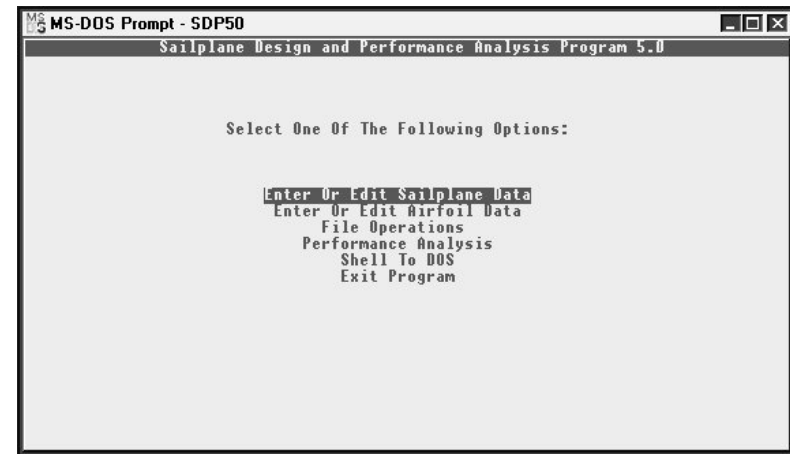
```
C:\cd\sdp50      <ENTER>
C:\SDP50\sdp50 A: <ENTER>
```

Note: The argument on the command line (A: after the command SDP50) is the path for the data disk! This can be any valid DOS path (i.e. C:\SDP50\DATA or A:). If the program resides in the same place as the data, no command line argument is needed.

If the same data path is going to be used, a batch file (or shortcut in Windows) may be useful to ease starting the program. See your DOS or Windows documentation for more information about batch files.

Getting around in the program

A title screen will appear with various copyright notices, along with a reminder to run GRAPHICS.COM to have graphics printing capability. Press any key to remove the screen and display the main menu. If you forgot to run GRAPHICS.COM before starting the program, select Exit Program, press 'E' to exit, and run GRAPHICS.COM before continuing. The opening screen should look like the following:



Throughout the program, several keys can be used for control and data entry. The <UP>, <DOWN>, <LEFT>, and <RIGHT> arrow keys can be used to move the highlight bar. The <PgUp> and <PgDn> keys can be used to change the active data "page" in memory. The data page contains data and analysis results for each design stored in memory. The <HOME> and <END> keys can be used to quickly move the highlight bar to the beginning or end of a data screen. The function key <F5> can be used to output data to screen or printer. The function key <F10> can be used to move from one screen to another or to exit from a particular screen. The <ENTER> key is used to execute options or enter data. A highlighted bar at the bottom of the screen will summarize these keys and their functions.

For the main menu, use the <UP> and <DOWN> arrow keys to highlight the desired selection and the <ENTER> key to execute it.

The rest of the manual will be written in a tutorial style so that the program's features may be learned through examples. In the following tutorial, a sample design will be entered from the keyboard, displayed on the screen, and its data printed on the printer. Airfoil data will then be edited, displayed on the screen, and printed on the printer. The example design will then be saved to disk, recalled into a different page in memory, edited, re-saved to disk, and then the

original deleted from disk. Finally, the two designs will be analyzed simultaneously using both graphs and tabular data.

See the Appendices at the end of the manual for additional information about the technical details and practical uses of the program.

TUTORIAL

Entering and editing sailplane data

Select Enter or Edit Sailplane Data from the main menu. A screen will appear like the one shown below:

```
MS-DOS Prompt - SDP50
Sailplane Physical Data Entry Screen
Page 1
Sailplane Name: [ ] Airfoil: [ ]
Weight: 0.0 (oz) Launch Height: 0 (feet) Units: English
WING Root Chord: 0.0 (in) CG Location: 0.0 % Of Wing Root Chord
Seg # Wing Span (in) Wing Outer Chord (in) Wing Tip Displacement (in)
1 0.0 0.0 0.000
2 0.0 0.0 0.000
3 0.0 0.0 0.000
4 0.0 0.0 0.000
5 0.0 0.0 0.000
Width Between Wings: 0.00 (in) Planform Correction Factor: 0.000
STABILIZER Span: 0.0 (in) Root Chord: 0.0 (in)
Leading Edge Displacement: 0.0 (in) Tip Chord: 0.0 (in)
FUSELAGE Length: 0.0 (in) Tail Moment: 0.0 (in)
Wetted Area: 0.0 (sq in)
RUDDER Height: 0.0 (in) Area: 0.0 (sq in)
F10-Continue F5-View Design PgDn-Next Page
```

To perform the necessary performance computations, all design parameters must be present in the computer memory. Start by entering a name for the sailplane. Since the highlight bar is already beside the Sailplane Name entry, type EXAMPLE 1. Pressing either <ENTER>, <UP>, or <DOWN> will cause the name to be entered and the highlight bar will move to the next entry. Now enter a value for the weight, say 96.0. Notice the digits slide into the field from the right as you type. This field is pre-formatted to contain one digit to the right of the decimal point (XX.X). With this system of entering data, you don't even have to type the decimal point, because it is already in place.

Go ahead and move to the next field, the Launch Height. Enter the number 5000 and move to the next field. Oops! Instead of 5000, we should have entered 500. Go back to the field with the arrow keys and re-type 500. The new value replaces the old one. Also notice that if you make a mistake while entering the value, the

<BACKSPACE> key can be used to correct the mistake before the highlight bar is moved to the next field.

The next field, Units, is used to control the unit system attached with a particular design. The <UP> and <DOWN> keys are used to toggle the units. Try it now. Notice the weight change from ounces to kilograms and back as the arrow keys are pressed. The units can be changed at any time just by moving to this field with the <LEFT>, <RIGHT>, or <ENTER> keys and then pressing the <UP> or <DOWN> keys.

