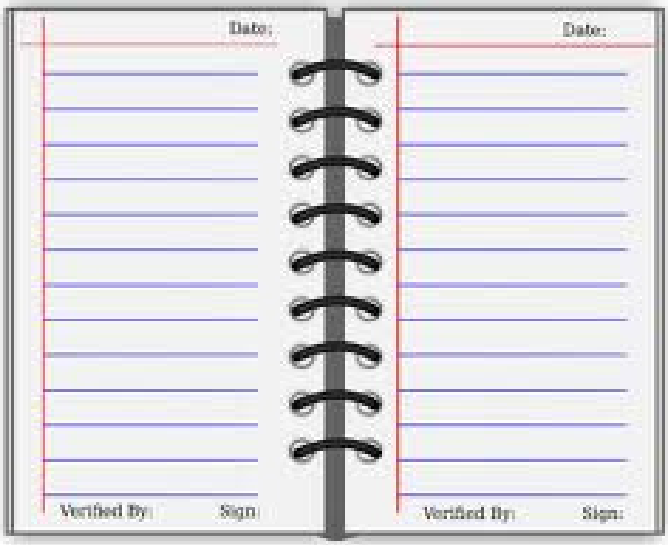
Student Team Challenge Journal



Supporting Science Investigation 1: Exploring Glider Design

Concept

A glider operates under the same four aerodynamic forces as any other aircraft. The only difference is that the initial thrust is applied to the vehicle prior to its flight from an outside system. The glider is either towed by another aircraft or given a push prior to flight.

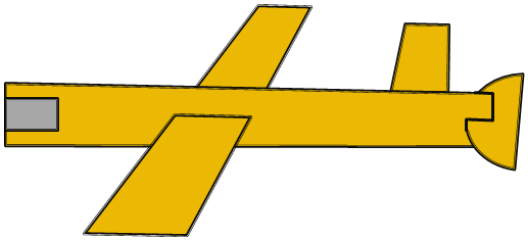


Figure 29. Illustration of a simple balsa wood glider.

As an aircraft moves through the air, it may move away from straight and steady flight. This may be intentional (controlled by the pilot) or unintentional (caused by wind or unbalanced weight in the aircraft). When this happens, the aircraft rotates around its center of gravity, the point in any object where the weight of the object is evenly dispersed and all sides are in balance. This rotation occurs in one or more dimensions at the same time:

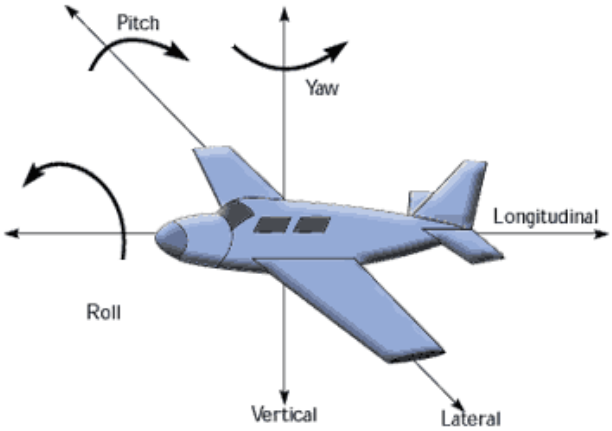


Figure 30. Illustration of the axes of rotation of an aircraft in three dimensions.

- Rotation around the horizontal/longitudinal (x) axis is called **roll** (clockwise and counter-clockwise).
- Rotation around the vertical (y) axis is called **yaw** (left and right).
- Rotation around the lateral (z) axis is called **pitch** (up and down).

In this investigation, you will assemble a balsa wood glider and explore the functions of its parts by flying it with a part removed or adjusted.

Materials

One set of the following materials is needed for each student:

- Safety glasses or goggles
- Basic balsa wood glider
- Marker
- Colored pencils
- Masking tape, rope, or other item to serve as a starting line
- Open area for flying gliders, such as a gymnasium or an outdoor field (if there is no wind)

Procedure

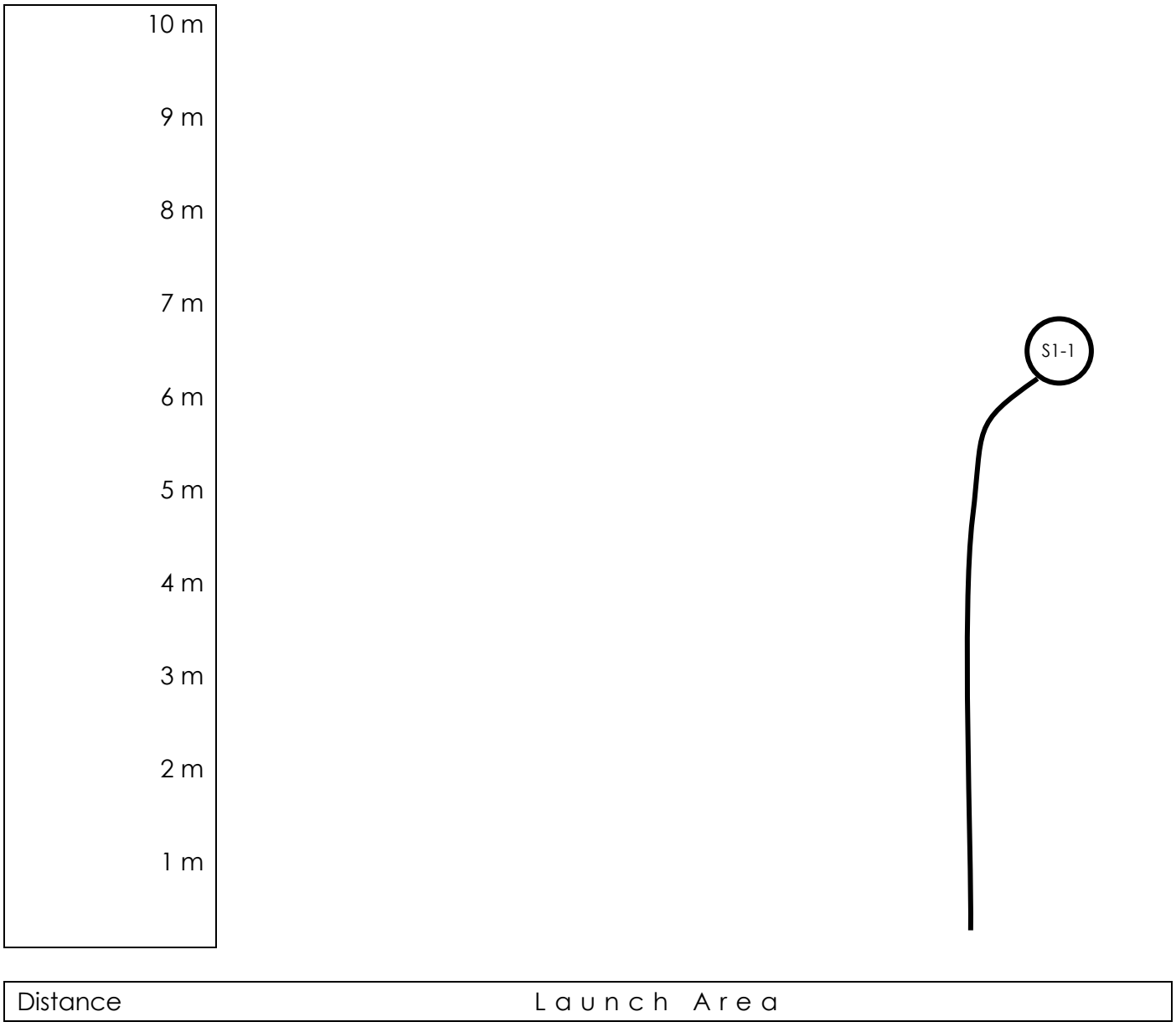
1. Assemble the glider per its instructions. Make sure that all pieces are centered and balanced for the initial control flights. Write your name on your glider to identify it.
2. Throw your glider three times to serve as control tests. Try to launch it with the same force and angle each time. This will demonstrate how the glider behaves under normal conditions. If your glider hits another midflight, redo the flight. Record your tests on the first page of the Data Collection Sheet as "C-1," "C-2," and "C-3" to represent the "control" tests, and draw the flight path for each test on the second page. Select a colored pencil or some other characteristic to uniquely identify this set of tests.
3. Choose one adjustment to make to the glider. This could be any of the following adjustments, or you may come up with your own.
   - Slide the wing considerably off center to the left or to the right of the body.
   - Slide the horizontal stabilizer considerably off center to the left or to the right of the body.
   - Remove the horizontal stabilizer completely.
   - Remove the vertical stabilizer completely.
   - Change the location of the weight at the nose of the glider.
   - Remove the weight at the nose of the glider completely.
4. Record on your Data Collection Sheet what adjustment you made and your prediction of how you think this adjustment will affect the flight of the glider.
5. Throw your modified glider three times. Again, try to throw the glider with the same force and angle every time. Record any observed changes in flight on the first page of the Data Collection Sheet, and draw the flight path for each test on the second page. Select a different colored pencil and label these tests as "E1-1," "E1-2," "E1-3" to represent "experiment 1" test flights.
6. Return your glider to its original configuration.
7. Repeat steps 4 through 6, making a different modification and labeling your results "E2-1," "E2-2," and "E2-3" for this modification. Continue modifying and testing for as many tests as time allows.
8. When testing is finished, discuss what observations you made and what conclusions you can draw about how the modifications made to the glider changed its performance.

