

## Designing An Airfoil Using NASA Foilsim

NASA has a free, on-line java airfoil simulator suitable for introductory use. It is available at:

<http://www.grc.nasa.gov/WWW/K-12/airplane/foil3.html>

View: Edge Top Side-3D Find  
Display: Streamlines Moving Frozen Geometry

FoilSim III Units: Imperial Reset

Input Student Version 1.3b Output

Flight Shape Probe Gages

Size Analysis Geometry Data

Select Plot Plot

Lift 1490 lbs Reynolds # 4811956

Drag 139 lbs L/D ratio 10.652

Airfoil Shape Airfoil

Angle-deg 5.0

Camber-%c 0.0

Thick-%crd 12.5

Free Stream

Press psi

14.877

14.754

14.631

14.508

14.385

0.0 25.0 50.0 75.0 100.0

X % chord

Rescale

**Step 1)** Click on the “units” and set them to metric.

**Step 2)** Click on the “size” box. Use the sliders or text boxes to set:

- The chord length to your desired value (typically 0.10-0.15 metres)
- The wing span to your desired value (typically 0.3 – 0.6 metres)

Note the wing area and aspect ratio change as you change these values

**Step 3)** Click on the “flight” box. Use the sliders or text boxes to set:

- The speed to your estimated airplane speed in km/h (typically 20-40km/h)

Note the “lift” and “drag” boxes now have useful values in them

One Newton (1N) is roughly the equivalent of 100g of mass

If you have tested your motor & prop you know your max thrust

*The predicted drag must be lower than measured thrust*

Or else you won't be able to fly that fast!

*The predicted lift must be greater than predicted mass*

Airplanes are typically 100-200g (1-2N)

Unless you are going for “heavy lift”, of course

The predicted lift and drag will change as you do step 4

Note that the Reynold's number changes as you change speed and chord length  
You can leave the other values set to their defaults on this screen

Or you can set them to try flying on Mars, or at high elevation on Earth

If you will be testing your plane on Mars, please follow all field trip rules

**Step 4)** Click on the “shape” box. Use the sliders or text boxes to set:

a) Your angle of attack. This is the angle that the airfoil “cuts through” the airflow  
Note that if you set the angle too high that your wing stalls (not good!)

b) Your camber

c) The thickness of the wing relative to the chord length of the wing.

Keep watching your lift and drag boxes.

Try for a maximum Lift to Drag (L/D) ratio

Keep Drag lower than your maximum measured thrust

Keep lift higher than your estimated airplane weight

**Step 5)** Click on the “select plot” box. Select lift vs. Angle. You may need to click on “rescale”

a) What does this plot tell you? Can you see what angle will cause a stall?

b) Try “Drag vs. Angle” Is there a large range of angles that have about the same drag?

c) Now go back to “shape”, “flight” and “size” to optimize your airfoil.

**Step 6)** Click on the “geometry” box. A bunch of data will scroll past your lower right corner window

a) Look in the lower right corner window and see what is there

There should be some general flight test parameters

There should be “Upper Surface” followed by a list of numbers

These are the co-ordinates for the upper surface of your airfoil

We mainly want the X and Y, we don’t need Pressure or Velocity

There should be “Lower Surface” followed by a list of numbers

b) You may want to copy and paste all of this data in to a text editor and save/print it.

c) If you know Excel or AutoCAD, you can use these numbers in those programs.

Multiply the “x” values by the chord length of your wing to get the “x” stations

Multiply the “y” values by the chord length of your wing to get the “y” positions

Plot the x and y values for each data point for the lower surface

Plot the x and y values for each data point for the upper surface

Join them with a smooth curve and print at a 1:1 scale.

**Step 7)** Complete the “Plotting an Airfoil” worksheet using the “geometry” data, but first, record:

**Shape:**

**Size:**

**Flight:**

Angle: \_\_\_\_\_ degrees

Chord: \_\_\_\_\_ meters

Speed: \_\_\_\_\_ km/h

Thickness: \_\_\_\_\_ % of chord

Span: \_\_\_\_\_ meters

Lift: \_\_\_\_\_ N

Length: \_\_\_\_\_ metres

Aspect Ratio: \_\_\_\_\_

Drag: \_\_\_\_\_ N

Lift to Drag Ratio: \_\_\_\_\_

You may want to repeat this test several times to find idea airfoils for speed trials and heavy lift trials.  
Be sure to record this data if you do, so that you can re-create your airfoil when you need it.

## Plotting An Airfoil Using NASA Foilsim Co-ordinates

After you have designed an airfoil using NASA's Foilsim Software, this is how you can draw the airfoil life size. Once you have drawn the airfoil, you can use your drawing as guide to cut templates out of wood, and then use the wooden templates to cut the wing out of a piece of styrafoam.

This is an ideal task for a spreadsheet. If you know how to use a spreadsheet such as Excel or Open Office Calc, use copy and paste from Foilsim to transfer your data, do your calculations for Step 1 and Step 2 and print your results.