Now, try entering all the values shown below using the arrow keys and the numeric keypad:

```
MS-DOS Prompt - SDP50
Sailplane Physical Data Entry Screen
Page 1
Sailplane Name: EXAMPLE 1 Airfoil: E214C-PT
Weight: 96.0 (oz) Launch Height: 500 (feet) Units: English
WING Root Chord: 10.0 (in) CG Location: 36.0 % Of Wing Root Chord
Seg # Wing Span (in) Wing Outer Chord (in) Wing Tip Displacement (in)
1 36.0 8.5 1.125
2 36.0 5.5 2.250
3 0.0 0.0 0.000
4 0.0 0.0 0.000
5 0.0 0.0 0.000
Width Between Wings: 2.50 (in) Planform Correction Factor: 1.120
STABILIZER Span: 30.0 (in) Root Chord: 6.0 (in)
Leading Edge Displacement: 2.0 (in) Tip Chord: 4.0 (in)
FUSELAGE Length: 56.7 (in) Tail Moment: 23.4 (in)
Wetted Area: 467.0 (sq in)
RUDDER Height: 12.0 (in) Area: 67.8 (sq in)
F10-Continue F5-View Design PgDn-Next Page
```

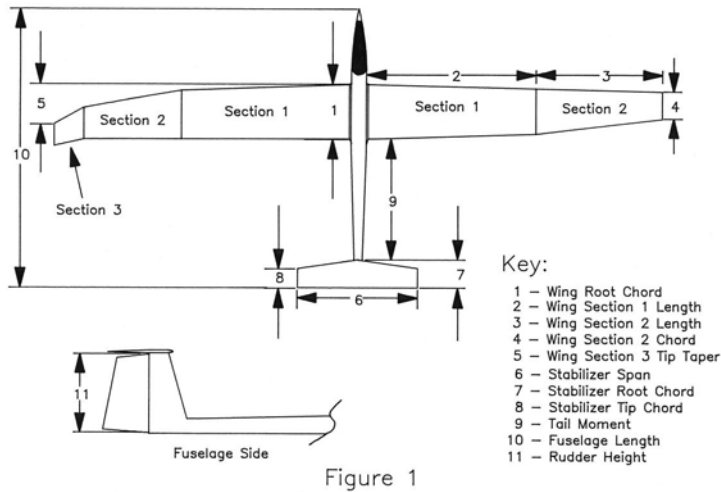
Keep in mind that any changes made to the data need to be saved to disk to be preserved. Refer to the section of the tutorial about saving airfoil data to disk for more details.

Here are some notes to further explain some of the parameters:

- The Width Between Wings is the average distance between the two wing halves (left and right) measured at the fuselage junction. If the wings plug into the sides of the fuselage, then the width between wings is the average width of the fuselage at the point of wing attachment. If the wing halves join together and

then are mounted on top of the fuselage, then the width between wings should also be the average fuselage width.

- One wing half panel may be divided into five sections for data entry. By using this method, odd planforms may be easily approximated. The only drawback is that data files created from versions of the program prior to (but not including) version 4.0 become obsolete.
- When entering data for the wing, any values for the Wing Tip Displacement may be used. Forward swept wings may be entered using negative values of wing tip displacement. The tip displacement is always measured relative to the leading edge of the wing at the root. See the Figure 1 below for more details:

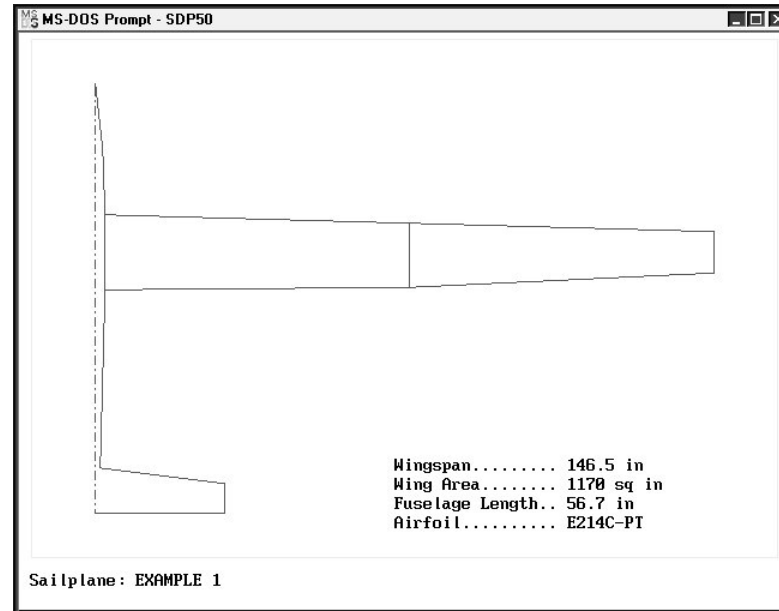


- The Wetted Fuselage Area is the ENTIRE wetted area of the fuselage. This number will equal the area of covering material required to cover the fuselage of the plane.
- The wing Planform Correction Factor is a number that multiplies the induced drag coefficient. It corrects induced drag for wing planforms that are not perfectly elliptical. The number is

ALWAYS greater than 1.0, and the limits allowed by the program are between 1.0 and 1.5. For a typical wing with a straight center section and tapered wing tips, the planform correction factor might be 1.12, representing a 12% increase in induced drag. For more information on the planform correction factor, see Martin Simon's article on performance prediction with a programmable calculator in Soartech 1⁽²⁾.

Drawing a sailplane design on the screen

After completing the data entry, press the <F5> key to see the design drawn on the screen. The EXAMPLE 1 design is shown below:



Printing a sailplane design on a printer

While the sailplane drawing is on the screen, press <SHIFT> and <PrtScr> simultaneously. The drawing should begin printing immediately. If not, be sure the printer is turned on and ON LINE. Before using this option, please be sure the GRAPHICS.COM program is loaded into memory! When the printout has finished, press any key to return to the data entry screen.

Notice that pressing <PgDn> will change the current page in memory. The original data entered on page 1 is still there and can be recalled with <PgUp>. New data can be entered on page 2 just as it was entered on page 1. There are a total of 5 pages available for sailplane data. Browse through the pages now with <PgUp> and <PgDn>. Return to page 1 when you are finished.

Now, press <F10> to move to the airfoil data entry screen. A list of airfoils will be placed on the screen. Move the highlight bar using the arrow keys to select the desired airfoil. Pressing <ENTER> will move the highlight bar to the lower part of the screen. Again, use the arrow keys <UP> and <DOWN> to move the airfoil to the desired page in memory. Pressing <ENTER> again will load the data. Load the airfoil named Eppler 214 into the page 1 slot.

Press <F10> to enter the specification display screen. The control <PgUp> and <PgDn> will allow the specifications for each different design to be viewed on the screen. Return to page 1 when you are finished.

Printing numerical sailplane data on a printer

To print specifications on the printer, be sure the data specification screen is displayed and the page containing the data to be printed is selected. Be sure the printer is turned on and is ON LINE and press <F5>. Try this now.