Data Collection Sheet

In the table below, describe what modifications you made to your glider for each set of tests, how you predict each modification will affect the glider's flight, and what you actually observed from the tests.

Test	Modification Made to Glider	Prediction of This Modification's Effect	Observations of Actual Flights
Control (C)	None	None	Flight 1:
			Flight 2:
			Flight 3:
Experiment 1 (E1)			Flight 1:
			Flight 2:
			Flight 3:
Experiment 2 (E2)			Flight 1:
			Flight 2:
			Flight 3:
Experiment 3 (E3)			Flight 1:
			Flight 2:
			Flight 3:
Experiment 4 (E4)			Flight 1:
			Flight 2:
			Flight 3:

In the diagram below, draw the flight path and circle the landing location of each flight. Inside the circle, label the flight path with the experiment number and the flight number (for example: E1-1). A sample, labeled S1-1, is shown.



Discussion Questions

This activity showed us how a glider reacts when a major change to a flight control or wing design is made.

1. Describe how the glider reacted when a major change was made to its design.

_____

_____

_____

_____

_____

2. If you could make one change to improve the performance of the glider, what change would you make? Explain why.

_____

_____

_____

_____

_____

3. How will you apply what you learned in this investigation to your design?

_____

_____

_____

_____

_____

Supporting Science Investigation 2: Air Force Three

Concept

In this investigation, you will experience the effects of Bernoulli's principle, which states that as air moves faster, it exerts less pressure perpendicular to the direction the air is moving. Airfoils utilize this principle to help create lift by increasing air speed over the wing compared to air moving under the wing. Bernoulli's principle also applies to all fluids (all liquids and gases).

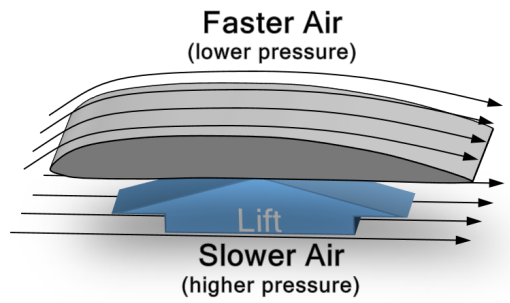


Figure 31. Illustration of Bernoulli's principle.

Here are three simple investigations to demonstrate this concept.

Materials

One set of the following materials is needed for each student:

- Sheets of paper
- Index cards
- Straws
- String
- Round balloons

Procedure

Investigation A: Tent With a Straw

1. Fold an index card in half to make a tent.
2. Place the tent on the desk.
3. On the Data Collection Sheet, make a prediction of what will happen when you blow air under the tent.
4. Using the straw, blow under the tent and observe what happens. Record these observations on the Data Collection Sheet.
5. Compare and discuss all predictions and observations.

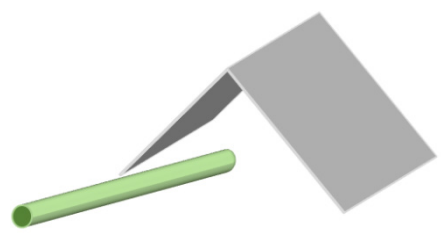


Figure 32. Index card tent with a straw for Investigation A.

Investigation B: Two sheets of paper

1. Hold two sheets of paper in front of your face as shown in Figure 33.
2. Space the two sheets of paper a few inches apart from each other.
3. Predict what will happen if you blow air between the sheets of paper. Record your prediction on the Data Collection Sheet.
4. Blow between the sheets of papers. Observe and record what happens. Specifically note the direction each sheet of paper moves.
5. Compare and discuss all predictions and observations.

Figure 33. How to hold the two sheets of paper for Investigation B.

Investigation C: Single sheet of paper

1. Use two hands to hold one sheet of paper just under your bottom lip as shown in Figure 34.
2. On the Data Collection Sheet, predict what will happen if you blow across the top of the paper.
3. Blow across the paper. Record your observations on the Data Collection Sheet.
4. Compare and discuss all predictions and observations.

Figure 34. How to hold the sheet of paper for Investigation C.

Data Collection Sheet

Follow the procedures as directed for each investigation. Be sure to make predictions before testing. Then record your observations.

Investigation	Prediction	Observation	Explanation
A. Tent With a Straw			
B. Two Sheets of Paper			
C. Single Sheet of Paper			

Discussion Questions

This activity demonstrated how Bernoulli's principle affected pieces of paper when subjected to wind.

1. Describe how Bernoulli's principle can be applied to help design a brand-new shape of wing.

_____

_____

_____

_____

_____

2. Bernoulli's principle was demonstrated on Earth. Do you think the principle would work the same, differently, or not at all on Mars? Explain your thoughts.

_____

_____

_____

_____

_____

3. How will you apply what you learned in this investigation to your design?

_____

_____

_____

_____

_____

Supporting Science Investigation 3: Airfoil on a String

Concept

In this investigation, you will experience how an airplane wing can direct the air above and below it depending on the wing's angle of attack. This is an application of Newton's third law of motion, which states that for every action, there is an equal and opposite reaction. Because the wing is symmetrical, Bernoulli's principle would not create lift. In this case, the wing needs to be tilted at a positive angle of attack, which pushes air downward, creating upward lift on the wing.

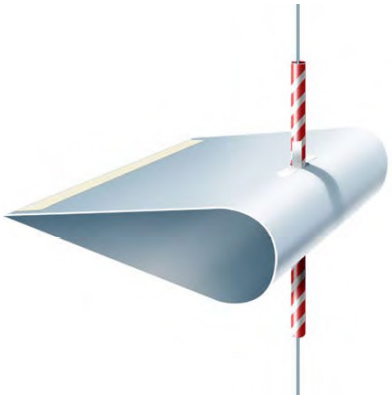


Figure 35. The airfoil on a string for this investigation.

