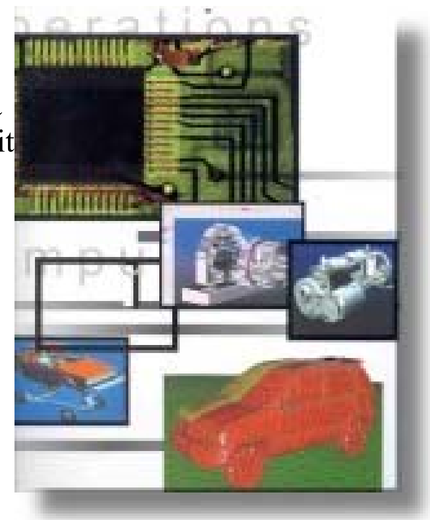
ACHIEVEMENT #8:

CAD/CAM and CAE Technology

Teacher's Guide

Introduction



In 1950 when engineers wanted to use a computer to help them design a product, they had to fill out a form, enter the data on punch cards, submit the data to a computer center and wait for the results. This could take weeks. When they got the information back, it looked like this (shows stack of papers). In 1960, a young MIT graduate student, Ivan Sutherland, wondered if computer graphics could be used to help engineers design products differently. His idea was called Sketchpad, and it was an important first step in changing the way design engineers worked.

Other engineers contributed their ideas, and soon they had a tool that helped engineers see their products on a computer screen for the first time. Instead of building expensive models of products to see if they would work, they could design entire automobiles, airplanes and jet engines in 2 and 3 dimensions – and test their theories on the screen. Products that once took several years to design and manufacture can now be made in just months. This is important to the average family, because it means that products are cheaper and in greater supply. And it all started with one engineer's curiosity and good detective skills.

Lesson Focus: **Computer Aided Engineering**

Lesson Synopsis: Students use the NASA applet **FoilSim** to test various airplane wing designs in a simulated wind tunnel.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to:

- Identify Appropriate Problems for Technological Design,
- Design a Solution or Product,
- Implement a Proposed Design,
- Evaluate Completed Technological Designs and Products, and
- Communicate the Process of Technological Design.

Related Benchmarks from Benchmarks for Science Literacy:

Section 9B (Symbolic Relationships):

By the end of 8th grade, students should know that:

- Graphs can show a variety of possible relationships between two variables.

Section 11B (Models):

In grades 6-8, **"student use of computers should have progressed beyond word processing to graphing and simulations that compute and display the results of changing factors in the model."**

Glossary:

CAD (Computer Aided Design or Computer Aided Drafting) Use of microcomputer systems to engineer and design complex parts in today's manufacturing environment. Prior to the 1980's, draftsmen used drawing boards, T Squares and a plethora of tools to draw blueprints manually, today, engineering design and drafting work is done on CAD Systems, where highly trained operators construct blueprints, models, and complete engineering designs on personal computers, workstations, and networked computer terminals

CAM (Computer Aided Manufacturing) Use of computers in manufacturing workplaces to model parts being constructed in machining operations and design processes, not only for modeling purposes, but for design and quality assurance purposes as well. CAM systems are used for determining the accuracy of design prior to manufacturing. Models can be checked for diameters, wall thickness, stress analysis, clearances, and many other features determined to be critical before the initial product is ever constructed, thus eliminating unnecessary production cost as well as reducing the time it takes to produce the part.

CAE (Computer Aided Engineering) Use of computers and software to solve engineering problems. CAE is a branch of engineering that involves the use of computer technology to solve complex problems that are too difficult, or impossible, to solve with traditional analytical techniques.

Virtual Reality A way for humans to visualize, manipulate and interact with computers and extremely complex data. The visualization part refers to generating visual, auditory or other sensual outputs to the user of a "world" that exists solely within the computer. This "world" may be a CAD model, a scientific simulation, or a view into a database.

airfoil An object with a special shape that is designed to produce lift efficiently when the object is moved through the air. For example, the cross-section of a wing is an airfoil.

lift A force that is perpendicular to the airflow around an aircraft. In normal, forward flight, the lift force "lifts" the aircraft into the air. Engineers design airplanes so that the lift created by the wings can overcome the force of the weight of the airplane.

camber The curvature of an airplane wing.

angle of attack The angle of a wing to the oncoming airflow. A pilot pulls back on the control stick to increase the angle of attack.

wind tunnel testing A tool of aeronautics that involves placing a model of an aircraft or part of an aircraft into a wind tunnel and using instruments to gather data while air is blown past the model. Wind tunnel testing is used to investigate and accurately describe the effects of airflow on an aircraft or part of an aircraft.