At this point, you should be able to start the program, enter data into memory, draw the design on the screen, and print the drawing and data on the printer.

Editing numerical airfoil data

Now, for the second part of the tutorial, select Enter or Edit Airfoil Data from the main menu. This option allows the airfoil data points to be displayed and edited. At the top of the screen, you will notice a highlight bar over the Airfoil Name field. The <UP>, <DOWN>, <LEFT>, <RIGHT>, <HOME>, <END>, <PgUp>, and <PgDn> keys work the same with this screen as with all others. A sample of what appears on the screen is shown below:

| Cl | Reynolds | Numbers | | | |
|------|----------|---------|--------|--------|--------|
| 0.10 | 97600 | 150200 | 199200 | 298800 | 0 |
| 0.20 | 0.0217 | 0.0159 | 0.0140 | 0.0127 | 0.0000 |
| 0.29 | 0.0190 | 0.0133 | 0.0115 | 0.0116 | 0.0000 |
| 0.39 | 0.0164 | 0.0118 | 0.0107 | 0.0112 | 0.0000 |
| 0.49 | 0.0146 | 0.0113 | 0.0104 | 0.0109 | 0.0000 |
| 0.58 | 0.0136 | 0.0112 | 0.0103 | 0.0108 | 0.0000 |
| 0.68 | 0.0139 | 0.0113 | 0.0108 | 0.0111 | 0.0000 |
| 0.77 | 0.0152 | 0.0123 | 0.0113 | 0.0116 | 0.0000 |
| 0.87 | 0.0168 | 0.0134 | 0.0120 | 0.0124 | 0.0000 |
| 0.97 | 0.0177 | 0.0140 | 0.0133 | 0.0130 | 0.0000 |
| 1.06 | 0.0182 | 0.0148 | 0.0144 | 0.0139 | 0.0000 |
| 1.16 | 0.0190 | 0.0159 | 0.0156 | 0.0151 | 0.0000 |
| 1.25 | 0.0221 | 0.0175 | 0.0176 | 0.0172 | 0.0000 |
| | 0.0259 | 0.0275 | 0.0316 | 0.0400 | 0.0000 |

Slope of Cl vs α Curve: 0.085 Theoretical Data
 Y - Intercept of Cl vs α Curve: 0.394 * Measured Data
 Pitching Moment: -0.138 Sailplane: EXAMPLE 1

↑←←-Move Bar F10-Exit F5-View F1-Print PgDn-Next Page

Move the cursor around using the arrow keys and try changing one of the data points. Notice the field is pre-formatted, and the number slides into the field from the right as it is typed. The decimal point does not need to be typed, as in the sailplane data entry fields.

Keep in mind that any changes made to the data need to be saved to disk to be preserved. Refer to the section of the tutorial about saving airfoil data to disk for more details.

Below the main data matrix are fields for the slope & y-intercept for the C_l vs. α curve. These numbers are used to calculate the decalage angle between the wing and stabilizer for a given coefficient of lift of the wing. The pitching moment coefficient is used to determine the stabilizer lift coefficient for a particular wing lift coefficient. The pitching moment is usually taken about the 1/4 chord of the wing. See Appendix C for more information.

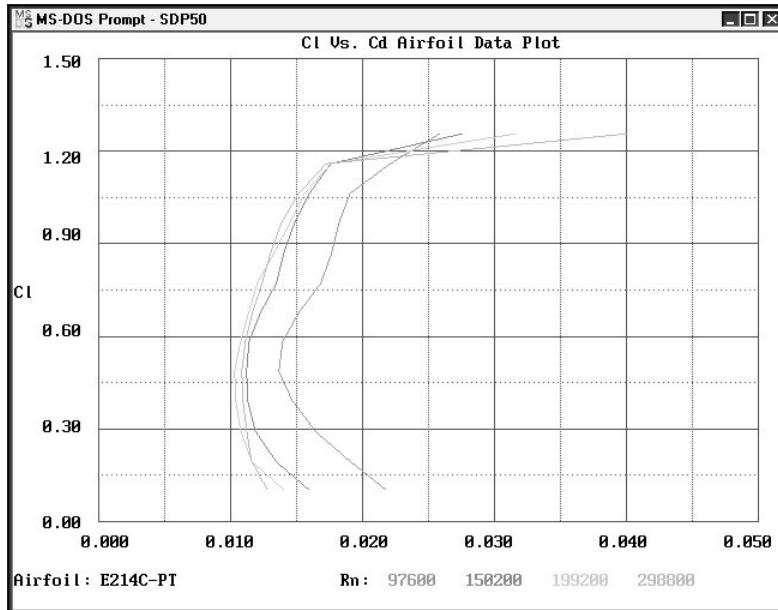
Finally, the last set of fields for either Measured or Theoretical Data can be selected by placing the cursor over the slope of C_l vs. α curve field and pressing the <RIGHT> arrow key. Now, move the <UP> or <DOWN> arrow keys to select the proper data type. This label is simply a reminder of where the type of airfoil data and does not affect the analysis results.

As with the sailplane data entry screens, the <PgUp> and <PgDn> keys can be used to change the current data page. Up to five sets of

airfoil data may be stored in memory at once, so try moving between the different pages now. Return to page 1 when you are finished.

Drawing graphical airfoil data on the screen

To view the airfoil data on the screen, simply press <F5> from the data entry screen. Try this now and see what happens. The example airfoil data should look like the following:



These curves are often referred to as airfoil polars. They represent coefficient of lift versus coefficient of drag for several different Reynolds numbers (R_n). Appendix B has more information.

Printing graphical airfoil data on a printer

While the airfoil data is displayed on the screen, press <SHIFT> and <PrtScr> simultaneously. The printout should begin immediately. If not, be sure the printer is turned on and ON LINE. Before trying this, please be sure the GRAPHICS.COM program is loaded into memory! When the printout has finished, press any key to return to the data entry screen.