Materials

One set of the following materials is needed for each student:

- Scissors
- Pencil
- Airfoil template (photocopied from guide)
- Drinking straw, cut down to 10 cm (4 in.)
- String, 45 cm (18 in.) in length
- Transparent tape, 6 cm (2.5 in.)
- Fan (1 is sufficient for the entire group)

Procedure

1. Carefully use a pencil to push holes through the designated spots on the template.
2. Bring the short ends of the paper together to make an airfoil shape and tape the two ends together. Be sure not to crease the paper.
3. Push the straw through both holes. Tension should keep the straw in place, but it can be taped in place if necessary.
4. Thread the piece of string through the straw. Hold the string vertically, with one end in each hand.
5. Place the wing in front of the fan. Observe and record results on your Data Collection Sheet.
6. Adjust the wing's angle of attack by moving the top end of the string. Observe and record results at a variety of angles.

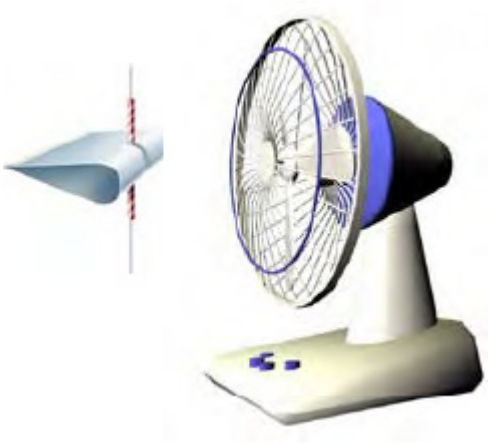
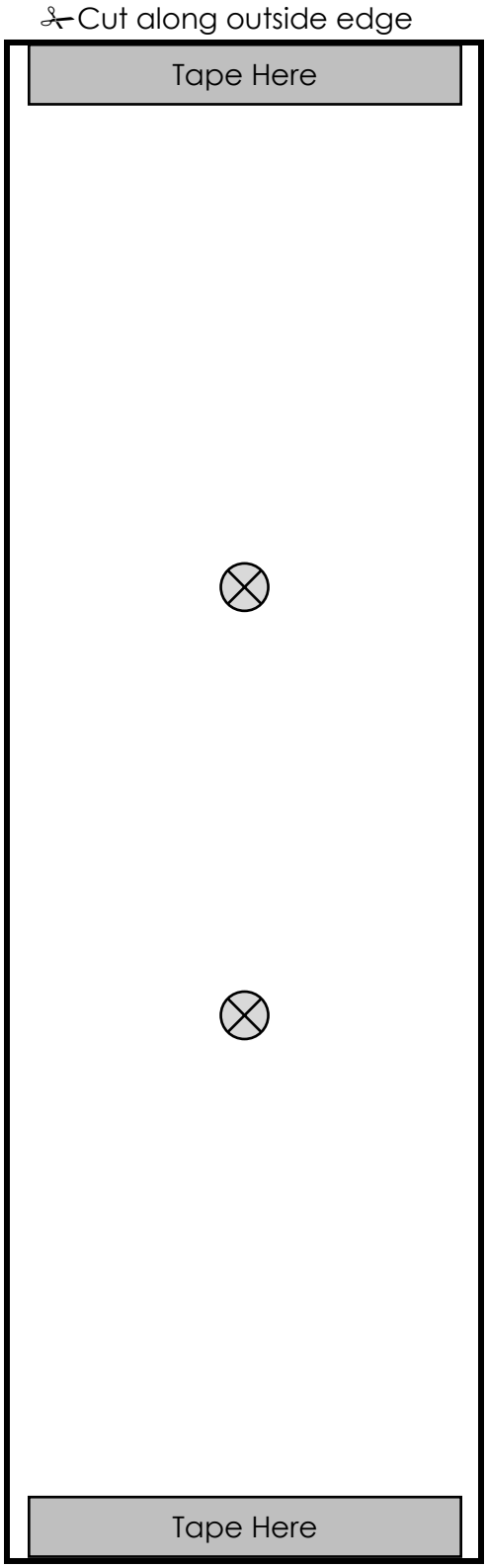


Figure 36. Proper placement of the airfoil in front of the fan.

Airfoil Template



Data Collection Sheet

Complete the table below using the results from your investigation.

Trial	Angle of Attack	Observations
1	Level	
2	Angled up	
3	Angled down	

Let It Glide

Note any observations you made during this experiment:

_____

_____

_____

_____

_____

Discussion Questions

In this activity, we documented how an airfoil reacts at different angles of attack. Based upon your observations:

1. Do you think it is possible to design a wing that has no critical angle of attack?

_____

_____

_____

_____

_____

2. We performed this experiment on Earth. Do you think the wing would behave the same or differently if we performed this experiment on Mars?

_____

_____

_____

_____

_____

3. How will you apply what you learned in this investigation to your design?

_____

_____

_____

_____

_____

The Engineering Design Process

The engineering design process (EDP) consists of a series of steps, each designed to help you develop a solution to a problem. Start with "Identify a Need or Problem" and use the EDP diagram shown here to help solve this challenge.

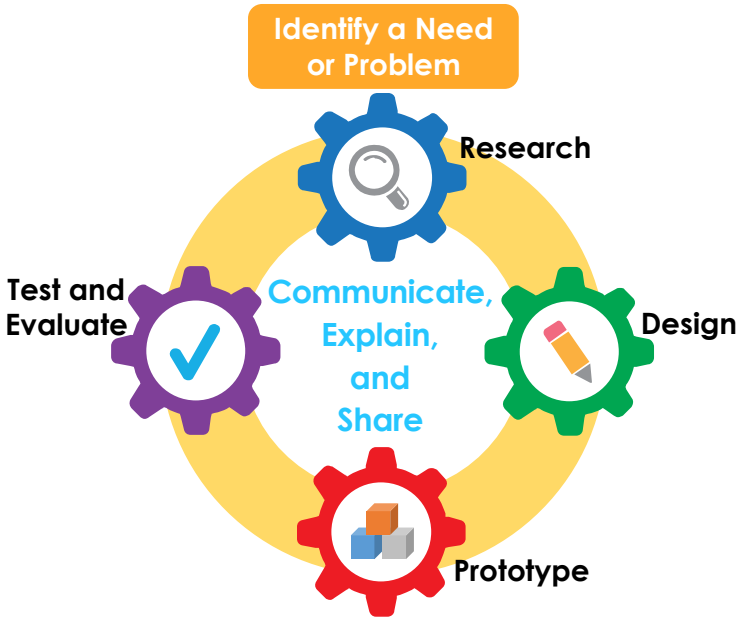


Figure 37. Engineering design process model. Model and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

Identify a Need or Problem. Identify a need or problem to be solved, improved, or fixed. Identify the criteria and constraints that will need to be met to solve the problem.

Research. Use resources from the internet, the library, or discussions with NASA scientists and engineers to learn more about the need or problem and possible solutions. Investigate how this problem is currently being solved or what efforts scientists and engineers are making to find a solution.

Design. Use all information gathered to create the design(s). Design includes modeling possible solutions, refining models, and choosing the model(s) that best meets the original need or problem.

