National Aeronautics and Space Administration

21st Century Community Learning Center
NASA Engineering Design Challenge

Let It Glide

STEM Facilitation Guide

NASA: Why We Explore

Humanity's interest in the heavens has been universal and enduring. Humans are driven to explore the unknown, discover new worlds, push the boundaries of our scientific and technical limits, and then push further.

Human space exploration helps address fundamental questions about our place in the universe and the history of our solar system. Through addressing the challenges related to human space exploration, we expand technology, create new industries, and help foster peaceful connections with other nations. Curiosity and exploration are vital to the human spirit. Accepting the challenge of going deeper into space will invite the citizens of the world today and the generations of tomorrow to join NASA on this exciting journey.

The United States is a world leader in the pursuit of new frontiers, discoveries, and knowledge. The National Aeronautics and Space Administration, more commonly known as NASA, performs a unique role in America's leadership in space. NASA has landed people on the Moon, sent spacecraft to the Sun and every planet in the solar system, and launched robotic explorers to travel beyond the solar system. NASA's vision is to discover and expand knowledge for the benefit of humanity.

NASA was formed in 1958 and has amassed a rich history of unique scientific and technological achievements in human space flight. From John Glenn's 1962 orbit around the Earth in Mercury Friendship 7, through the Apollo missions and the space shuttle years, to today's orbiting International Space Station (ISS), NASA is on the forefront of manned space flight.

Figure 1. Illustration of the Orion Spacecraft, a multi-purpose crew vehicle designed to carry astronauts into deep space. (NASA)

NASA is leading the next steps into deep space near the Moon, where astronauts will build and begin testing the systems needed for challenging missions to deep space destinations, including Mars. This area of space near the Moon offers a true deep space environment to gain experience for human missions that push farther into the solar system, yet astronauts will be close enough to access the lunar surface for robotic missions and, if needed, return to Earth in days rather than weeks or months.

NASA's future success and global leadership will be determined largely by the investments and innovations we make today in scientific research, technology, and our workforce. NASA's focus has always been, and always will be, to discover, invent, and demonstrate new technologies, tools, and techniques that will allow our Nation to explore space while improving life on Earth.

Career Connection

Figure 2. Aerospace Engineer Chris Randall tests rocket parts and life support systems to ensure they work as planned. (NASA)

What is an engineer? An **engineer** is a person who works on a team to solve a problem that humans want to solve or make better. Engineers are at the heart of every engineering challenge. Engineers design and build things we use every day. The NASA for Kids video "Intro to Engineering" explains the role of an engineer and can be shared with your students: http://youtu.be/wE-z_TJyzil. After viewing the video, have students discuss what they learned about what an engineer does.

Some examples of NASA-engineered products include the following:

Figure 3. Simulation System Engineer Debbie Martinez works on developing general aviation flight simulation software. (NASA)

- Portable x-ray machines: NASA engineers worked to create a small, low-radiation x-ray machine so medical professionals can examine people's injuries at accident scenes.
- Infrared ear thermometers: NASA engineers developed infrared temperature sensors for space missions, and these sensors were adapted to create a faster and easier way to take someone's body temperature.
- Food processing control: NASA engineers worked with food production companies to create a process to identify the critical points where food could be contaminated.
- Airplanes: NASA engineers work with private companies to design and develop aircraft that are safer, quieter, lighter, more fuel efficient, and more reliable.

Engineers help to improve society. Women and men of all races, ethnicities, and walks of life can become engineers. Encourage students to explore NASA engineer career profiles at https://www.nasa.gov/audience/forstudents/careers/profiles/index.html

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Introduction to the Engineering Design Challenge

Figure 4. Artist's rendering of the Space Launch System. (NASA)

Facilitator's Overview

NASA has created an **engineering design challenge (EDC)** that involves students in using the **engineering design process (EDP)** to develop solutions to authentic NASA mission-centered challenges.

The EDC serves as an authentic, standards-driven investigation that allows students to engage in the process of answering questions and solving problems like today's scientists and engineers do. This EDC provides students with opportunities to gain tangible skills that are essential in science, technology, engineering, and mathematics (STEM) careers. This guide is organized into three sections:

1. **Introductory Materials** establish a basic level of understanding about the EDP and the EDC and provide tools to support students through the challenge.
2. **Facilitator Instructions** provide instructions for facilitators to use throughout the design challenge and include tools to assess student understanding throughout each step.
3. **Student Team Challenge Journal** contains prompts and tools to guide students through the cycle of steps in the EDP while documenting their work for each step. It is suggested that each student have a copy of this journal.

What is the Engineering Design Process?

The EDP is a systematic practice for solving problems. Engineers work through the process to solve problems and create new technologies and systems that enhance our lives. All EDP models begin by identifying a need or problem, but there is no defined or fixed path toward the end goal. The EDP model allows problem solvers the flexibility to move between steps as appropriate for the challenge faced.

What is an Engineering Design Challenge?

The EDC is a learner-centered instructional approach that organizes learning around a shared goal or challenge. Students are presented with a challenge or problem and, using the EDP, work in teams to complete activities and experiments to develop solutions toward solving that problem. These challenges facilitate teamwork and engage students in problem-solving practices used by real-world engineers.

Engineering Design Process

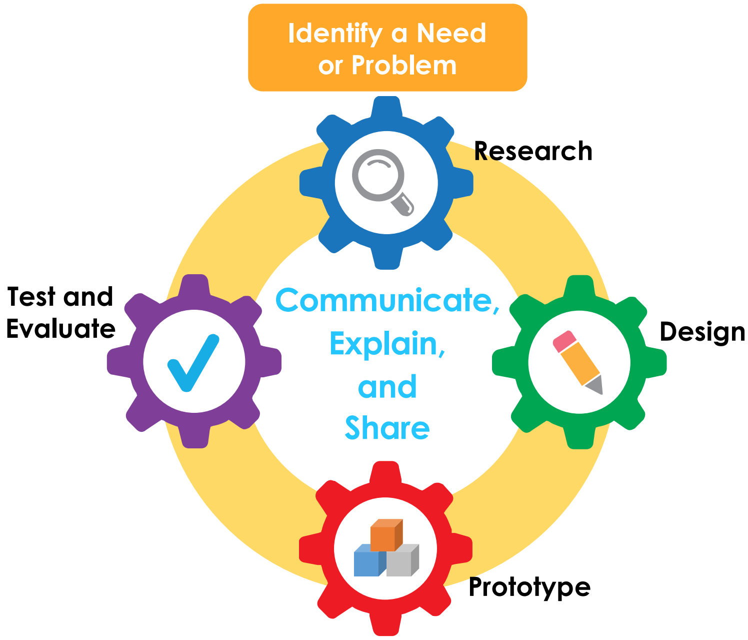


Figure 5. Engineering design process model. Model and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

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.