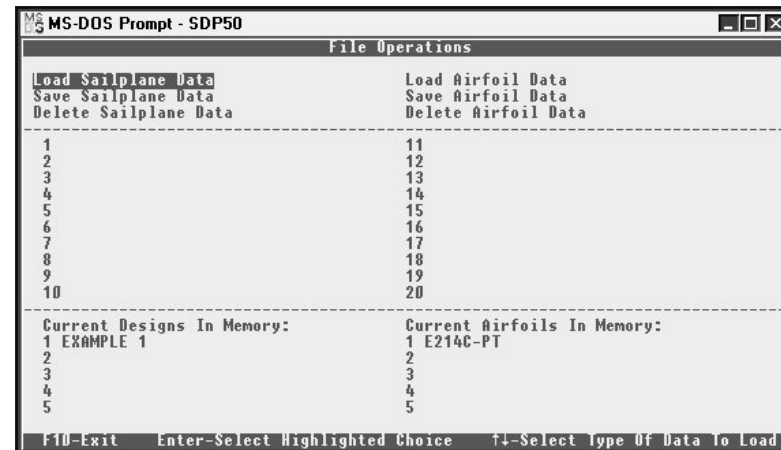
Printing numerical airfoil data on a printer

To print the numerical airfoil data on a printer, be sure the data screen is displayed and press the <F1> key. The airfoil data should start printing immediately. Go ahead and try this now.

After the printout is finished, press <F10> to return to the main menu.

Loading sailplane or airfoil data from disk

From the main menu, select File Operations. The screen will look like the one shown below:



Select the option from the top portion of the menu with the <UP> and <DOWN> arrow keys. Select Load Sailplane Data now. After pressing <ENTER>, a list of the sailplane designs available will appear in the center of the screen. Now, pressing <PgUp> and <PgDn> will scroll through the designs. Remember to use the <HOME> and <END> keys to go to the beginning and end of the page. Press <ENTER> to select the design you want. Notice that the highlight bar now moves to the lower portion of the screen. Now, select the page in memory where you wish to put the design.

Just for the fun of it, put the WINDSONG design in the first page of memory, overwriting the EXAMPLE 1 design. When <ENTER> is pressed to load the design into memory, a red warning bar appears at the bottom of the screen asking if you want to overwrite the existing

design. Press 'N' for now, and put the WINDSONG in page 2 of memory with the arrow keys. Press <ENTER> to load the design. Notice also that the design and the airfoil are loaded together.

To go back to the top level of the screen, press <F10>. Now you are ready to load another design or airfoil. Let's change the airfoil of EXAMPLE 1 from Eppler 214 to the Selig S-3021-095-84 using the same keystrokes and techniques as before.

From the top of the screen, select Load Airfoil Data with the <DOWN> arrow key. Press <ENTER>. Now use <PgUp> and <PgDn> to select the Selig S-3021-095-84 airfoil from the list. Pressing <ENTER> again moves the highlight bar to the page 3 slot in memory. Move the highlight bar to page 1 and press <ENTER>. Answer the red warning bar with 'Y' this time to overwrite the existing airfoil data. Again, press <F10> to go to the top of the screen.

Saving sailplane or airfoil data to disk

Now, try saving the EXAMPLE 1 design in page 1 of memory to disk. Select Save Sailplane Data. Position the highlight bar over EXAMPLE 1 from page 1 in memory and press <ENTER>. The design is now saved to the disk. Simple, huh?

Deleting sailplane or airfoil data from disk

To delete sailplane data from disk, select Delete Sailplane Data. Position the cursor over EXAMPLE 1, this time in the middle of the screen. Press <ENTER> and answer the red warning bar question with 'N', indicating that the design will be not be deleted. Now, press <F10> to return to the main menu. The same procedure can be repeated for the airfoil data, also.

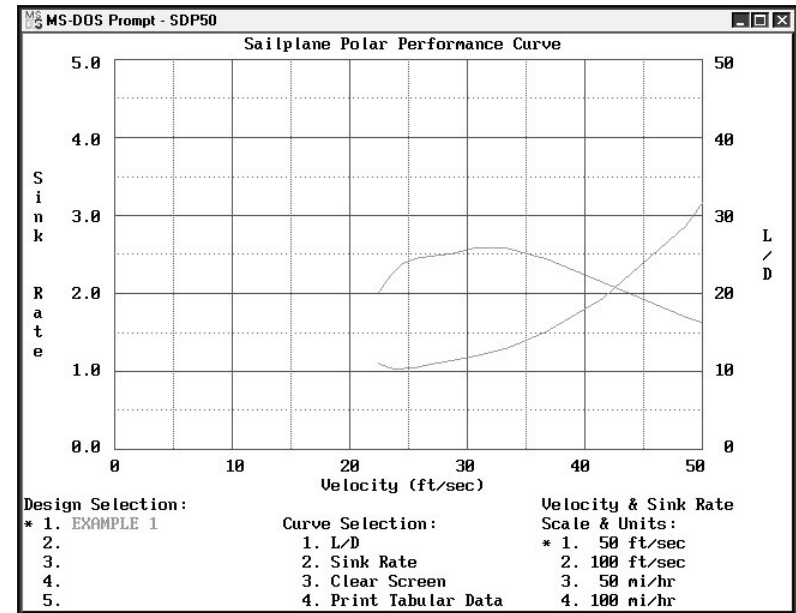
Deleting sailplane or airfoil data from memory

To delete sailplane data from memory, select Load Sailplane Data. Position the cursor over any blank entry in the list (such as design number 100). Press <ENTER> and position the blank bar over the design you wish to delete. For now, let's put the bar over the WINDSONG design. Press <ENTER> and answer the "Clear Sailplane Data From Memory" question with 'N', indicating that the design will not be deleted. Now press <F10> to return to the main

menu. The same procedure can be repeated for the airfoil data, if needed. This option is helpful for removing unwanted data from memory.

Drawing graphical analysis data on the screen

Select Performance Analysis from the main menu. As the each design in memory is analyzed, the progress will be displayed on the screen. When finished, the following graphic screen will appear:



Notice the blinking asterisk beside EXAMPLE 1 under the Designs heading. This asterisk can be controlled with the <UP>, <DOWN>, <LEFT>, and <RIGHT> arrow keys. Notice also that each column has its own non-blinking asterisk that indicates the current selection for Design, Curve Selection, and Scale & Units. The <ENTER> key is used to draw a curve for the combination of selections made by the user.

Lets draw a curve of the sink rate for the sailplane EXAMPLE 1 on a velocity scale of 100 ft/sec. The design selection is already made for EXAMPLE 1, so move the asterisk to the <RIGHT> and then

<DOWN> so that the blinking asterisk is on Sink Rate under Curve Selection. Now, move <RIGHT> again to go to the Scale & Units selection. Move <DOWN> to select 100 ft/sec. Now press <ENTER>. A solid curve should appear which will be the sink rate versus velocity for EXAMPLE 1.