Important Concepts:

- Computers can be used to design and test a variety of products, including aircraft.
- Lift is affected by the angle of attack of the wing and by wing shape, including its thickness and curvature (camber).
- Lift is also affected by air speed.

Materials for Each Inquiry Team:

- Computer, with FoilSim Applet installed
- Inventor's Log
- Copies of FoilSim Tutorial

Safety Precautions:

Remind students of rules for computer use, as appropriate.

Procedure:

Engagement:

If you have not shown the video, you may choose to do so now. Explain what the terms CAD, CAM, and CAE stand for and then hand out and discuss the **Timeline** portion of the **Student Handout**.

Exploration and Explanation:

- Download the FoilSim II Applet to each computer your students will be using. (See http://www.lerc.nasa.gov/WWW/K-12/FoilSim/ for details on downloading.)
- Have students follow the **FoilSim Tutorial** to experience using a computer simulation to explore factors that affect lift.

Extension:

Have students test a modified wing design under conditions different than the default conditions.

Evaluation:

Have students print out or sketch a Side-3D view of a wing they tested and write a brief report on how it performed under test conditions.

Ideas for Further Exploration:

- Have students research the use of Computer Aided Engineering in the space program and in the automobile industry.

References:

NASA FoilSim Applet, available for downloading at:
http://www.lerc.nasa.gov/WWW/K-12/FoilSim/

ACHIEVEMENT #8:

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Student Handout

Timeline of Events Related to Achievement #8:

1947	first commercial computer (UNIVAC)
1950	Air Force develops a system to display computer-processed radar data.
1960	Boeing coins term "computer graphics".
1961	Integrated circuits used in computers.
1962	Sketchpad, first 2D CAD program, created by Ivan Sutherland.
1965-1968	Sutherland begins development of Virtual Reality technology.
1968	First commercial CAD system.
1971	General Motors begins using DAC (Design Automated by Computers)
1989	Jaron Lanier coins the term "Virtual Reality"

Computer Aided Engineering (CAE)

Our timeline for this achievement is much shorter than the others! Fifty years ago, mechanical engineering students would have taken a course in Mechanical Engineering, in which they would have learned to use drafting tools to make engineering drawings by hand. With the development of microcomputers, it has become possible to create designs with Computer Aided Drafting (CAD) without having to create drawings by hand.

In 1901, the Wright Brothers built a wind tunnel to test wing designs. The blower fan, driven by an overhead belt, produced a 25 to 35 mph wind for testing the lift of various flat and curved surfaces. Data derived from these tests were vital to the successful design of the Wright 1903 Kitty Hawk airplane. Now, engineers can test wing designs in a simulated wind tunnel.

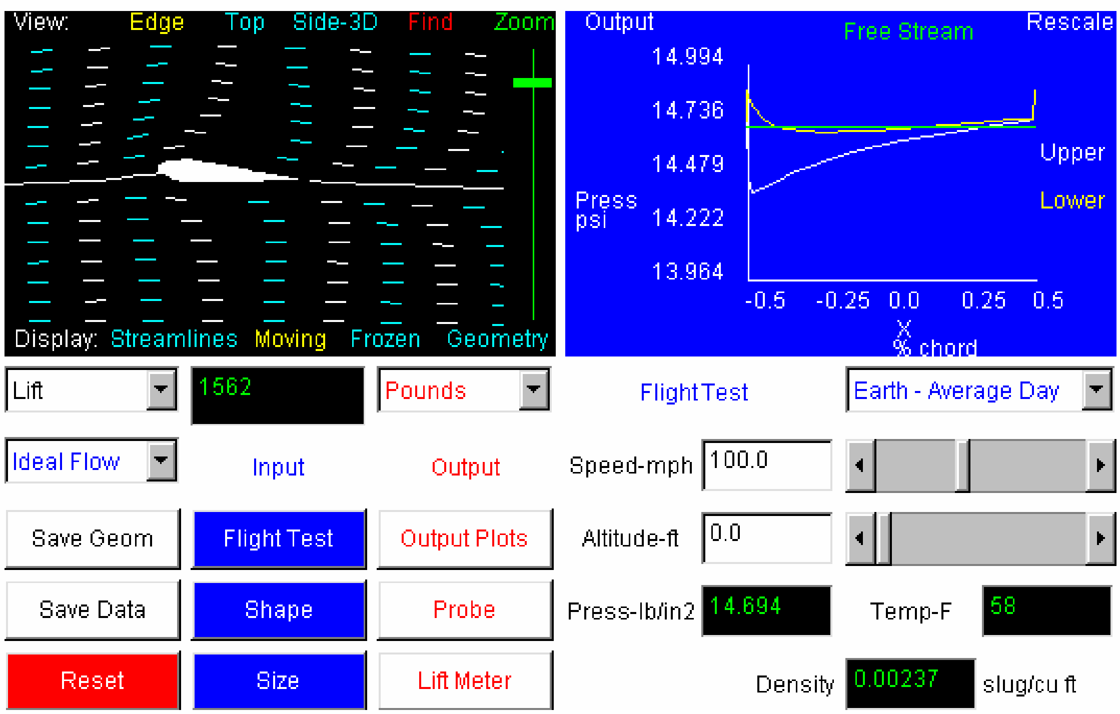
To see what it is like to use a computer to do engineering tasks that formerly required hand drawings and models, we will be using FoilSim, software developed by NASA to simulate the design and of wind tunnel testing of aircraft wings. Although FoilSim is designed primarily as a teaching tool, it was derived from "real-life" engineering software.