Engineering Design Challenge: Let It Glide

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.


Figure 6. On reentry from space, the space shuttle orbiter did not use engines and landed as a glider. (NASA)

The Challenge

Using the engineering design process, students 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 students should consider in their designs include aircraft and wing materials, shapes, and structure, as well as the weight of the vehicle.

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.

Suggested Pacing

The following pacing guide serves to assist facilitators in planning each session. Facilitators should feel free to condense or expand the structure of these activities or add additional engineering design process (EDP) iterations to fit their specific needs. It is estimated that the entire EDP for this challenge will take between 12 and 20 hours.

Activity	Approximate Time
Facilitator Preparatory Work	2 hours
Engagement: • Access prior knowledge • Watch the introductory video • Present background information	1 hour
Exploration and Explanation:	
• Supporting Science Investigation 1: Exploring Glider Design	60 minutes
• Supporting Science Investigation 2: Air Force Three	30 minutes
• Supporting Science Investigation 3: Airfoil on a String	30 minutes
Elaboration:	
• Introduction to the Engineering Design Process (EDP) *The following activities represent the steps of the EDP. They may be completed in any logical order and should be repeated as often as necessary to complete the challenge.*	30 minutes
• Identify a Need or Problem	30 minutes
• Research	1 hour
• Design	1 hour
• Prototype	1 hour
• Test, Evaluate, and Redesign	2 hours
• Communicate, Explain, and Share	30 minutes
Evaluation: • Creating solution presentations • Student debriefing questions	1.5 hours

Learning Outcomes

Education Standards

The engineering standards addressed here are tailored for 6th–8th grade students based on Next Generation Science Standards. Even if your state has not adopted these standards, similar core ideas are likely found in other terms in your state's standards.

Standards Addressed

Next Generation Science Standards
Engineering Design • **MS–ETS1–1** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. • **MS–ETS1–2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • **MS–ETS1–3** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. • **MS–ETS1–4** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. • **MS–PS2–1** Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. • **MS–PS2–2** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Connected Concepts

Common Core State Standards	
Mathematics	***English Language Arts***
• **MP.2** Reason abstractly and quantitatively. • **MP.4** Model with mathematics. • **6.RP.1** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. • **6.RP.3** Use ratio and rate reasoning to solve real-world and mathematical problems. • **7.RP.2** Recognize and represent proportional relationships between quantities. • **7.EE.3** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.	• **RST.6–8.2** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. • **RST.6–8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). • **WHST.6–8.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. • **WHST.6–8.8** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. • **WHST.6–8.9** Draw evidence from informational texts to support analysis, reflection, and research. • **SL.6–8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

Evidence of Learning

This guide uses a number of tools to indicate student progress, including the following:

- Accessing of existing knowledge and assessment of level of understanding
- Supporting Science Investigations, Data Collection Sheets, and post-investigation discussions
- Sample guiding questions to assist in facilitating discussions
- A final assessment, including creation of a video or slide presentation explaining the iterative design process, challenges encountered, and how decisions were made based upon the concepts learned

Student Team Challenge Journal

The engineering design process (EDP) that each team uses will vary from team to team. Prior to starting the engineering design challenge, print and assemble enough copies of the Student Team Challenge Journal into three-ring or loose-leaf binders so that each student receives a complete journal. Included in the journal are the EDP practices students will use to record their progress. Print extra copies of these EDP sheets and make them available for students. Students will select the appropriate sheets as they move through the process. Instruct students to work page-by-page through their journals, documenting the challenges they faced and the steps they took. This documentation will help students prepare their final presentations.

Solution Presentation Criteria

Student teams should use the Student Presentation Rubric to guide them as they work through the challenge. The Student Presentation Organizer and the Team Progress Chart are tools students can use to help them create a final product that clearly communicates the team progress through the engineering design challenge.

Once the video or slide presentation is complete, submit according to the guidelines on the Y4Y (You for Youth) website.

Student Presentation Rubric

This rubric can be used to review and assess the quality of each final presentation. Each category will be scored from 0 to 3 points. Totals for each column will be added for a final score.

Team name: ______________________________ **Total score:** ____________________________

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.

Facilitator Instructions

Recommended Materials

The following materials are required to complete this challenge. The quantity will depend on the number of students participating. Alternatives and additional materials can be used if desired, but be mindful of safety when allowing students to bring in or handle materials that could potentially be dangerous.

Each team will require the following items:

- Shoebox, including lid
- Yard or meter stick
- Tape measure, at least 8 m (or 25 ft) long
- Cardboard
- Sample rib templates
- Heavy-duty scissors
- Writing utensils
- Pennies, washers, or other objects to use as counterweights
- Scale

Figure 7. Household supplies that could be used as construction materials for the challenge.

Examples of additional materials that may be used:

- Cardstock
- Craft sticks, lollipop sticks, or tongue depressors
- Dowel rods (various sizes)
- Glue
- Heavy-duty aluminum foil
- Magnifying lenses and mirrors
- Manila folders
- Paper (copier, construction, and waxed)
- Paper bags
- Plastic wrap (clear and colored)
- Polystyrene cups
- Poster board
- Rubber bands
- Skewers
- Staplers and staples
- Tape (packing, duct, masking, and transparent)

Safety

Safety, an important issue for all curricular areas of education, is of special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote development of student knowledge and abilities in a safe learning environment.

School administrators, teachers, and facilitators are responsible for providing a learning environment that is safe, suitable, and supportive. Facilitators are also responsible for their students' welfare in the classroom and laboratory.

Facilitators should

- Approve all drawings before students start building their designs.
- Look for flimsy structure designs and potentially hazardous combinations of materials.
- Ensure that resources are clean and dry, with no sharp edges exposed.
- Make sure all materials are undamaged and in good repair.
- Prohibit students from bringing in or using additional materials for their designs without prior approval.