Now, using the same technique, put the L/D curve for the same design on the screen. These curves don't do much good unless they are compared with another design of known performance. Try putting the same set of curves on the screen for the WINDSONG. Notice that the color of the curves matches the name of the sailplane on the screen.

If the screen gets too cluttered or messy looking, select the third option under Curve Selection: Clear Screen. This will clear all the curves from the screen.

Printing graphical analysis data on a printer

While the analysis data is displayed on the screen, press <SHIFT> and <PrtScr> simultaneously. The drawing should begin printing immediately. If not, be sure the printer is turned on and ON LINE. Before using this option, please be sure the GRAPHICS.COM program is loaded into memory!

Displaying numerical analysis data on the screen

The fourth option under Curve Selection is Print Tabular Data. When the center asterisk is placed on this option, a set of tabular data will be displayed when <ENTER> is pressed. Be sure the correct design and units are specified under the Design and Scale & Units headings, also. A sample screen printout appears in the next column:

The screenshot shows a window titled 'MS-DOS Prompt - SDP50' with a sub-header 'Sailplane Design Analysis Tabular Printout'. The main content is a table with columns: CLW, U (ft/sec), L/D, VS (ft/sec), and TIME. The data rows show values for CLW from 0.10 to 1.25, U from 93.94 to 22.41, L/D from 5.24 to 20.20, VS from 17.92 to 1.11, and TIME from 0 Min 27 Sec to 7 Min 30 Sec. Below the table, summary statistics are listed: Gross Weight (96.00 oz), CG Location (36.0 % of Wing Root Chord), Airfoil (E214C-PT), Wing Loading (11.82 oz/sqft), and Decalage Angle For Highlighted CLW (0.16°). At the bottom, navigation instructions are provided: ↑↓-Move Cursor, F5-Print, F10-Exit, PgDn-Next Page.

| CLW | U (ft/sec) | L/D | VS (ft/sec) | TIME |
|------|------------|-------|-------------|--------------|
| 0.10 | 93.94 | 5.24 | 17.92 | 0 Min 27 Sec |
| 0.20 | 60.87 | 11.17 | 5.45 | 1 Min 31 Sec |
| 0.29 | 48.43 | 17.01 | 2.85 | 2 Min 55 Sec |
| 0.39 | 41.42 | 21.61 | 1.92 | 4 Min 20 Sec |
| 0.49 | 36.77 | 24.40 | 1.51 | 5 Min 31 Sec |
| 0.58 | 33.41 | 25.82 | 1.29 | 6 Min 26 Sec |
| 0.68 | 30.82 | 25.82 | 1.19 | 6 Min 58 Sec |
| 0.77 | 28.76 | 25.13 | 1.14 | 7 Min 17 Sec |
| 0.87 | 27.06 | 24.80 | 1.09 | 7 Min 38 Sec |
| 0.97 | 25.63 | 24.39 | 1.05 | 7 Min 55 Sec |
| 1.06 | 24.41 | 23.74 | 1.03 | 8 Min 6 Sec |
| 1.16 | 23.34 | 22.20 | 1.05 | 7 Min 55 Sec |
| 1.25 | 22.41 | 20.20 | 1.11 | 7 Min 30 Sec |

Gross Weight..... 96.00 oz
CG Location..... 36.0 % of Wing Root Chord
Airfoil..... E214C-PT
Wing Loading..... 11.82 oz/sqft
Decalage Angle For Highlighted CLW..... 0.16°

↑↓-Move Cursor F5-Print F10-Exit PgDn-Next Page

This analysis printout is called the performance map. CLW is the coefficient of lift of the main wing, V is the velocity of the sailplane, L/D is the predicted lift to drag ratio, VS is the vertical sink rate, and TIME is the theoretical flight time expected from the specified launch height.

It must be remembered that these values are theoretical and they are not to be taken literally! The value of the analysis is in the general patterns it produces, not in the actual values. For example, if a general trend toward better L/D is seen with the addition of extra weight on a particular design, then this trend probably will be true in actual practice. For practical uses of the analysis output, refer to Appendix A.

Printing numerical analysis data on a printer

To print the numerical analysis data on a printer, be sure the data screen you wish to print is displayed and press the <F5> key. The data should start printing immediately. Go ahead and try this now. After the printout is finished, notice the differences between the screen printout and the printer hardcopy. An extra column is added to the printer output that is the decalage angle. For each coefficient of lift of the wing, a certain angle between the wing and stabilizer is required to maintain equilibrium. This angle is printed on the numerical printout. Notice now that the final line on the screen shows the same information, but only for the highlighted row on the

analysis screen. Scroll through the values with the <UP> and <DOWN> arrow keys. Try this now.

To exit from the numerical analysis back to the graphical analysis, press <F10>.

Shelling to DOS and exiting the program

The DOS shell is a neat tool to use when you want to go to DOS to execute a few commands without having to save the data and exit the program completely.

To activate the shell, select Shell to DOS from the main menu. The DOS prompt will appear. Once finished with any DOS commands you want to do (such as getting a directory, changing the active disk drive, or copying or deleting a file), type 'EXIT' to return to the main menu of the program. Try this now.

Please note that the GRAPHICS.COM program must be run BEFORE running the design program, not from a shell to DOS. The screen printouts will be blank if GRAPHICS.COM is run from the Sailplane Design Program shell.

To exit the program, select Exit Program from the main menu. As shown on the screen, pressing 'E' will exit from the program to DOS, while pressing any other key will go to the preserve/reset routine. This handy feature allows ALL data in memory to be either erased or preserved. Press 'P' to preserve the current variables, or press 'R' to erase all variables. Be sure any data you wish to save is saved before using the reset option of the exit routine!

At this point, you should feel comfortable using the program and doing basic data entry and performance analyses. There are many more things that can be found through trial and error by using the program to analyze real-world sailplanes and then to help design new ones. Have fun and good luck!