Using FoilSim to Explore Factors that Affect Lift of an Airplane Wing

I. An Introduction to FoilSim

With this software you can investigate how an aircraft wing produces **lift**, by changing the values of different factors that may affect lift. If the resulting lift value is a positive number, then the wing is being pushed up. If the lift value is a negative number, then the wing is being pushed down. If the value is zero, then the wing is neither being pushed up nor being pushed down.

Basic Screen Layout:



The program screen is divided into three main parts:

View Window

At the top of the screen are two **graphics windows**. The window on the left is the **View Window**, in which you can display a simulation of the flow of air around the wing you design.

Control Panel

Under the **View Window** is the **Control Panel**. There are 3 **choice boxes**, which allow you to select Lift vs. Coefficient of Lift, Pounds vs. Newtons, and Ideal Flow vs. Stall Model, with Lift, Pounds, and Ideal Flow being the settings when you first open FoilSim.

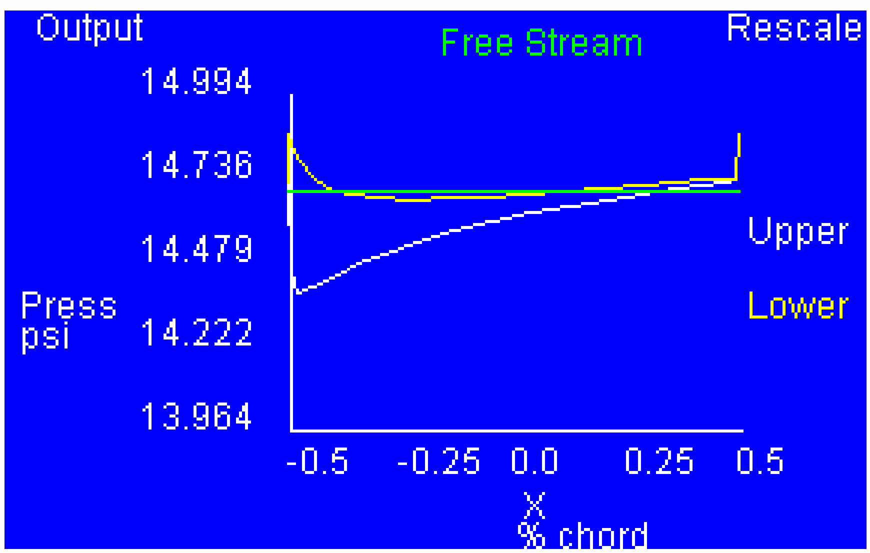
Notice that the **Control Panel** also contains 9 **choice buttons**. The three **blue** choice buttons under the heading **Input** allow you to change the **Flight Test** conditions, the **Shape** of the wing, and the **Size** of the wing.

Output Window

The **graphics window** on the right is the **Output Window**, in which you can display a **Plot** of the flow variables, a **Probe** panel you can use to investigate the pressure and and velocity in the flow field, or a **Lift Meter**.