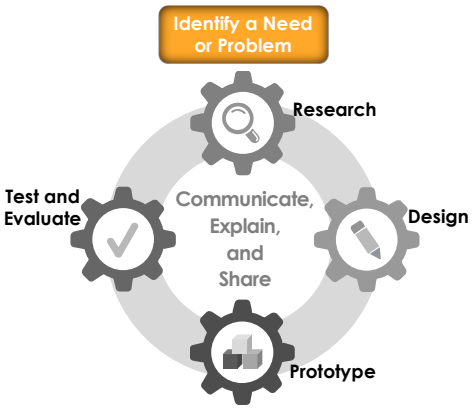
Prototype. Construct a prototype, or physical model, based on the design model(s). Prototypes are used to test proposed solutions.

Test and Evaluate. Test prototype to determine how effectively it solves the need or problem. Collect data to use as evidence of success or need for improvement. Redesign and refine prototypes to continue looking for possible solutions.

Communicate, Explain, and Share. Communicating, explaining, and sharing the solution and design is essential to tell others how it works, how it solves (or does not solve) the identified need or problem, and how it meets (or fails to meet) the criteria and constraints. Determining how to communicate and act on constructive criticism is critical.

The Engineering Design Process: Identify a Need or Problem

NASA has been at the forefront of wing design and is responsible for many of the wing designs in use commercially today. Engineers are constantly working to make aircraft more efficient. They do this by focusing on the shape of the wings to decrease the drag while producing sufficient lift, and by reducing the overall weight as much as possible. Lighter weight and less drag produce higher fuel efficiency.



The Challenge

Using the engineering design process, you will work in a team to design, develop, and build a shoebox glider and then improve it to produce the greatest glide slope (the ratio of distance traveled to decrease in altitude) possible. Things to consider in your design include aircraft and wing materials, shapes, and structure, as well as the weight of the vehicle.

Figure 38. On reentry from space, the space shuttle orbiter did not use engines and landed as a glider. (NASA)

Criteria and Constraints

1. The glider must include an intact shoebox that simulates a space for a scientific payload to carry instruments for in-flight research.
2. The glider must show improvement in glide slope with a positive percent change over the course of the challenge.
3. The glider must not break apart in flight or upon landing.

Based on this information and the challenge's introductory video, answer the following questions.

1. Using your own words, restate the problem in this form: "How can I design a _____that will _____?" Be sure to include all expected criteria and constraints.

_____

_____

_____

2. What general scientific concepts do you and your team need to consider before you begin solving this need or problem?

_____

_____

_____

The Engineering Design Process: Research

Page Number_____

Conduct research to answer the following questions related to the challenge. Cite where you found your information on the lines labeled "Source(s)."

1. Who is currently working on this problem (or a similar problem)? What solutions have they created? What solutions are they currently working on?

_____

_____

_____

Source(s): _____

2. What questions would you ask an expert who is currently trying to solve problems like this one?

_____

_____

_____

3. Who in our society will benefit from this problem being solved? How could this relate to everyday use?

_____

_____

_____

_____

Source(s): _____

4. What have you learned from the Supporting Science Investigations that you can apply to this challenge?

_____

_____

_____

The Engineering Design Process: Design

Page Number_____

Sketch your initial design in the space below and label each part of your drawing.

Notes

_____

_____

_____

_____

The Engineering Design Process: Select the Best Possible Solution

Page Number_____

Collaborate with your team to analyze each team member's final drawing using the table below. Based on a team discussion, determine which design elements will be used to solve the problem and what features will be included to create the team's prototype. The most promising solution should include elements from more than one design.

Designer Name	Does this design meet all problem criteria and constraints?	What are the strongest elements of this design?	What elements need to be improved?
1			
2			
3			
4			

The Engineering Design Process: Prototype

Page Number_____

Make a team drawing of your prototype. Prior to building, have it approved by your facilitator. Include labels and a key.

Approved by _____

List what resources will need to be gathered.

_____

_____

For which part of the build will each team member be responsible?

Team Member				
Responsibilities in the building process				

The Engineering Design Process: Test and Evaluate

Page Number_____

1. Does the shoebox glider function as intended?

   YES NO

2. If not, explain why. Provide details.

_____

_____

_____

_____

3. Does it meet all of the criteria and constraints? (Check the box for each one that is met.)
   - ☐ The glider design included an intact shoebox.
   - ☐ The glider showed improvement in glide slope with a positive percent change over the course of the challenge.
   - ☐ The glider landed intact and sustained no damage.

4. If not, explain why. Provide details.

_____

_____

_____

Perform three tests of your design to see how well it performs. Record your results.

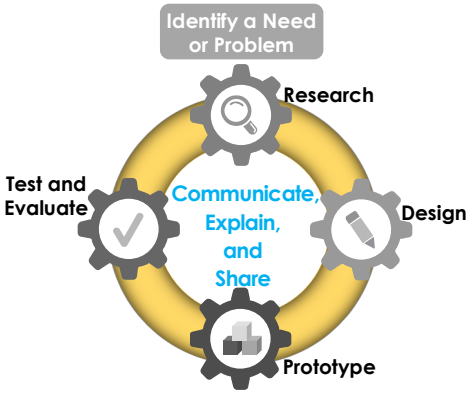
Iteration–Trial	Horizontal Distance	÷	Vertical Distance	=	Glide Slope	Percent Change From Iteration 1	Best Glide Slope in Iteration
1–1		÷		=			
1–2		÷		=			
1–3		÷		=			
2–1		÷		=			
2–2		÷		=			
2–3		÷		=			
3–1		÷		=			
3–2		÷		=			
3–3		÷		=			

The Engineering Design Process: Communicate, Explain, and Share

Page Number_____

Indicate the step you are discussing.

_____



1. What did YOU think about your team's solution at the end of this step?

_____

_____

_____

2. What did OTHER MEMBERS of your team think about the team's solution at the end of this step?

_____

_____

_____

3. Was your personal feedback different from your team's feedback? If so, in what way was it different?

_____

_____

_____

4. Which step of the engineering design process (EDP) will your team move to now?

_____

_____

_____

_____

5. Explain why your team chose this step.

_____

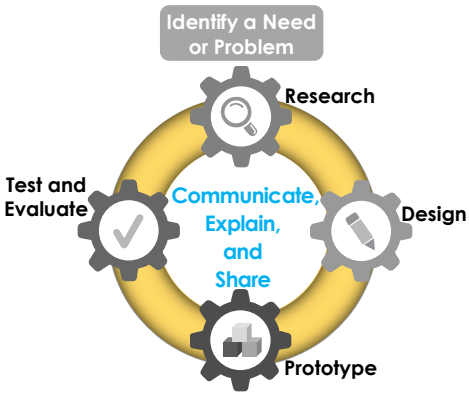
_____

_____

_____

The Engineering Design Process: Communicate, Explain, and Share

Student Presentation Organizer



Use the organizer below to plan how your team will present its final solution. Keep track of the engineering design steps you take so you can tell your audience how your team accomplished the process.

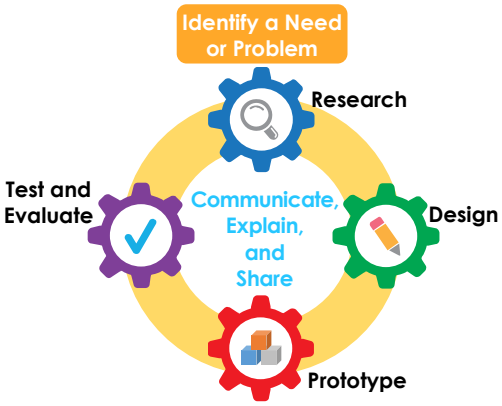
Keep in mind that these steps may have happened in any order or may have been repeated. Use additional sheets if necessary.