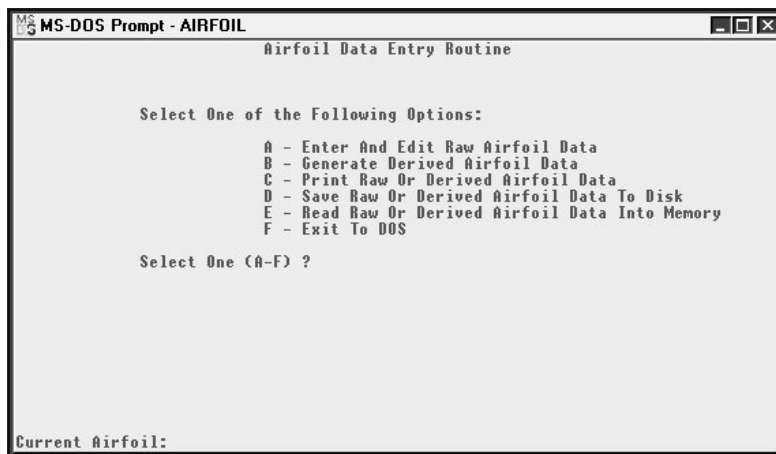
The AIRFOIL Program

The AIRFOIL program allows the wind tunnel data produced by Selig, Donovan, and Fraser to be entered from the tables published in Chapter 13 of Soartech 8⁽¹⁾. The data can then be converted into a format that can be used by the Sailplane Design Program. The raw data is available directly from the tabulated data in Chapter 13 and the derived data file is an interpolated version where the coefficients of lift have been standardized and resulting coefficients of drag have been interpolated using a linear interpolation method. Both the raw data and the derived data can be saved to disk.

The program must be run from DOS and can only be started after exiting from the Sailplane Design Program. At the DOS prompt, type:

```
C:\airfoil <ENTER>
```

The main menu for this program, which will appear when the program starts running, is shown on the following page:



```
MS-DOS Prompt - AIRFOIL
Airfoil Data Entry Routine

Select One of the Following Options:

A - Enter And Edit Raw Airfoil Data
B - Generate Derived Airfoil Data
C - Print Raw Or Derived Airfoil Data
D - Save Raw Or Derived Airfoil Data To Disk
E - Read Raw Or Derived Airfoil Data Into Memory
F - Exit To DOS

Select One (A-F) ?

Current Airfoil:
```

A couple of general notes about the AIRFOIL program are in order. First, it is designed specifically for entering and editing Selig, Donovan, and Fraser wind tunnel data. The raw form of the data as it appears in Chapter 13 of Soartech 8⁽¹⁾ CANNOT be used by the Sailplane Design Program because the coefficients of lift are not

equal for different values of R_n . The raw data must be entered into memory and the usable data derived. A common range of coefficients of lift must be found for all R_n and then each set of drag data must be linearly interpolated to find values for the coefficient of drag at each coefficient of lift. This process is entirely automatic and is done when the user selects Option B - Generate Derived Airfoil Data from the AIRFOIL program's main menu. After the data has been derived, it can be printed, checked, and saved to disk. The derived data files and the raw data files are tagged so the Design Program can only use the derived data files. These data file checks are done automatically.

The same menu structure is kept in the AIRFOIL program as in the Sailplane Design Program. Each option will be discussed in detail in the sub-sections to follow:

Option A - Entering and Editing Raw Airfoil Data. This option allows data to be entered and edited directly from the tabulated tables located in Chapter 13 of Soartech 8⁽¹⁾. The name is first entered, and a screen appears that is formatted like the listings in the book. A highlighted bar can be moved around the screen with the arrow keys or the enter key. Simply type the number into the field highlighted by the highlight bar. As with the data entry of the Sailplane Design Program, the decimal points and number fields are pre-formatted and that the numbers 'slide' in from the right to left. Please note that all data in the tables must be typed in. Press <F2> to enter the next set or <F1> to edit the previous set of R_n . A maximum of five R_n can be entered. After all data has been entered, press <F10> to exit the routine. Finally, enter the pitching moment coefficient. Note that the raw data can also be edited using this option after it has been saved.

Option B - Generate Derived Airfoil Data - This option allows the user to generate interpolated data that is usable by the Sailplane Design Program. An option to change the name of the airfoil is given, so that the user can rename the derived data to distinguish it from the raw data.

Option C - Printout Raw or Derived Data - This option allows either the raw or derived data to be printed on a printer. If both raw and

derived data are contained in memory, the program will ask which to printout.

Option D - Save Raw or Derived Data to Disk - This option allows the user to save either the raw or derived data to the data disk for later recall. Be sure to use different airfoil names to distinguish the raw data from the derived data, as raw data cannot be used in the Sailplane Design Program. If the airfoil name already exists, the program will ask if you want to overwrite the existing file.

Option E - Read Raw or Derived Airfoil Data from Disk – This option allows the user to read previously saved data from the disk into memory. If the data is raw, the program will load it into memory as raw data. Likewise, if the data is derived, the program will load it as derived data. The page features work the same as the paging for the Enter or Edit Airfoil Data option in the Sailplane Design Program's main menu.

Option F - Exit to DOS - This option allows the user to exit to the DOS prompt. If any data is in memory that has not been saved, the user is warned before exiting so that the data can be saved if need be.

APPENDICES

Appendix A - Description of the Analysis Process

The analysis process is a combination of many different routines. First, Eric Lister's *Sailplane Designer's Handbook* ⁽³⁾ has been a tremendous influence in a great number of the computational routines in the program. Secondly, Martin Simon's article in *Soartech 1* ⁽²⁾ provided the interpolation routine for computing the profile drag coefficient of the main wing, as well as equations for computing profile drag of the stabilizer, rudder, and fuselage.

The first thing the routine does is to assign a coefficient of lift for the main wing. Next, the coefficient of lift for the stabilizer is computed using an equation from Lister. Following that, the velocity is computed, followed by stabilizer induced drag. Reynolds numbers are computed next for each segment of the main wing, the stabilizer, the vertical fin/rudder, and fuselage. Again, equations from Lister are employed.

The wing profile drag coefficient is calculated next. The routine, adapted from Martin Simon's article on performance computation from *Soartech 1* ⁽²⁾, fits a parabolic curve between R_n at a coefficient of lift to find a coefficient of drag. Extrapolation routines are employed in case a R_n for any particular section falls outside the range of available data. This parabolic interpolation routine is used for each wing section and the resulting coefficients of drag are then reduced to a single coefficient of drag using a weighted averages technique based on the wing area of the particular section. The routine starts by finding a R_n lower than that computed for the particular wing section and estimating the coefficient of drag. Next, a higher R_n is found and the estimation of the coefficient of drag is made again. Then the two estimates are combined in one equation to produce a final coefficient of drag for the wing section.