**Step 1:** After you have pressed "geometry" in foilsim, copy the data it shows to the "X" and "Y" columns boxes, below. Do this for both the Upper Surface and the Lower Surface.

Stn.	Upper Surface				Lower Surface			
	X	X*chord	Y	Y*chord	X	X*chord	Y	Y*chord
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

**Step 2:** What is your chord length? \_\_\_\_\_ Metres.  
 Multiply each X and Y value by the chord length and record that in the X\*chord and Y\*chord columns. Round your answers to three decimal places. (eg: -0.083m)  
 Want to save time? You can skip Stn (station) #4,6,8,10,12,14 and 16 completely.

**Step 3:** Jump ahead to the sheet for step 3 titled "Airfoil Cross Section" and sketch your airfoil. If you are familiar with AutoCAD, or a similar drafting program, you may choose to do step 3 in CAD, and connect the points using a smoothed polyline.

**Step 4:** You will use the sketch of the airfoil to generate four templates for cutting your wing. Two will be "top templates" and will follow the upper surface of the airfoil. Two will be "bottom templates" and will follow the bottom surface of the airfoil.

To make it so that the hot wire cutter can follow your templates you need to provide entry and exit points for the hot wire.

Mark a vertical line to indicate the leading edge of the template and foam about 1 cm to the left of the leading edge of your airfoil.

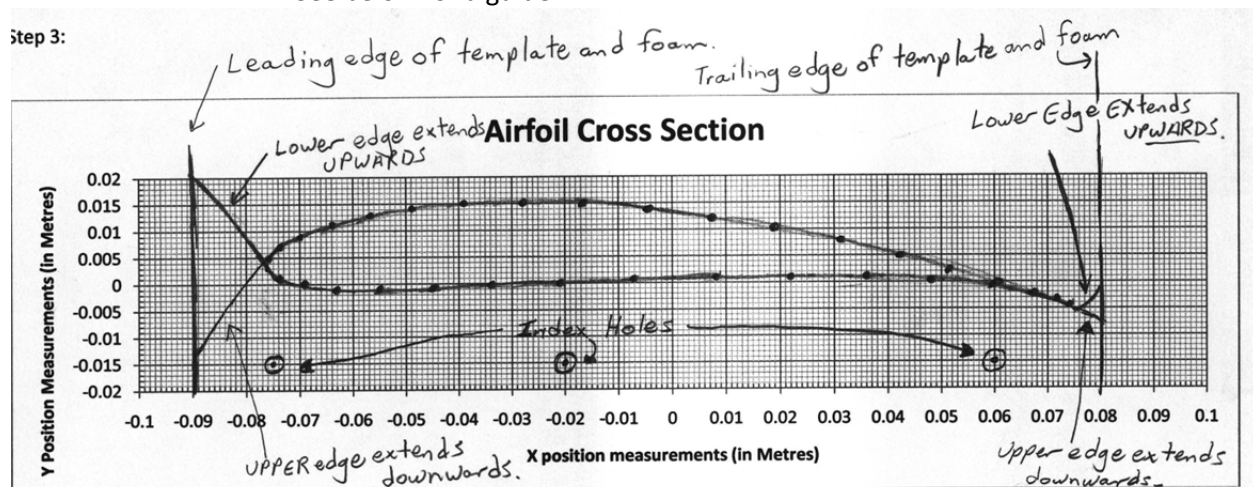
Mark a vertical line to indicate the trailing edge of the template and wing about 1 cm to the right of the trailing edge of the airfoil.

Smoothly extend the front lower edge (leading lower surface) of the airfoil upwards so that it exits near the leading edge of the template.

Smoothly extend the front upper edge of the airfoil downwards, so that it exits the leading edge of the template about 1 cm above the very bottom of the template.

Do similar steps for the trailing edges of the upper and lower airfoil surface. It is okay to have these lines emerge from the trailing edge of the template.

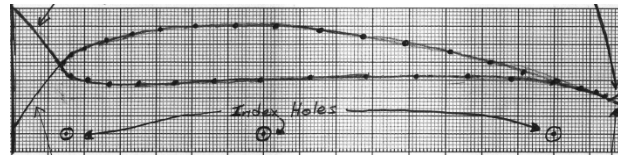
See below for a guide.



**Step 5:** Mark three "Index Holes" about 0.5cm above the bottom of the template. The index holes MUST be BELOW the bottom surface of the airfoil. We will put pins through these holes later to hold the template to the foam

**Step 6:** Make two photocopies of your Airfoil Cross Section. Do NOT lose or destroy the original sketch at any time during this project.