Welcome	Share your team name, which challenge you worked on, and the title of your presentation.	
Engineering Design Process (EDP) Practice	**Ideas for what should be included in each step of the presentation**	**Use this space to organize notes and think about the evidence to present. Make note of what your team wants to show and say in the presentation.**
Identify a Need or Problem	Talk about the problem. Discuss the criteria and constraints that will need to be met to solve the problem.	
Research	Discuss what your team discovered during the research and through your interaction with a NASA subject matter expert (SME). Who did you speak with? What did you learn? Where did you find answers to your questions?	
Design	Show each team member's original designs. Show what each team member contributed to the original team drawing.	

Prototype	Show materials used and how you put the prototype together.	
Test and Evaluate	Talk about how your team tested the design and discuss the results. Using the data, discuss the strengths and weaknesses of your team prototype.	
Communicate, Explain, and Share	Talk about your data. Was your team able to solve the problem or not? What improvements did your team make to reach your final solution? Discuss any further action your team would take to improve this solution.	
	Describe how your team members communicated with each other to improve the solution. Also describe how you discussed options with people outside your group.	

Engineering Design Process Team Progress Chart

Use the table below to keep track of which practices your team did, and in what order. This table, along with your Student Presentation Organizer, will help you in summarizing your team's entire process from beginning to end.



Practice Order	Which engineering practice did your team do?	Notes on what your team did or learned during this practice
1	**Identify a Need or Problem**	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Solution Presentation

The final stage of the challenge is to document your progress for sharing with other groups who have completed this engineering design challenge. Your journey may be documented using video or slide presentations.

The finished presentation must meet the following guidelines:

- The introduction must say this: "This is team (team name), and we worked on the (name of challenge). The title of our presentation is (presentation title)."

  Do not identify by name any student, teacher, school, group, city, or region in your presentation. Submissions that do not follow these directions will be disqualified.

- The presentation must document every step you took to complete the challenge, including the Supporting Science Investigations. Use every page of your Student Team Challenge Journal to help complete this presentation.
- Identify any information provided by NASA subject matter experts (SMEs) that helped you in your design or testing.
- Explain which characteristics of the design provided the most reliable results and why.
- The total length of the presentation should be 3 to 5 minutes.

Student Presentation Rubric

This rubric will be used to assess your final presentation. Use it as a checklist to make sure you have included something from every category. Try to achieve as many 3's as you can!

Engineering Design Process	Exemplary = 3	Proficient = 2	Novice = 1	Not Included = 0
We can **identify** the challenge and the criteria.	Challenge was restated and all criteria and constraints were described.	Challenge was restated with only the challenge criteria.	Only the challenge story was stated.	Team did not include a description of the challenge or the criteria.
We can discuss the results of our **research**, the Supporting Science Investigations, and connections with a NASA scientist or engineer.	Three or more facts relating to the challenge were discussed.	Two facts relating to the challenge were discussed.	One fact relating to the challenge was discussed.	No facts relating to the challenge were discussed.
Each of our team members sketched an original **design** that demonstrated the challenge criteria and constraints.	All criteria and constraints were represented (sketches and photos) in each team member's design.	Two criteria were represented (sketches and photos) in each team member's design.	One criterion was represented (sketches and photos) in each team member's design.	No criteria were represented.
Our final team **design** represented elements from each team member's original design.	Team design included the best from each member's design to represent the challenge and the criteria.	Team design included ideas from two team members' designs to represent the challenge and the criteria.	Team design included ideas from one team member's design to represent the challenge and the criteria.	Team was not able to provide a design to represent the challenge and the criteria.
Our team constructed a **prototype** to represent the challenge criteria and constraints.	A prototype was completed that met all of the challenge criteria and constraints.	A prototype was completed that met only two of the challenge criteria and constraints.	A prototype was completed that met only one of the challenge criteria and constraints.	A prototype was completed that did not meet the challenge criteria or constraints.
Our team collected and recorded data to **test and evaluate** our model's solutions.	Data were collected by testing to represent all of the criteria and constraints.	Data were collected by testing to represent only two criteria.	Data were collected by testing to represent only one criterion.	No data were collected and/or no testing was completed.
Our team made **design** improvements after testing the prototype.	All improvements to the prototype were described.	Two improvements to the prototype were described.	One improvement to the prototype was described.	No improvements to the prototype were described.
Our team was able to **communicate and explain** our design and how we solved the challenge.	Difficult issues were explained and their solutions described.	Difficult issues were explained with no solutions offered.	Discussion of difficult issues was unclear and no solutions were presented.	No discussion of difficult issues was included.
Our team was able to **share** our work through the **presentation process**.	All the presentation requirements and procedures were met.	Three or more of the presentation requirements and procedures were met.	One or two of the presentation requirements and procedures were met.	The presentation requirements and procedures were not met.

Vocabulary List

Aerodynamics. The branch of mechanics dealing with forces exerted by air or other gases in motion

Aeronautics. The science and art of flight through the atmosphere

Airfoil. The shape of a wing as seen in cross section, designed to produce aerodynamic forces as it moves through the air

Angle of attack. The angle of the chord line of the wind to the oncoming relative wind, controlled by the pilot during flight

Area. The number of square units of surface a figure covers

Bernoulli's principle. Guiding principle in fluid dynamics that states as a fluid's speed increases, the pressure within the fluid decreases. For flight through air, the pressure on top of an airfoil must be less than the pressure below

Camber. The asymmetry between the top and bottom curved surfaces of an airfoil to maximize lift

Center of gravity. The point in any object where the weight of the object is evenly dispersed and all sides are in balance

Chord (airfoil). A line connecting the leading edge of an airfoil to the trailing edge

Drag. A slowing force acting on a body moving through a fluid, including air, parallel and opposite to the direction of motion

Force. A cause of motion; power or energy exerted against an object in a given direction

Fuselage. The basic structure of the airplane to which all the other parts are attached

Glide ratio. The horizontal distance traveled divided by the change in altitude

Gravity force of attraction that exists between all matter in the universe

Horizontal stabilizer. A fixed piece, usually on the tail, that prevents up-and-down motion of the nose, called pitch

Lift. The upward force that opposes the pull of gravity

Leading edge (airfoil). The edge that meets relative wind first

Mass. The amount of material in an object

Pitch. The movement of an aircraft up and down

Rib. Forming element of the structure of a wing, running parallel to the fuselage and perpendicular to the spars

Roll. The movement of an aircraft in a spinning direction

Skin (airfoil). The thin, durable outside surface of the wing that surrounds the spars and ribs

Spar (airfoil). The main structural member of a wing, running from the aircraft's fuselage toward the wingtip

Stabilizer. A fixed wing section used to provide stability for the aircraft to keep it flying straight

Appendix

The following pages contain templates of ribs that can be used to create more advanced three-dimensional (3D) wing shapes. These templates were created using cross sections of original airfoils tested by the National Advisory Committee for Aeronautics (NACA). They have been selected to emphasize a variety of wing styles: a thinner symmetric wing, a thicker symmetric wing, an asymmetric flat-bottom wing, and a cambered wing. While these templates can serve as the basis for 3D designs, they can be modified by teams to create their own rib shapes.

Because lift is the largest factor keeping aircraft in the air, wings are carefully shaped and structured to generate as much lift as possible. Modern wings contain spars, ribs, and skin to provide strength, structure, and shape. **Spars** are straight beams that run from the body of the aircraft to the wingtips. **Ribs** sit perpendicular to the spars and give a wing its distinct shape. The **skin** is the thin, durable outside surface of the wing that surrounds the spars and ribs.