When reading the detailed analysis printout, the wing section R_n is given, along with the high and low estimates for R_n and coefficients of drag. The column labeled EF is for the extrapolation flag. When an L or an H appears, it indicates an extrapolation has been made

beyond the highest or lowest given R_n . Data that has been extrapolated should be treated with care.

The profile drag coefficients for the stabilizer, rudder, and fuselage are computed next. Here, the Blasius equation ⁽⁴⁾ for the turbulent drag of a flat plate is used. The drag is dependent on the R_n of the surface as well as its surface area. Next, the lift to drag ratio (L/D) for the entire sailplane is computed using an equation from Lister. It uses the coefficient of lift for the wing and stabilizer, the coefficients of profile and induced drag for the wing and stabilizer, and the profile drag coefficients of the vertical fin/rudder and fuselage. Once the L/D has been computed, the sink rate is computed by dividing the velocity by the L/D. Finally, the sink rate is used to compute a theoretical flight time from a given starting altitude (launch height). Keep in mind that all values can be used for comparison, but should NOT be taken literally. The trends that are produced are far more important than the actual values.

All of the preceding steps are carried out for one particular coefficient of lift. During a typical performance analysis, there may be 10 to 12 coefficients of lift, so you can readily see the value of the computer when doing sailplane performance calculations.

Some modifications that I have been thinking of have to do with the wing profile drag interpolation routine. An interpolation routine suggested by W.M.J. Schlosser and J.P.A. Schlosser for finding drag coefficients at low R_n in *Soartech 5* ⁽⁵⁾ is now being looked at. The routine that they suggest involves a full logarithmic fit, which seems to provide a very close approximation to the data points. The only problem is that there is no extrapolation routine, although this problem can be easily overcome. Chuck Anderson of Tullahoma, TN has suggested taking the slope of the last two data points and using the resulting line to find the drag value. The method proposed by the Schlossers is rather simple, and looks to be quite effective. I will be trying this routine in the program and possibly offering it as an option in the future.

Appendix B - Practical Applications of the Program

There are several practical applications of the Sailplane Design Program. The multiple analysis routine provides valuable data for several different wing loadings, just the thing to look at loading ballast into a design. The polar curves for several wing loadings can be gathered and assembled onto a graph of velocity versus sink rate versus wing loading. Thus you can find the optimum wing loading for the best L/D or best minimum sink rate at a given sailplane velocity.

Also, as mentioned in the opening paragraph in the introduction, it is neat to be able to modify existing designs and see the effects on performance. More importantly, specific TRENDS can be found, such as the effect of increasing the wing or stabilizer chords on sink rate, the effect of changing the center of gravity locations, or increasing the aspect ratio of the wing.

With the ability to add files for airfoils and sailplane designs, a constantly updated library of airfoil data and designs can be kept. The program is designed to keep pace with the changes that are occurring in current sailplane technology.

Appendix C - Technical Description of the Program

The Sailplane Design Program is a compilation of several methods of performance prediction. First, Eric Lister's Sailplane Designer's Handbook ⁽³⁾ has been a tremendous influence in the actual computation equations used in the analysis routines. Also, Martin Simon's article that appeared in Soartech 1 ⁽²⁾ provided the interpolation method for computing the profile drag coefficient of the main wing sections. For details on the analysis procedure, see section 13.

The program has undergone several changes, additions, and corrections over the past four years. First written for a TRS-80 Model I, the basic performance routines were developed and tested. Next, a version for the Apple II was developed. Both of these versions were 'stripped down' from the Commodore 64 version and the first two releases of the IBM-PC version. The first two releases

of the IBM versions were virtually identical to the Commodore 64 version. This latest version 5.0 for the IBM has changed significantly over the previous two versions and is hardly recognizable as a descendent of the original TRS-80 and Apple II versions.

Basically, the program is built of subroutines that perform different operations. Included within the program are routines to compute the quarter chord of the main wing and stabilizer, routines which allow both airfoil and design data to be saved and read from the disk, a routine to generate a polar curve on the printer, as well as several other 'housekeeping' routines. Previous versions of the design program required that the polar curve plotting routine be included as a separate program. However, in the last 2 versions of the program, all functions have been integrated into a single compiled program. The program is written in Microsoft QuickBASIC Version 7.1 and the source code is copyrighted and unavailable for distribution.

Appendix D - Differences Between Previous Versions of the Program

Several things have been changed in this version of the program. A list appears below:

- Detailed analysis routine has been added which gives more detailed information for particular coefficients of lift.
- A different wing analysis routine has been added which allows a wing half panel to be broken into five separate panels. This feature is analogous to finite element analysis available in several computer-aided design (CAD) packages.
- Polar curve plotting on the screen gives a quick look at a graph so that it can be assessed before producing a full polar curve plot on the printer.
- Alternative unit systems (English or Metric) are now supported and can be changed anytime.
- Seven printers are now supported including the Epson Fx/Mx/Rx series, Blue Chip, Gemini Star, Panasonic, NEC, C-Itoh, and IBM.

- The program is contained in one compiled module that can be executed from DOS. BASIC no longer needs to be loaded before running the program.
- The multiple analysis routine now allows a choice of either performance maps or polar curve on the screen or printer in any combination.
- The airfoil routine allows airfoil C_l vs. C_d graphs (commonly referred to as "airfoil polars") to be printed on the screen. It is easier to see gross errors this way.
- The addition of C_l vs. α airfoil data allows the calculation of decalage angles for individual coefficients of lift. If the airfoil data contains the C_l vs. α information (slope and y-intercept) then the decalage angle can be found in the detailed analysis routine for the particular coefficient of lift. Note that since the C_l vs. α curve is approximated using a straight line, the accuracy of the decalage calculation will be in error toward the highest and lowest coefficients of lift (approximately < 0.3 and > 0.9) and must be interpreted with care.
- The AIRFOIL program was introduced in Version 4.0. It allows the wind tunnel data produced by Selig, Donovan, and Fraser to be entered from the tables published in Chapter 13 of Soartech 8⁽¹⁾ and converted into a format which can be used by the Sailplane Design Program's analysis routines. Both the raw data and the derived data can be saved to disk. The raw data is a data file which is generated directly from the tabulated data and the derived data file is an interpolated version of that file where all of the coefficients of lift have been standardized and resulting coefficients of drag have been interpolated using a linear interpolation method.

Appendix E - General Information and Definitions

Airfoil - The shape of the wing's cross-section is known as an airfoil. Airflow across the airfoil causes a pressure difference between the upper and lower surfaces that provide the lift force.