Students should

- Make safety a priority during all activities.
- Wear safety goggles when conducting all investigations and the challenge.
- Demonstrate courtesy and respect for ideas expressed by others in the group.
- Use tools and equipment in a safe manner.
- Assume responsibility for their own safety and the safety of others.

Team Building

Begin by dividing students into teams of no more than four to give all students an opportunity to contribute. By working as members of a team, students develop skills such as trust, cooperation, and decision making. Working as a team member, however, can be challenging for some students. The following exercises are recommended to help teams begin to work together effectively.

Figure 8. This Apollo 11 patch depicts an eagle landing on the Moon with a view of the Earth in the background. (NASA)

Establish a team name. Many NASA teams are named based on the work they do.

Design a mission patch. Teams that work on NASA missions and spacecraft are unified under a mission patch designed with symbols and artwork to identify the group's mission.

Create a vision statement. This is a short inspirational sentence or phrase that describes the core goal of the team's work. NASA's current vision statement is "*To discover and expand knowledge for the benefit of humanity.*"

As students begin to work together, their individual strengths will become apparent. Students can volunteer or be assigned tasks or responsibilities that are vital to completing the challenge. Team jobs can also be rotated throughout the team members to give all students an opportunity to improve their team skills. The following list includes examples of jobs that student teams will need to complete. Feel free to come up with others, and remember that all team members should serve as builders and engineers for the team.

Design engineer. Sketches, outlines, patterns, or plans the ideas the team generates

Technical engineer. Assembles, maintains, repairs, and modifies the structural components of the design

Operations engineer. Sets up and operates the prototype to complete a test

Technical writer/videographer. Records and organizes data and prepares documentation (text, pictures, and/or video) to be reported and published

NASA Mission Background

The National Advisory Committee for Aeronautics: 100 Years of Flight Research

The National Advisory Committee for Aeronautics (NACA) was founded on March 3, 1915, to improve the Nation's competitiveness in world aviation. The NACA worked to improve all aspects of aircraft and flight, including wing and body shapes, retractable landing gear, construction materials, and fuels, allowing planes to fly faster and higher as well as more safely and efficiently. The NACA also contributed to developing technologies that made it possible to fly faster than the speed of sound. This early aviation research became the foundation for America's space program.

Figure 9. The NACA emblem on the Flight Research Building at the Ames Aeronautical Laboratory, now called Ames Research Center. (NASA)

In 1917, the NACA set up four research laboratories where scientists and engineers could experiment with many aspects of flight. These research centers became part of the National Aeronautics and Space Administration (NASA) in 1958 and are known today as Langley, Ames, Glenn, and Armstrong.

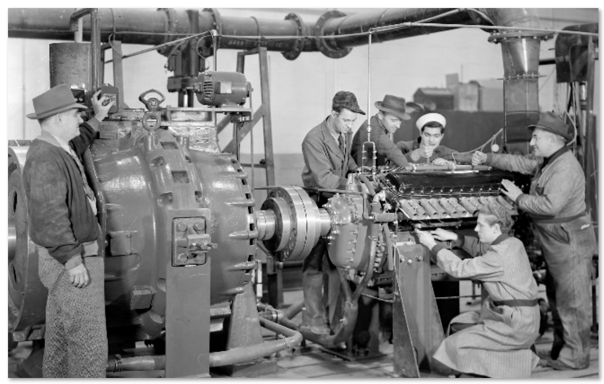


Figure 10. NACA crew working on an Allison V–1710 engine in the Engine Research Building at the Aircraft Engine Research Laboratory, now called Glenn Research Center. (NASA)

In the early years, research focused on improving the basics of the airplane itself, but researchers soon realized that flying higher and faster was limited by the capabilities of an aircraft's engines. Scientists created wind tunnels that simulated actual flight conditions so they could test aircraft engines to maximize power, test material durability, and study the effects of icing at high altitudes. This testing improved all aircraft used in World War II. Aircraft fuel research at Lewis Research Center (renamed Glenn in 1999) allowed scientists to discover that liquid hydrogen could be used as a very high-powered rocket fuel for space flight.

Figure 11. Changing the lettering on the Cleveland laboratory hangar from "NACA" to "NASA." (NASA)

Current NASA Flight Research

NASA continues aeronautics research as one of its key missions, working on innovative concepts and technology to enable revolutionary advances in air vehicles to help them fly faster, cleaner, quieter, and with improved fuel efficiency.

NASA uses a variety of aircraft to conduct in-flight research, from single-engine propeller aircraft to multi-engine jets. The design of each aircraft provides unique performance capabilities, and each aircraft is custom fitted with a variety of sensor ports and view ports for research. The interiors of the research aircraft have been redesigned to accommodate the size and weight of racks of scientific equipment used to collect and store data during flights. In-flight research conducted out of Glenn Research Center has included tests of wing deicing systems and remote flight control for uncrewed aircraft systems. In-flight environmental studies have explored the continuous melting of icecaps in Greenland and the ecological effects of toxic algae in Lake Erie.

Figure 12. NASA scientist sitting beside a rack of scientific equipment for an airborne communications and data transfer project aboard one of Glenn's jet aircraft. (NASA)

In July 2015, scientists predicted that the rapid reproduction and growth of algae, known as an algal bloom, would be severe in Lake Erie for the remainder of the summer and fall. Algae thrive when there is an abundance of nutrients (often from agricultural runoff) and sunlight as well as warm water temperatures. Harmful algal blooms can lead to massive deaths in fish populations and can affect the safety of water for recreation and consumption. Glenn Research Center used in-flight research to gather more detailed information and data about this and other ecologic events to help in understanding and combating their destructive effects.

Figure 13. Photograph of algal blooms, visible as swirls of green, in western Lake Erie. Photo taken July 28, 2015, by the Landsat 8 satellite in orbit around the Earth. (NASA)

Flight Research for the Future: NASA's X–59 Aircraft

Current NASA research includes the development of an experimental aircraft designed as a "low-boom" vehicle, reducing or almost eliminating sonic booms—the thunder-like sound produced when an aircraft flies faster than the speed of sound (about 767 mph). This extremely loud noise is heard on the ground when an aircraft or other type of aerospace vehicle flying overhead breaks the sound barrier. Sonic booms are so loud that the United States banned most supersonic flights over land in 1973.