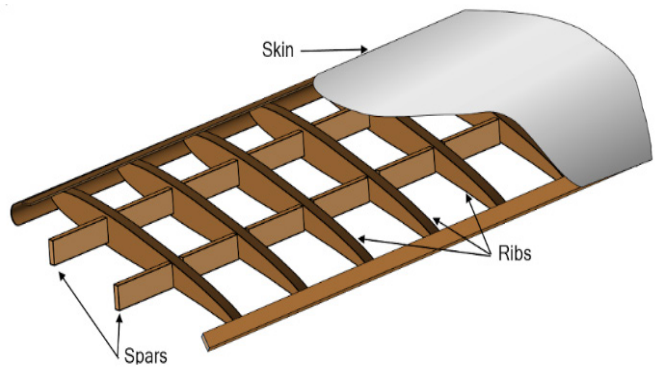


Figure 39. Illustration of the inside of a basic wing.

Instructions have been provided on the following pages to give a suggested concept for wing assembly for any of the templates. Each template page shows the model the rib reflects and includes a 7.5 x 0.2 cm (3 x 1/8 in.) slot in the center for the purpose of sliding multiple ribs onto a single spar. This feature can also be modified as desired by student teams to improve their design.

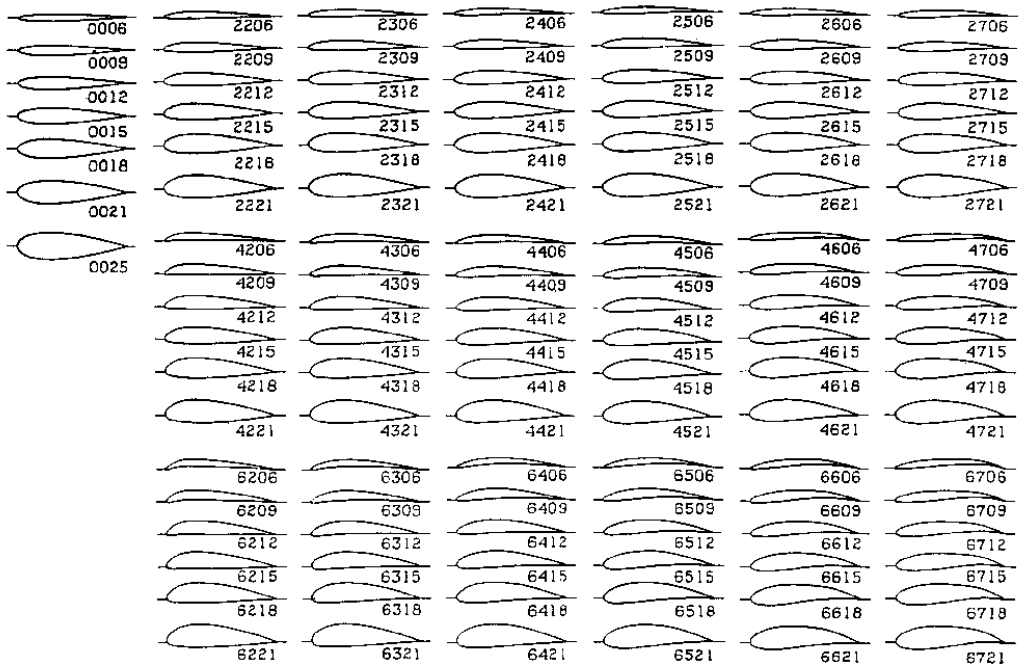


Figure 40. Illustration featuring a group of related NACA airfoils. Each design was proportioned with the same chord length for purposes of controlled testing.

Instructions for Wing Assembly

The following instructions can be used to create simplified starting wings for student gliders. These steps may be modified to allow for creativity in wing design.

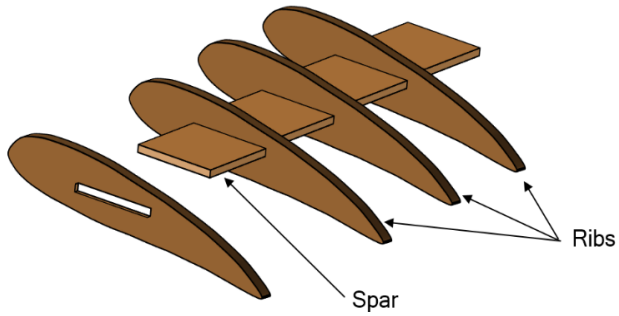


Figure 41. Sample wing structure made from engineering design challenge rib templates.

1. Choose a NACA-modeled rib design and cut it out, including the slot in the center.
2. Trace the rib design and slot on a piece of sturdy cardboard or any other desired material. Trace as many ribs as you wish to include on both wings.
3. Cut out the traced ribs, including the slot in each rib.
4. Create two rectangular spars of the same size using cardboard or any other desired material. Each spar should have a width of 7.5 cm (3 in.) to match the slot in each rib. The length of the spars depends on the desired length of each wing.
5. Slide the spar through each rib's slot, adding as many ribs to each spar as the design requires.
6. Secure the two spars onto the shoebox using tape, glue, or any other adhesive.
7. Cover the ribs and spars with a sturdy yet flexible material such as cardstock to act as a skin and create an aerodynamic wing surface.

To alter the amount of lift an aircraft's wings can generate, several features can be changed, including the following:

- Its **geometry**—the length and width of the wing
- Its **thickness**—the measurement through the wing from the top surface to the bottom surface
- Its **chord**—the measurement through the wing from the front edge to the back edge
- Its **camber**—the degree of curve of the wing's top and bottom surfaces, which may be different from each other
- Its **angle of attack**—the angle of the wing compared to the direction the aircraft moves forward through the air