Angle of Attack - The angle formed between the chordline of the airfoil and the oncoming airflow. The angle of attack is directly responsible for the coefficient of lift of the main wing. The angle of attack is related to the airspeed such that the steeper the angle of attack, the slower the sailplane will fly. Likewise, the lower the angle, the faster the sailplane will fly.

Aspect Ratio - The aspect ratio is the ratio of the wingspan to the average chord of the wing. Typical values for the aspect ratio of the main wing are between 8:1 and 14:1. It has a direct effect on the coefficient of induced drag and is a very important factor in determining the sailplane's performance. An easy formula for computing the aspect ratio is span squared divided by surface area.

Center of Gravity - The location where the sailplane balances statically. It is usually located at a point behind the leading edge of the wing that is 30% - 35% of the root chord. Its placement is important so that the sailplane can be flown at the most efficient angle of attack with the least amount of drag.

C_l vs. α curve - This curve is usually given with airfoil polar curve data. It relates the coefficient of lift and the physical angle of attack of the airfoil. This relationship is linear for the most part and is approximated in the program by a linear function ($y=mx+b$). See Appendix F for more details.

Coefficient of Induced Drag (C_{di}) - This is a dimensionless number that quantifies the drag force due to swirling patterns of air (vortices) which induce drag around a wing or stabilizer. The aspect ratio and C_l of the surface directly affect the value. Generally, increasing the aspect ratio decreases the induced drag, while lowering the aspect ratio increases the induced drag.

Coefficient of Lift (C_l) - A dimensionless number that relates the amount of lift generated by the wing (or stabilizer) to the angle of attack of the wing. In the program, this quantity is displayed in the performance map. It generally varies from 0.1 to 1.2 with 0.1 being a very low angle of attack (i.e. fast airspeed) and 1.2 being a very high angle of attack (i.e. slow airspeed, near stall).

Coefficient of Profile Drag (C_{dp}) - A dimensionless number that quantifies the drag force due to things such as skin friction and the shape of the surface. This number is plotted against C_l to give the airfoil polar curve. This number varies with the shape of the airfoil and the R_n of the surface. Predicting it theoretically is very difficult and often not reliable. The best values are determined experimentally in a wind tunnel. Examples of experimental airfoil data are included on the disk from sources such as Althaus ⁽⁶⁾ and Selig ⁽⁷⁾.

Decalage Angle - This is the difference in angle of attack of the main wing and the stabilizer. It determines the angle of attack of the main wing and the resulting speed of the sailplane. Theoretical values for this angle are given in the program under the detailed analysis for a particular coefficient of lift.

L/D ratio - This is a dimensionless ratio of the distance a sailplane will fly forward per unit of altitude loss. For example, if the sailplane has an L/D of 20:1 and it starts from a height of 500 feet, it can theoretically fly for a distance of 20x500 or 10,000 feet (roughly 2 miles!) before landing. Remember of course that this assumes a constant angle of attack, straight flight, and no lift or sink.

Polar Curve (Airfoil) - A curve that is plotted for C_l versus C_{dp} of an airfoil. The resulting shape is a "bucket" which tells the drag coefficient for a particular C_l . There are generally several curves presented, each curve corresponding to a particular R_n . This is the curve that must be entered into the airfoil data files stored on the disk.

Polar Curve (Sailplane) - This curve is plotted by the program and plots airspeed versus sink rate and L/D. Lots of good information can be found, such as the usable speed range of the sailplane (good for cross-country flying) and the best speed at which to fly to get the best L/D and sink rate. It graphically shows the data presented in the regular analysis output.

Quarter Chord - This is an imaginary line that extends perpendicular to the fuselage centerline through the main wing. One quarter of the total wing area lies forward of this line, while 3/4 of the total area lies behind the line. It can be assumed that all pitch forces acting on the wing act through this line (like a pivot line). Its distance from the

leading edge of the wing at the wing root is calculated and used by the program.

Reynolds Number (R_n) - This is a dimensionless number that is proportional to the velocity of the air and the length of the surface over which it travels. Typical R_n values for a model sailplane wing in flight range from 50,000 to 200,000. When the R_n falls between 50,000 and 100,000, there is a possibility of bubbles forming where the airflow transitions from laminar to turbulent airflow. The detailed analysis routine shows the calculated R_n for each wing section and for the various components of the sailplane.

Root Chord - The distance from the leading edge of the wing to the trailing edge of the wing measured closest to the fuselage. Parameters such as center of gravity and the quarter chord are measured at the wing root.

Sink Rate - The rate at which the sailplane is sinking or coming down. This value varies with the C_l and is plotted on the polar curve. The program allows the units to be either in feet per second, miles per hour, meters per second, or kilometers per hour.

Tail Moment - The distance from the trailing edge of the wing to the leading edge of the stabilizer measured along the top of the fuselage.

Tail Volume Coefficient - A dimensionless quantity that can be used to properly size the stabilizer and tail moment of the sailplane. Frequently, there are several good articles in the Soaring columns of model magazines that describe how to use the tail volume coefficient in determining the size of the stabilizer and tail moment.

Wing Loading - Wing loading is a ratio of the sailplane's weight to its wing area. The number gives a general indication of how fast the sailplane must fly in order to perform efficiently. Sailplanes with higher wing loadings must fly at faster speeds to perform efficiently.

Wing Planform Correction Factor - This is a quantity that multiplies the coefficient of induced drag to account for wing planforms not being perfect ellipses. It simply increases the drag by a certain percentage. If the shape of the wing is a perfect ellipse, then the correction factor will be 1.0. If the wing is double tapered or straight

center section with tapered tips, I usually use 1.12 (12% increase in drag), while if it is a straight taper (straight leading and trailing edges) then I generally use 1.13 (13% increase in drag). Refer to Martin Simon's article in Soartech 1⁽²⁾ on performance calculations with a programmable calculator for more details.

Appendix F- C_l versus α Curve Information

The program uses a linear approximation of the C_l vs. α curve (i.e. slope and y- intercept). To compute the slope, simply find the change in value of the C_l (vertical axis) for a change in angle of attack (α , horizontal axis) of 1.0 degrees. This is the slope (m) and it will always be a positive value. The y-intercept is simply the point where the curve crosses the vertical axis. For positively cambered airfoils, this will be a positive number. For all symmetrical airfoils, it will be zero. The intercept (b) is the value asked for in the airfoil data entry section of the program.

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