Figure 14. Artist's rendition of NASA's X–59 aircraft. (NASA)

NASA's X–59 Quiet SuperSonic Technology (QueSST) model was created to study how to reduce the intensity of sonic booms. The X–59 QueSST is shaped to reduce the loudness of a sonic boom to that of a gentle thump, if it is heard at all. This research could restore supersonic flights over U.S. land mass, making air travel faster and more efficient.

The Basics of Flight

A force is a push or a pull. How an airplane flies in the air is the result of four forces: weight, lift, thrust, and drag. The study of these forces is the science of aerodynamics. In order to achieve flight, an airplane must overcome the downward force of its weight. To counteract weight, an airplane produces an opposite upward force called lift, which is caused when air flows over and under the wing. Some of this airflow comes from the wind, but the majority happens as an aircraft uses its engines to create thrust, a force that speeds the plane forward. As more air flows over the wings, more lift is created. This is why airplanes speed down the runway into the wind to take off. A fluid resists objects moving through it, and this force is known as drag. You may have experienced this force if you have tried to walk through deep water. The water resists you passing through it. The same thing happens, to a lesser extent, as you push through the air.

Of the four forces, lift is the most complex. The wings of an aircraft create the lift force as the plane moves through the air. The lift force results from the fact that the wings turn air downward. Altering the lift can be done in several ways:

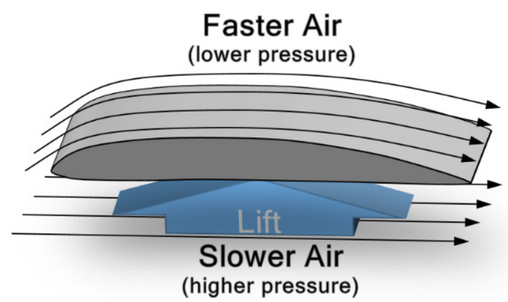


Figure 15. Illustration of Bernoulli's principle.

- Changing the shape of the airfoil—the cross-section shape of the wing—by changing the amount of curvature, known as camber, can create more lift. Airfoils are designed with specific cambers to keep air flowing closely over the wing and turn the air downward to create lift. Pushing the air down so the plane will move up demonstrates Newton's third law of motion: For every action there is an equal and opposite reaction. Changing the camber also causes the air at the surface of the wing to speed up. According to Bernoulli's principle, this causes a decrease in the pressure of the air at the wing's surface, especially over the upper surface where the air moves faster. The now-greater pressure of the surrounding air pushes up on the wing, adding to the lift force.
- Changing the area of the wing will affect the lift. You can vary the distance from the front edge to the back edge of the wing, called the chord, as well as the length of the wing. Long, thin wings create less drag.
- Changing the sweep of the wings will also affect lift. Swept-back wings create less drag than straight wings. This is more noticeable at high speeds.
- Changing the angle of attack—the angle at which the wing meets the air—also turns the air downward to create lift. (You may have experienced this by holding a hand palm-down out of the window of a car traveling at higher speeds and rotating your wrist.) Too much of an angle, however, stops turning air, causing the wing to lose lift and go into a stall. Without lift, gravity takes over and the plane falls.

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:

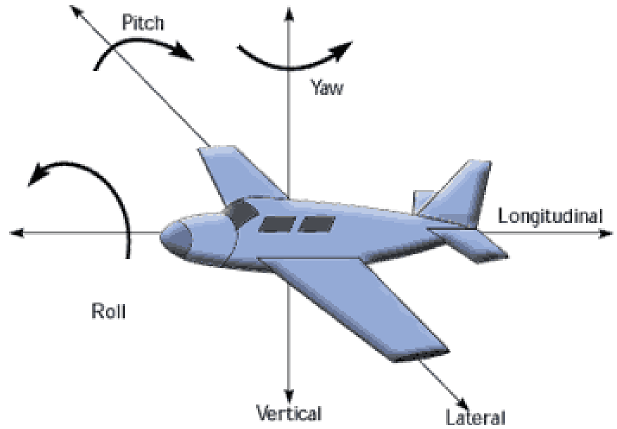


Figure 16. Illustration of the axes of rotation of an aircraft in three dimensions.

- 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).

Gliders

Gliders are a special type of flying vehicle. Since a glider lacks any means of thrust to push it forward, the drag caused by moving through the air gradually slows it down. As less air flows over the wing, the glider loses lift, and it descends to the ground. The ratio of the horizontal distance traveled to the vertical height the glider falls is called the glide slope. The most well-designed gliders will have the largest glide slopes.

Figure 17. The Space Shuttle Atlantis glides in for a landing at Edwards Air Force Base in 1989. (NASA)

NASA's best-known glider was the space shuttle. Its engines were only used during launch and to maneuver while in space, not when returning to Earth. At the end of each mission, the shuttle landed as a glider.

Engagement: Accessing Existing Knowledge

Prior to starting the engineering design challenge, it will be useful to identify students' existing knowledge and level of understanding using a series of guided questions related to this specific challenge. This discussion will allow facilitators to tailor the challenge and the Supporting Science Investigations to the group, maximizing the educational benefit.

The following questions provide a starting point from which additional topics may be discussed.

- What is a wing?
- What is the purpose of a wing?
- Can you name any different types of wing?
- What is a glider?
- What is the difference between a glider and an airplane?
- Can you name the forces that act upon an aircraft in flight?

STEM Vocabulary

Engineering design challenges and the engineering design process (EDP) are concepts that may be unfamiliar to your students. Younger students in particular may not have heard words like "criteria" or "constraints," which are commonly associated with engineering design.

A list of related STEM vocabulary words is included in this guide. If practical or appropriate, a vocabulary wall can be created to assist in familiarizing students with these words.

Student Team Challenge Journal

Before moving on to the Supporting Science Investigations, provide students with the Student Team Challenge Journal. Additional sheets should be made available as students work through the challenge. Where possible, engage students by relating the information to their everyday lives.

Exploration: Supporting Science Investigations

The following pages contain three Supporting Science Investigations to help with students' understanding of the background material. Ideally, students will perform all three investigations, but facilitators should ensure that at least one of these investigations is completed prior to commencing the engineering design challenge. These investigations will explore the primary concepts used during the challenge.

This section includes the following Supporting Science Investigations and their respective concepts:

- Investigation 1: Exploring Glider Design
  - An aircraft uses four forces while in flight.
  - An aircraft uses control surfaces in order to adjust those forces.
  - An aircraft has a theoretical point upon which all forces act—the center of gravity.
  - An aircraft moves in three axes around this point.