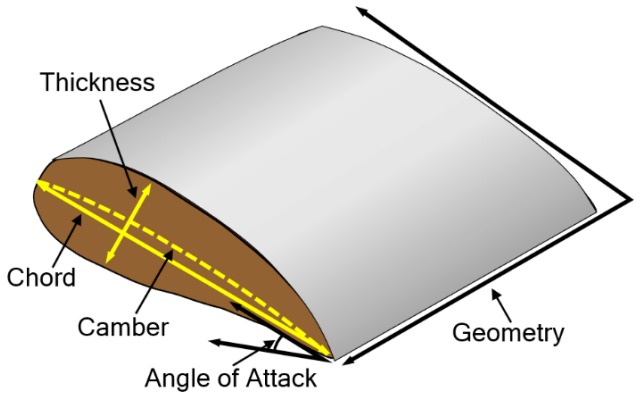
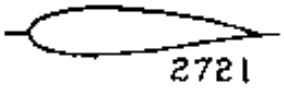
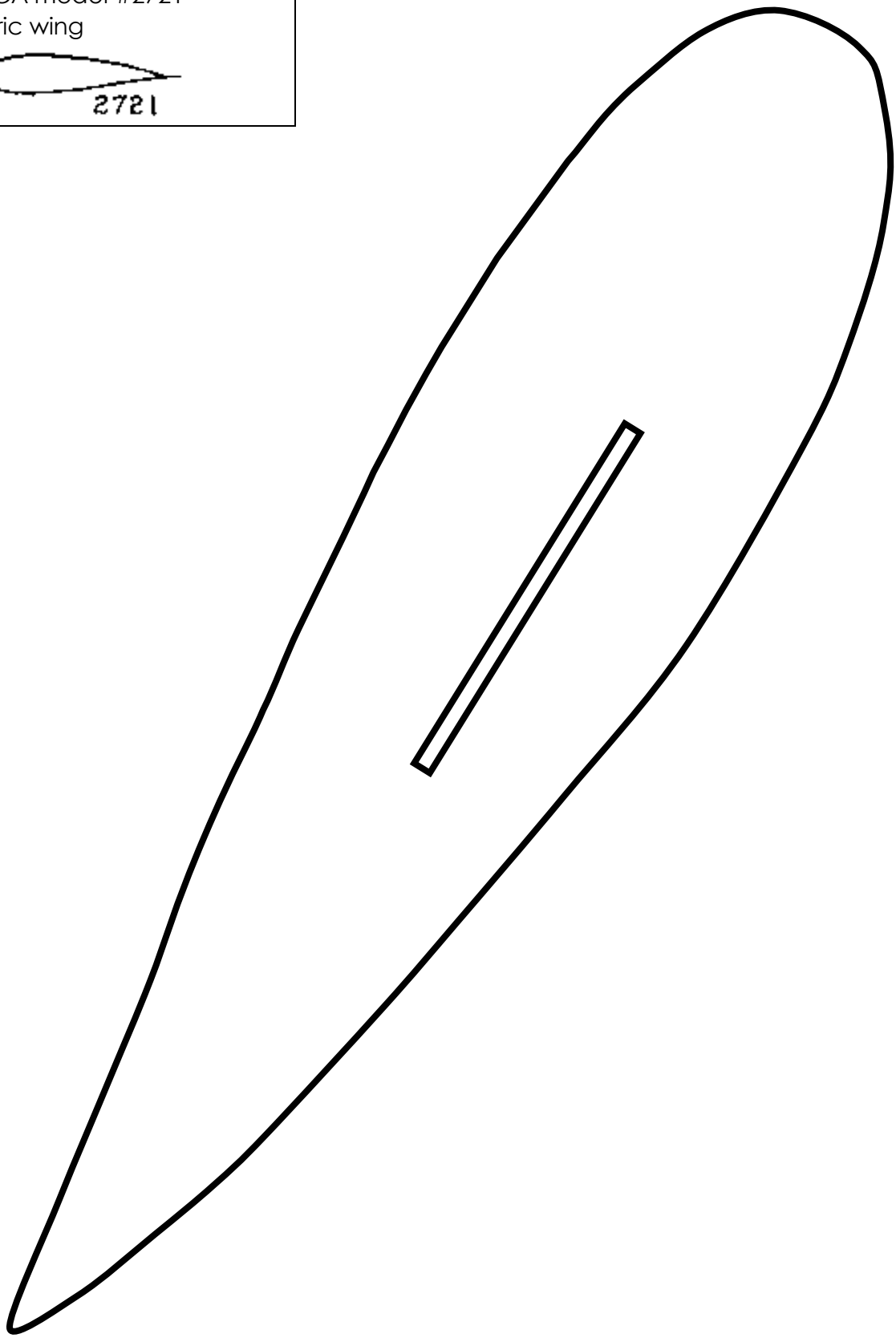
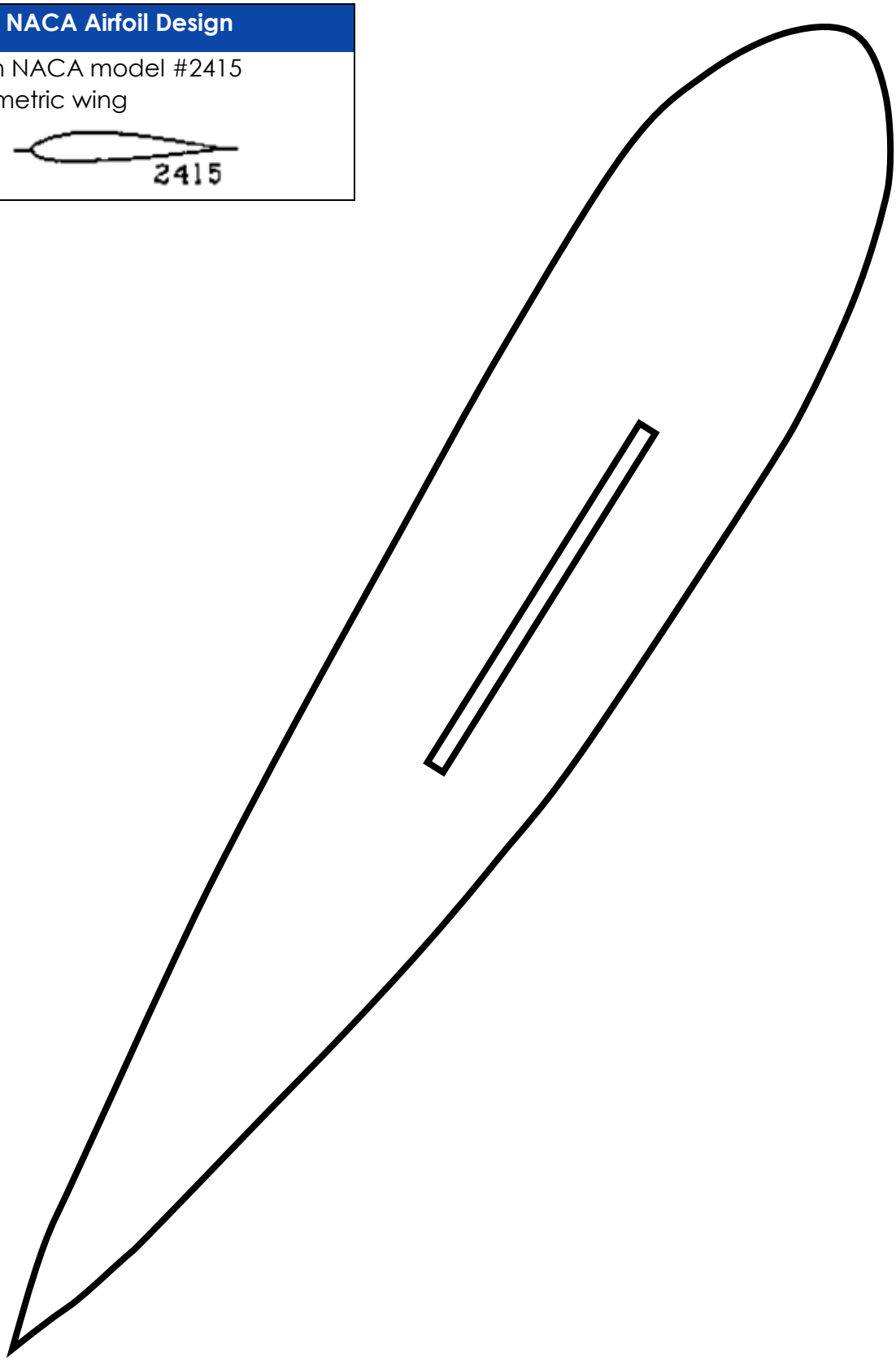


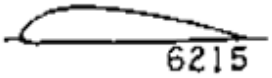
Figure 42. Wing features that can be modified to affect lift.