The Plot Display:

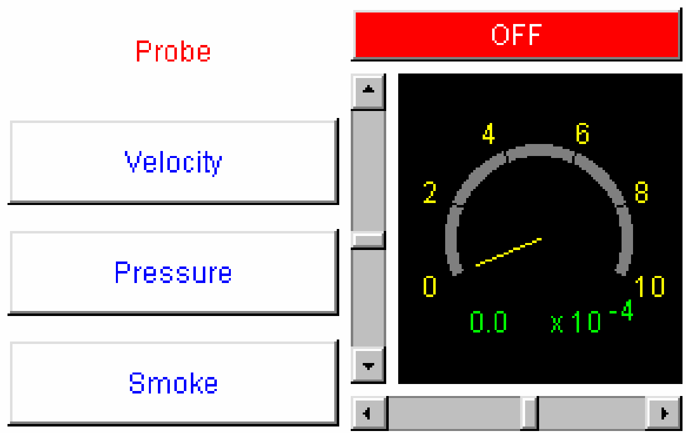
When you first start **FoilSim**, a **Plot** showing the pressure at points along the upper and lower sides of the wing is automatically displayed in the **Output Window**:



FoilSim allows a total of 12 different graphs to be displayed. To select which graph you wish to view, first press the white **Output Plots** button. When the **Select Plot** window opens in the **Output Window**, select and press one of the white buttons.

The Probe Display:

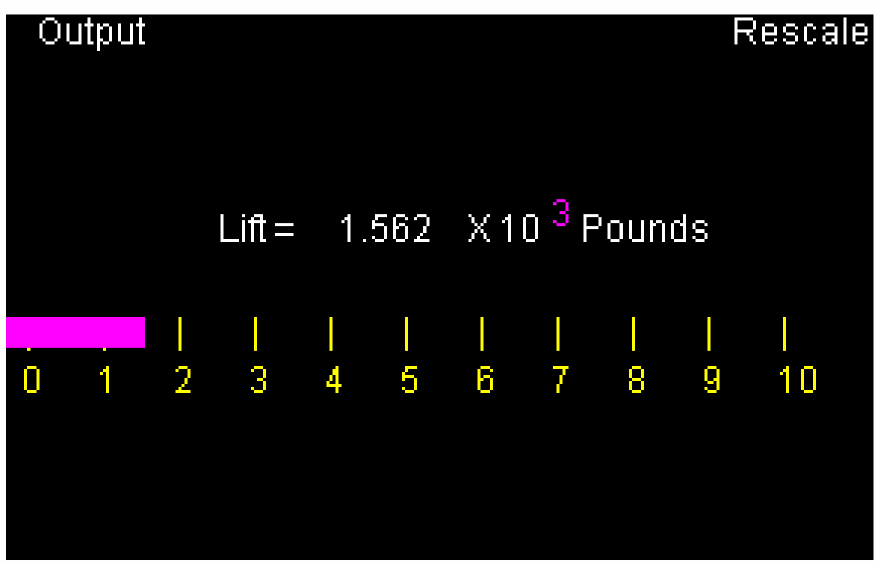
To display the **Probe**, press the white **Probe** button. A **Probe Panel** will appear in the **Output Window**:



You can change the location of the probe, seen as a magenta ball in the **View Window**, by using the two **sliders** to the left and below the **gauge**. The value of the pressure or the velocity at the location of the probe tip (magenta ball) is displayed on the gauge, or a green trail of "smoke" is swept downstream from the probe location. You can turn the probe off by pressing the red **OFF** button located above the gauge.

The Lift Meter:

To display the **Lift Meter**, press the white **Lift Meter** button and the **Lift Meter** will appear in the **Output Window**:

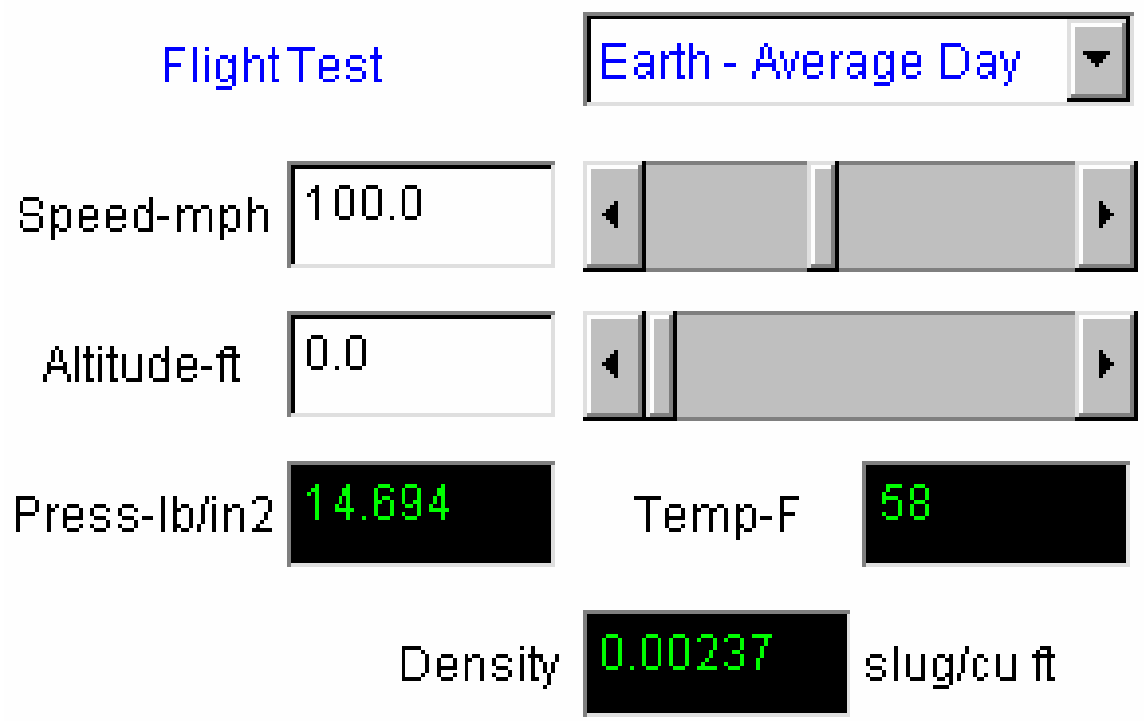


Input Panel

To the right of the **Control Panel** is the **Input Panel**, which changes when you click on one of the three blue buttons, to allow you to change the variables.

Flight Test Input Panel:

When you first start **FoilSim**, the **Input Panel** for the **Flight Test** conditions is displayed:



Note that **FoilSim** begins with a speed of 100 miles per hour and an altitude of zero feet above sea level. The testing temperature is given in degrees Fahrenheit and the pressure is given in pounds per square inch.

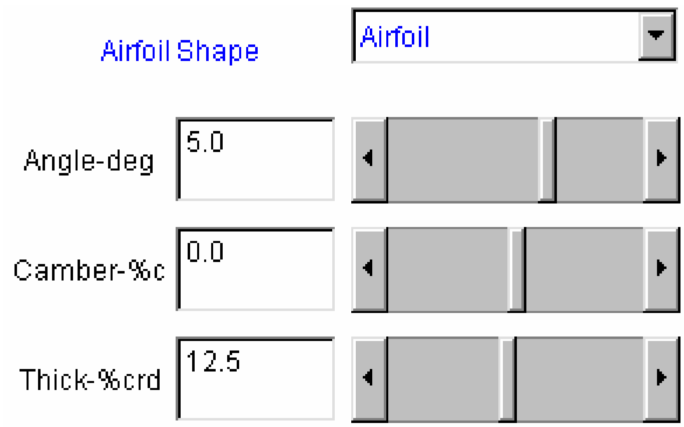
You can vary the speed or the altitude by typing a value into the text window and pressing the **Enter** key on your keyboard or by moving the sliders.

You can test your wing either **on the Earth** (default choice), **on Mars**, or **in water** by making your choice in the **menu box** at the upper right. (You can also choose to specify your own values of temperature and pressure for air, or to specify your own fluid by providing a value of the fluid density.)