- Investigation 2: Air Force Three
  - An aircraft wing is designed to produce lift.
  - Lift is produced based upon a principle discovered by a scientist named Bernoulli.
  - Air moving over the top of a wing is faster and of lower pressure than the air under the wing.

- Investigation 3: Airfoil on a String
  - A wing is designed to produce lift.
  - The amount of lift produced is dictated by the angle at which the wing moves through the air.
  - A wing angled beyond a certain critical point will produce no lift at all.

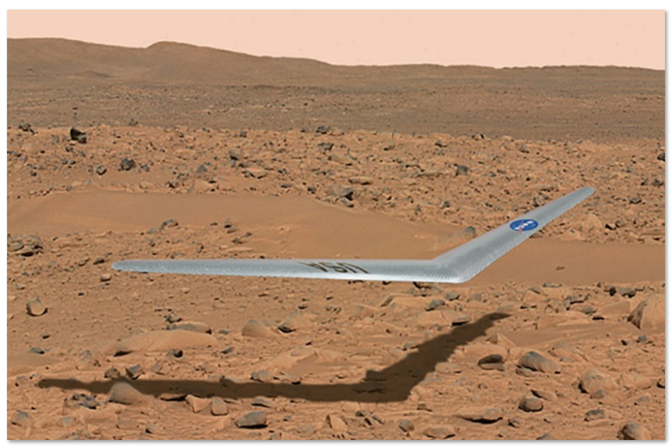


Figure 18. Illustration of what a glider might look like flying over the surface of Mars. This Prandtl-M glider was designed by a team of students and NASA engineers. (NASA)

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.

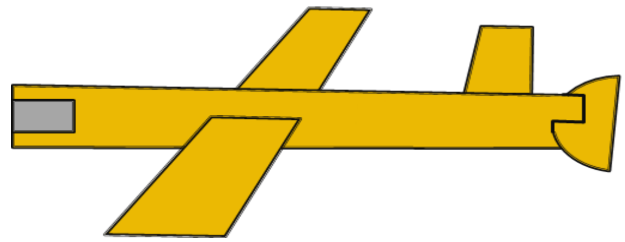


Figure 19. Illustration of a simple balsa wood glider.

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:

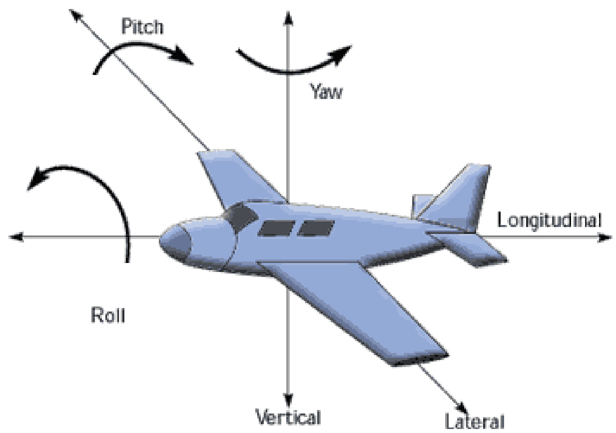


Figure 20. Illustration of the axes of rotation of an aircraft in three dimensions.

- 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, students will assemble a balsa wood glider and explore the functions of its parts by flying it with a part removed or adjusted.

Materials

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)

Notes

- An added suggestion is to have multiple gliders for each student, as the balsa wood gliders are delicate and students may need more than one to complete this important investigation.
- Pre-activity for this investigation includes using masking tape or rope to make a starting line at one end of the testing area. Students will throw all gliders from behind this line into the testing area, and all students must be behind this line before any gliders are thrown.

Procedure

1. Students assemble their gliders per the instructions and write their names on them. Make sure all pieces are centered and balanced for the initial control flights.
2. Students throw their gliders three times to serve as control tests. Encourage students to try to be consistent by throwing the glider with the same force and angle every time. This will demonstrate how the glider behaves under normal conditions. If the glider hits another midflight, redo the flight. Record the 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. Students make one adjustment to the glider of their choosing. This could be any of the following adjustments, or students may come up with their own ideas. Encourage creativity.
   - 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 the Data Collection Sheet what adjustment was made and a prediction of how this adjustment will affect the flight of the glider.
5. Give students enough time to run three glider tests. Encourage students to try to be consistent by throwing 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 the glider to its original configuration.
7. Repeat steps 4 through 6, making a different modification and labeling the results "E2-1," "E2-2," and "E2-3" for this modification. Continue modifying and testing for as many tests as time allows.
8. Allow time for whole-group discussion of observations and conclusions from this investigation.

Options for Differentiating Instruction

The following suggestions may be used when modifying this engineering design challenge for students outside of the designated age range or ability levels.

Modification

- Consider guiding students to focus on moving just the wing piece to a variety of positions.

Enrichment

- Tell students they need to modify their gliders to perform a specific task, such as flying in a continuous right-hand turn.

Supporting Science Investigation 2: Air Force Three

Concept

In this investigation, students 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).

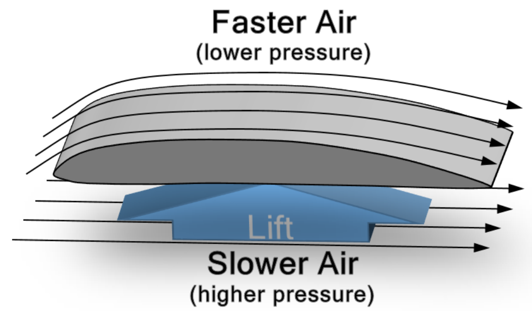


Figure 21. Illustration of Bernoulli's principle.

Here are three simple investigations to demonstrate this concept.

Materials

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, students make a prediction of what will happen when they 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.

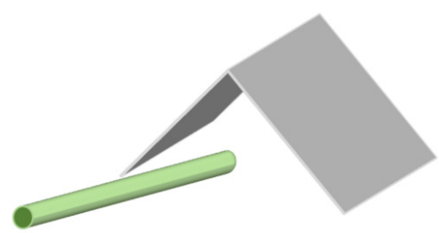


Figure 22. Index card tent and straw for Investigation A.