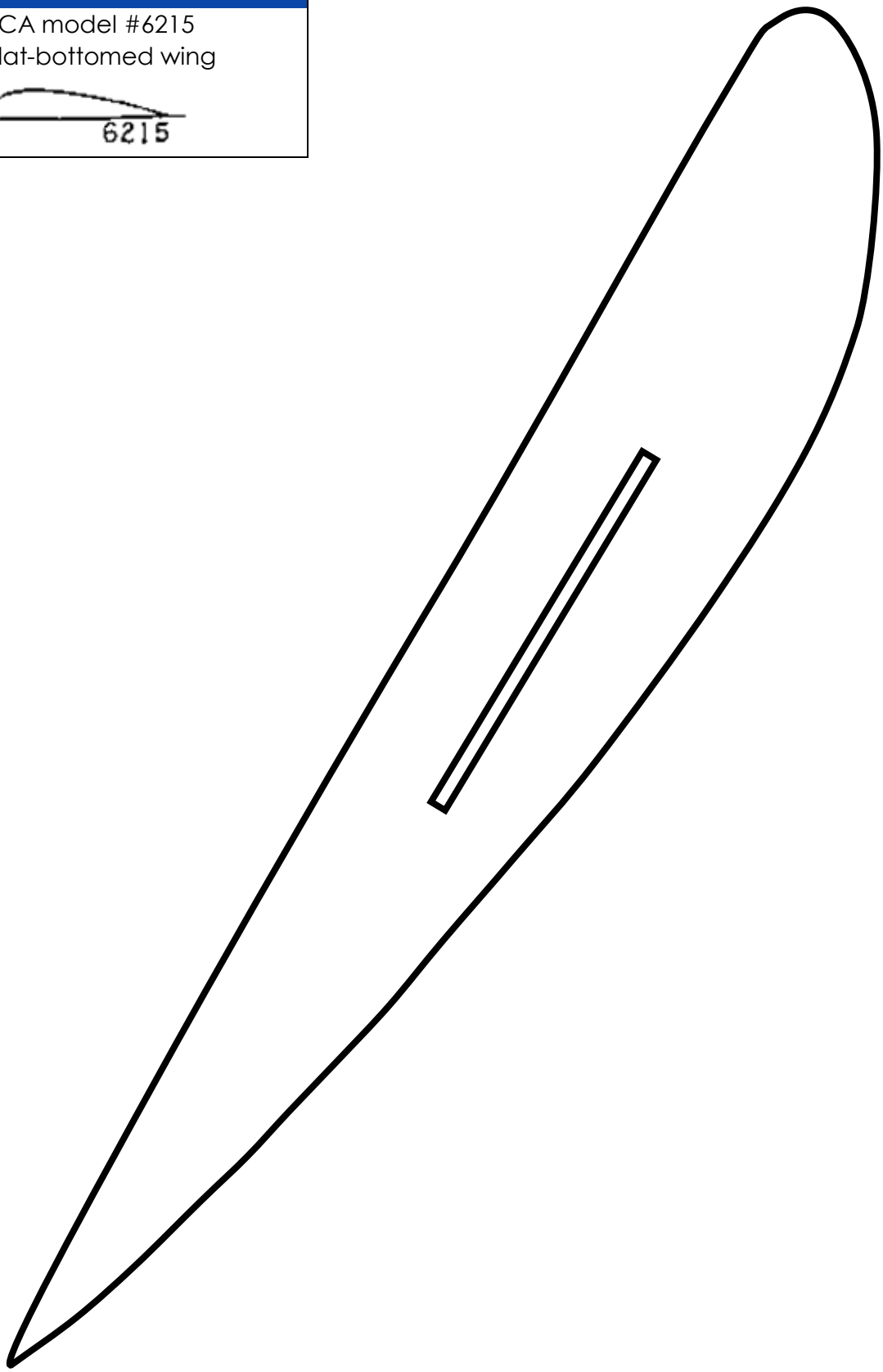
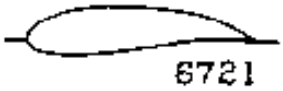
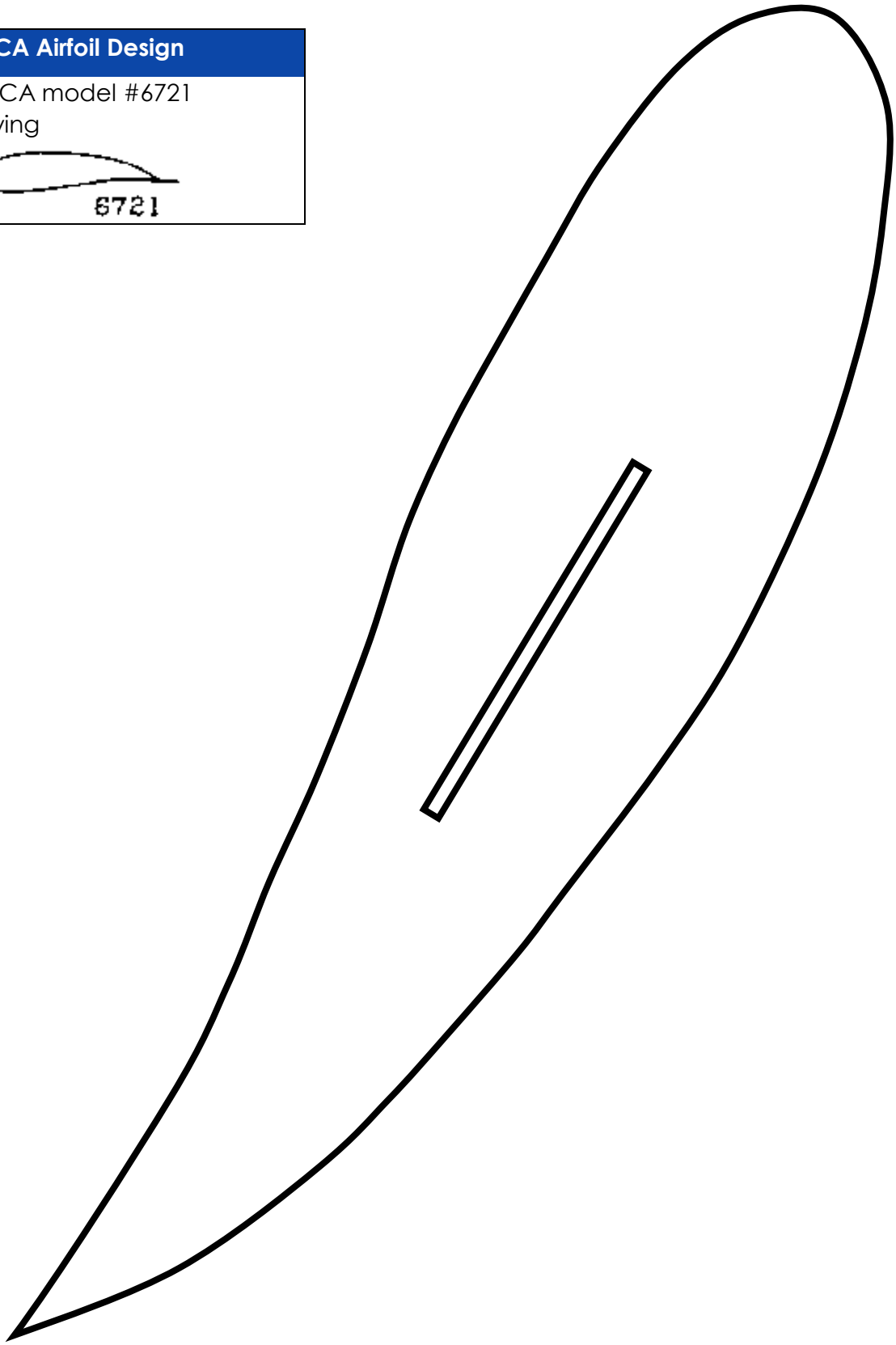
NACA Airfoil Design
Based on NACA model #2721 Thick symmetric wing 



NACA Airfoil Design
Based on NACA model #2415 Thin symmetric wing



NACA Airfoil Design
Based on NACA model #6215 Asymmetric flat-bottomed wing 



NACA Airfoil Design
Based on NACA model #6721 Cambered wing