Student Handout (continued)

Shape Input Panel:

When you press the blue **Shape** button, the **Shape Input Panel** will appear to the right of the **Control Panel**:

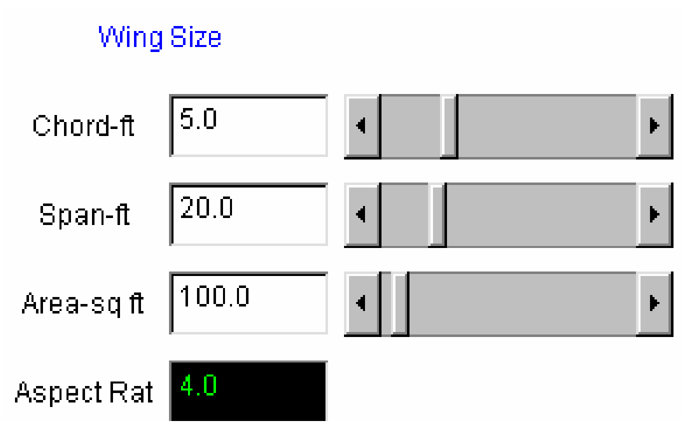


In the menu window, you can select a classic **airfoil** shape, an **ellipse**, or a flat "**plate**". (You can also choose to investigate the lift created by a rotating cylinder, or a spinning ball, but for these problems you must specify the spin rate and radius.)

You can change the **angle of attack** (the angle of a wing to the oncoming airflow), the **camber** (wing curvature), or the thickness of the wing either by entering a value in the text box and pressing the **Enter** key on your keyboard or by using the sliders.

Size Input Panel:

To change the size of the wing, press the white **Size** button and the **Size Input Panel** will be displayed to the right of the **Control Panel**:



Data Window

Under the **Control Panel** is a large text window in which output from the program can be displayed. You can display the airfoil geometry and surface flow data by pushing the **Save Geom** button on the **Control Panel**. You can display the test conditions and calculated lift by pushing the **Save Data** button on the **Control Panel**. (You can use the browser Print command to print out the screen and the data.)

II. Exploring Lift

1. Start the **FoilSim** applet by double clicking on the **FoilSim** icon.

2. In the **Control Panel**, under **Output**, press **Probe** to display the **Probe Panel**.

3. Press the red **Reset** button to reset all values to the basic starting conditions for the test.

4. Under **Input**, press **Flight Test** and record the starting test conditions:

Speed ____________________ Altitude _________________________

5. Press **Shape** and record the starting test conditions:

Angle ___________________ Camber ___________________________

6. Record the current Lift reading: ______________________

6. In the **View Window**, click on **Side-3D**.

A. How does Angle of Attack affect lift?

As you move the slider next to **Angle** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

B. How does Camber (wing curvature) affect lift?

Press the red **Reset** button and then reselect **Side-3D** to go back to your starting conditions.

As you move the slider next to **Camber** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

C. How does Thickness affect lift?

Press the red **Reset** button and then reselect **Side-3D** to go back to your starting conditions.

As you move the slider next to **Thickness** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

D. Using the Probe to Measure Air Pressure

1. Press the red **Reset** button.

2. Now you see in the **View Window** a cross section of our basic starting wing design.

3. Click on the blue **Probe** button and then on the white **Pressure** button to activate the pressure probe. Use the probe to measure the air pressure above the front of the wing and below the front of the wing:

Pressure above the wing ____________ Pressure below the wing ______________

4. By manipulating wing angle, curvature, and/or thickness, change the wing so that the lift is zero, or close to zero.

5. Record what combination of values you used:

Angle ________ Camber ________ Thickness ___________ Lift ______

6. Measure and record the pressure readings as before:

Pressure above the wing ____________ Pressure below the wing ______________

7. By manipulating wing angle, curvature, and thickness, change the wing so that the lift is negative.

8. Record what combination of values you used:

Angle ________ Camber ________ Thickness ___________ Lift ______

9. Measure and record the pressure readings as before.

Pressure above the wing ____________ Pressure below the wing ______________

10. Compare your data with that of other students. What conclusions can you draw about the relationship between lift and air pressure above and below the wing?

Student Handout (continued)

E. Viewing Graphs

Under **Output**, press the **Output Plots** button.

In the **Select Plot** window, press the **Angle** button. Based on the shape of the plot, describe in words **the relationship between Lift and Angle of Attack**, under the current test conditions:

Press **Output Plots** again and this time press the **Camber** button. Based on the shape of the plot, describe in words **the relationship between Lift and Camber**, under the current test conditions:

Press **Output Plots** again and this time press the **Thickness** button. Based on the shape of the plot, describe in words **the relationship between Lift and Thickness**, under the current test conditions:

F. Testing Your Own Designs

Now that you know how **FoilSim** works, you can create your own wing design and test it under different test conditions. Use the **Save Data** command to display the design data and test conditions in the **Data Window**. Record your design data, your test conditions, and your test results in an **Inventor's Log**.