Investigation B: Two sheets of paper

1. Students hold two sheets of paper in front of their faces as shown in Figure 23.
2. Space the two sheets of paper a few inches apart from each other.
3. Students predict what will happen when they blow air between the sheets of paper.
4. Have students blow between the sheets of paper and observe and record what happens. Specifically note the direction each sheet of paper moves.
5. Have a whole-group discussion to compare and discuss all predictions and observations.

Figure 23. How to hold the two sheets of paper for Investigation B.

Investigation C: Single sheet of paper

1. Students use two hands to hold one sheet of paper just under their bottom lips as shown in Figure 24.
2. On the Data Collection Sheet, have students predict what will happen when they blow across the top of the paper.
3. Have students blow across the top of the paper and record their observations on the Data Collection Sheet.
4. Have a whole-group discussion to compare and discuss all predictions and observations.

Figure 24. How to hold the sheet of paper for Investigation C.

Options for Differentiating Instruction

The following suggestions may be used when modifying this engineering design challenge for students outside of the designated age range or ability levels.

Modifications

- It may be necessary to provide one-on-one instruction to ensure students blow correctly onto the paper.
- Consider performing this as a demonstration only.

Enrichment

- Ask students to compare how the paper reacts when air is blown from a variety of angles.

Supporting Science Investigation 3: Airfoil on a String

Concept

In this investigation, students 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.

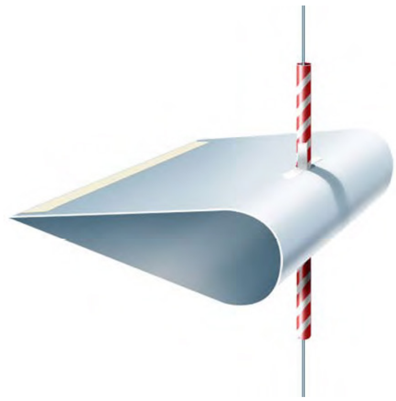


Figure 25. The airfoil on a string for this investigation.

Materials

Each student will need one set of the following materials. Provide extra copies of the template if there is time for students to explore the design.

- 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.
5. Hold the string vertically, with one end in each hand.
6. Place the wing in front of the fan. Observe and record results on the Data Collection Sheet.
7. Adjust the wing's angle of attack by moving the top end of the string. Observe and record results at a variety of angles.

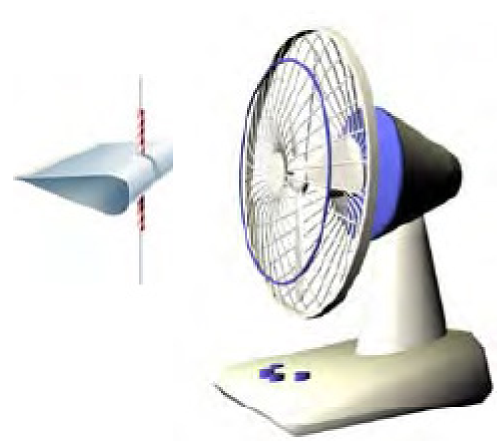


Figure 26. Proper placement of the airfoil in front of the fan.

Options for Differentiating Instruction

The following suggestions may be used when modifying this engineering design challenge for students outside of the designated age range or ability levels.

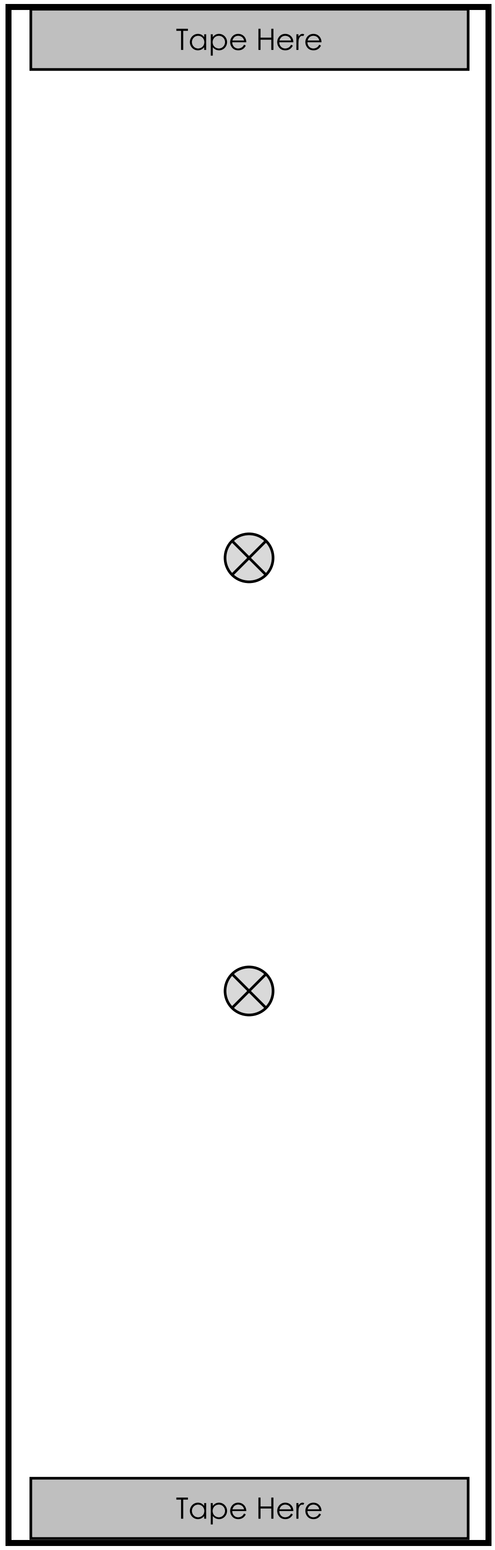
Modification

- Consider using premade wing assemblies and focus solely on how the wing reacts to the air from the fan.

Enrichment

- Allow students to modify the template for size or shape to investigate what effect that may have on the investigation.

Airfoil Template



Explanation: Supporting Science Investigations Discussion

The following investigation discussions are designed to reinforce students' understanding of the specific concepts learned during the Supporting Science Investigations.

Each discussion is based on the standard Think–Pair–Share strategy, which encourages individual participation, collaborative learning, and higher-level thinking. This strategy consists of three parts:

- **Think**: Students think independently about the question that has been posed.
- **Pair**: Students are paired to discuss their thoughts.
- **Share**: Students share their ideas with the whole class.