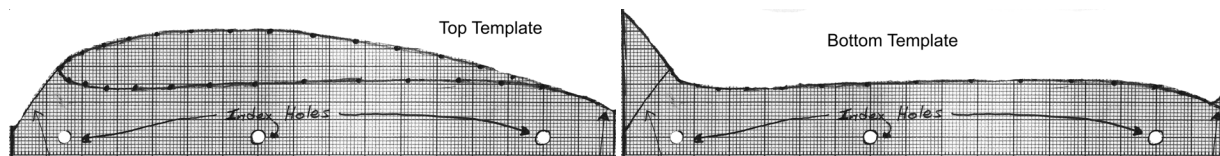
**Step 7:** Cut your photocopies along the top of the template and bottom of the graph. Cut them along the leading edge of the template and foam and the trailing edge of the template and foam. We call these your paper templates, and they should look something like this:



**Step 8:** Cut four pieces of  $\frac{1}{4}$ " thick hardboard (or other wood as provided) to the length and height of your paper template. It is okay if they are a bit too tall, but they be the correct length and have square (90 degree) corners. Take two pieces, align all four sides, and tape them together with double-sided tape. These will become your "upper templates". Take two pieces, align all four side, and tape them together with double-sided tape. These will become your "bottom templates". Use spray adhesive or glue stick to attach one paper template to the wood that will become the "upper template". Make sure you align the leading (left) and bottom edge of the paper template with the wood. Do the same, attaching the other paper template to the wood that will become the "bottom template".

**Step 9:** Take both pieces to the drill press and drill  $\frac{5}{32}$ " (4mm) holes at the locations marked as "Index Holes" on your paper templates.

**Step 10:** This is where a lot of people make mistakes, so pay attention! Use the bandsaw to cut along the top edge of the top template. Use the bandsaw to cut along the top edge of the bottom template. You should have two templates, as shown below. When you put your bottom template over top of your top template the difference between them will be your airfoil!



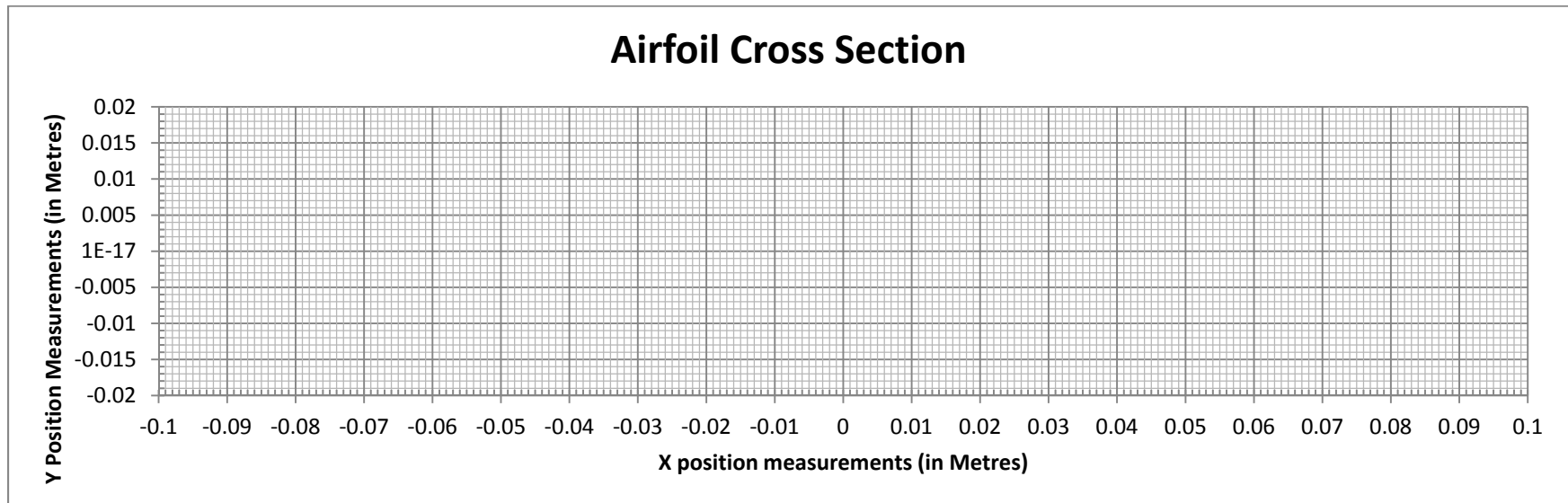
**Step 11:** Use a file and/or sandpaper to smooth your templates. There must be no bumps or dents that will catch the hot wire. Copy the location of each dark line (1cm spacing) on the paper template across to the wooden template that does not have paper on it. You will need these marks to guide you and your partner as you cut the foam. Separate your templates... you are now ready to cut some foam!

Name: \_\_\_\_\_

**Step 3:**

Take the data that you calculated in Step 2. Find the x and y co-ordinates for each point, or station, on the graph, below. Place a small, but clear dot in pencil at each point.

Once you have plotted the upper and lower surface of the airfoil, use a pencil to lightly sketch out the shape of the airfoil by joining the dots together. If you have a set of "French curves" (drafting tools) they might help. Once you have sketched out the shape of the airfoil, go over it in a single, clean, dark line. You may use a fine tipped felt pen, or soft pencil for this.



Now return to "step 4" on the instruction sheet.