Focus on one question at a time. When students are done sharing their thoughts and ideas on the first question, move to the second question and repeat the process.

Procedure

1. Discussion Questions for each Supporting Science Investigation are included in this guide.
2. Ask one of the Discussion Questions to begin the Think–Pair–Share process.
3. Provide approximately 5 minutes for students to think independently.
4. Next, provide approximately 5 minutes for the students to share in pairs.
5. Finally, have students share their ideas in a class discussion.

Investigation Discussion 1: Exploring Glider Design

Concepts Learned

The following scientific concepts should have been realized by performing this investigation:

- An aircraft uses four forces while in flight.
- An aircraft uses control surfaces in order to adjust those forces.
- An aircraft has a theoretical point upon which all forces act—the center of gravity.
- An aircraft moves in three axes around this point.

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?

Investigation Discussion 2: Air Force Three

Concepts Learned

The following scientific concepts should have been realized by performing this investigation:

- An aircraft wing is designed to produce lift.
- Lift is produced based upon a principle discovered by a scientist named Bernoulli.
- Air moving over the top of a wing is faster and of lower pressure than the air under the wing.

Discussion Questions

This activity demonstrated how Bernoulli's principle affected pieces of paper when they were 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?

Investigation Discussion 3: Airfoil on a String

Concepts Learned

The following scientific concepts should have been realized by performing this investigation:

- A wing is designed to produce lift.
- The amount of lift produced is dictated by the angle at which the wing moves through the air.
- A wing angled beyond a certain critical point will produce no lift at all.

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?

Elaboration: The Engineering Design Challenge

Using the Engineering Design Process

Discuss the engineering design process (EDP) with students and explain how students will use this process to work through the engineering design challenge. The following pages explain how each step of the EDP relates to the challenge and how to facilitate the process. Regardless of the step being undertaken by each team, it is important that they work in a scientific manner. Explain the EDP sheets and how to use the appropriate pages for recording group ideas. It is important for students to understand that they may choose any path through the EDP, but they should be able to communicate why they selected a particular path.

Discuss with your students the information covered within the engineering design challenge. Using the background information, talk about current NASA missions and how those relate to this challenge. As a class, discuss the individual components of this challenge. Explain the specific criteria and check with students for understanding. Discuss with students what the constraints mean, how and why they are important, and how they relate to their everyday experiences.

Consider using a budget sheet with students as an optional real-world component. Suggestions include the following:

- Provide students with a price sheet that lists the cost of the items they have used to complete the challenge.
- Have teams use the Budget Reporting Data Sheet included here to determine the cost of their solution as tested.
- For enrichment, advise students that NASA plans to mass-produce their design for use as a delivery vehicle for monthly supply trips to Mars, but due to financial constraints, the annual budget has been reduced. Students will be required to redesign their prototype to reduce costs, but without reducing performance.

Engineering Design Process

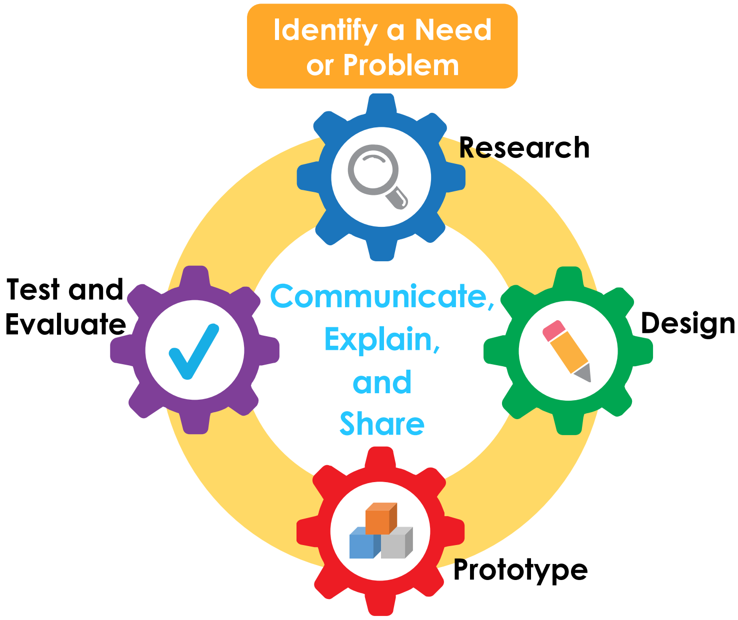


Figure 27. Engineering design process model. Model and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

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 Challenge

The Challenge

Using the engineering design process, students 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 students should consider in their designs include aircraft and wing materials, shapes, and structure, as well as the weight of the vehicle.

Figure 28. 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.

Options for Differentiating Instruction

The following suggestions may be used when modifying this engineering design challenge for students outside of the designated age range or ability levels.

Modification

- Consider pre-making a portion of the challenge glider and have students concentrate on designing the wings and testing the design.

Enrichments

- Advise students that the glider must be redesigned to be larger or smaller than their previous design while still meeting the criteria.
- Provide one or more realistic scenario difficulties that test a design's ability to perform under unfavorable conditions. Examples might include operations in windy conditions (use a box fan) or landing in unfavorable terrain (add rocks to the landing zone).

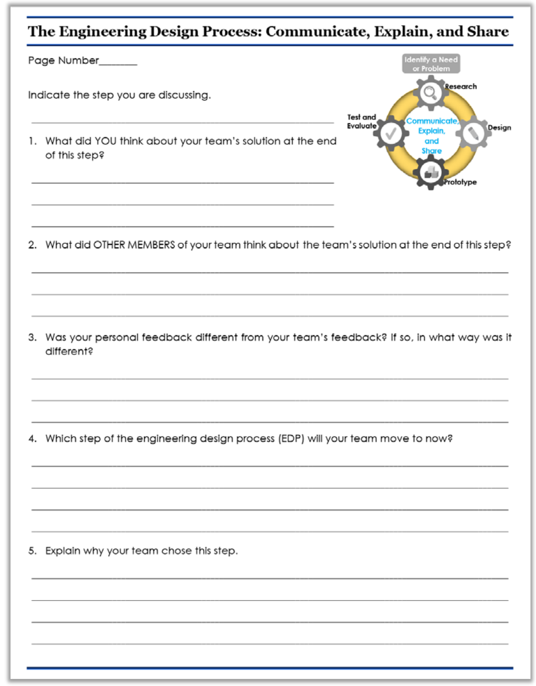
Student Team Challenge Journals

Students will be creating their Student Team Challenge Journals as they move through the engineering design process (EDP) to solve the challenge. Take time prior to starting the challenge to explain the best way for students to document their work and what the goals are for completing the challenge. The pages should document how student teams moved through the EDP. Students should be instructed to use as many sheets as needed to document each step of the process.

1. Always fill in the page number. This will help keep the pages in order.
2. Direct students to collaborate within their teams and use the five questions on the Communicate, Explain, and Share page to think about where they are in the process before they move on to the next step. Allow for extra copies of this section if needed. Here is an example: "We are moving back to the design phase because the prototype failed to meet the criteria. It was 50 g over the limit."
3. When documenting the prototype stage, remind students to make note of any challenges they faced in building the design and how those challenges were resolved.

As students proceed through the process, they should record steps accomplished on the Team Progress Chart, found at the back of the Student Team Challenge Journal. Think of this chart as a Table of Contents for the journals that are being created as students move through the process.

In order to successfully complete the engineering design challenge, teams must use the EDP. As they work the steps of the EDP, students will be engaging in authentic engineering practices.

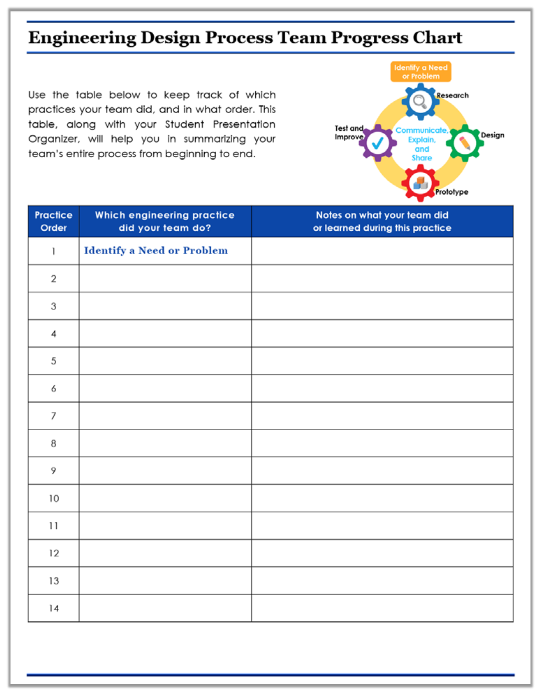


The Engineering Design Process: Communicate, Explain, and Share

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.



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		

Identify a Need or Problem

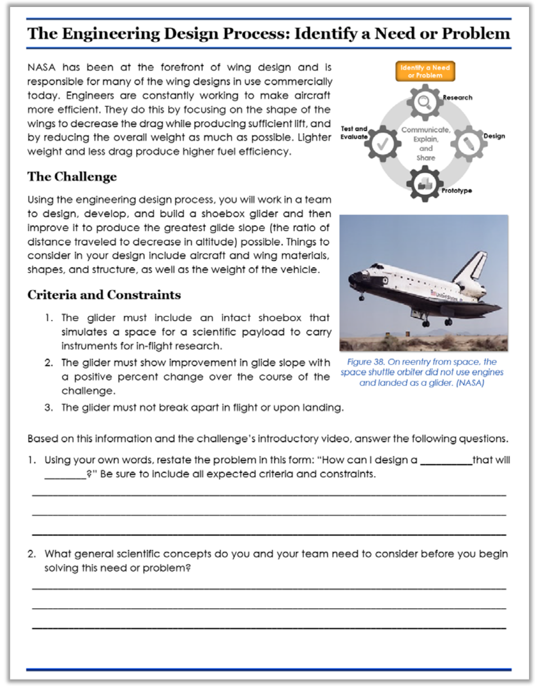
Students complete the Identify a Need or Problem page from the Student Team Challenge Journal.

Engineering design begins by identifying a need or problem that an attempt can be made to solve, improve, and/or fix. This typically includes articulation of criteria and constraints that will define a successful solution.

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- How can our team design a _____ that will _____?
- What needs to be solved or improved?
- What are we trying to accomplish?



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?

Instructional Procedure

1. Review the engineering design process with students.
2. Show the NASA Beginning Engineering Science and Technology (BEST) video titled "Repeatability," found at https://www.youtube.com/watch?v=-2Az1KDn-YM.
3. Ask students to identify the specific criteria and constraints of the design challenge.
4. Have students fill out the Identify a Need or Problem page in the Student Team Challenge Journal.

Differentiation Suggestions

Modifications

- Allow students extra time to discuss the challenge itself, the problem that needs to be solved, and how the problem could be solved.
- Introduce criteria and constraints one at a time. Allow student designs to meet one challenge requirement successfully before introducing additional requirements.

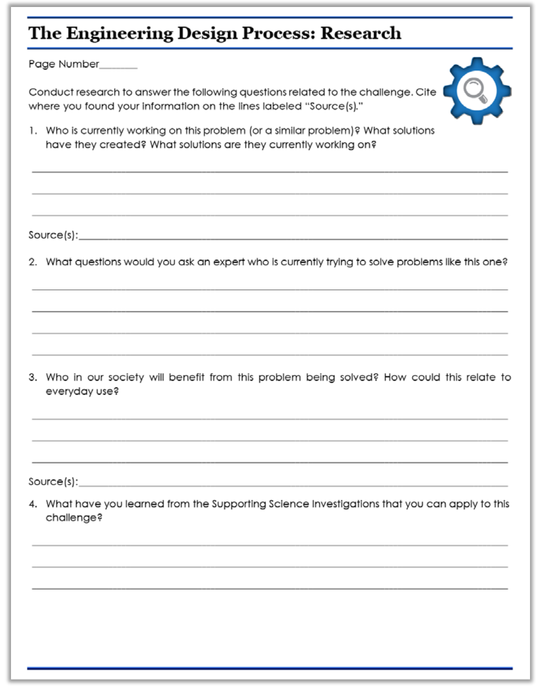
Enrichment

- Require students to write a letter or an email to a friend as if they were explaining their first job as a newly hired NASA engineer.

Research

Students complete the Research page from the Student Team Challenge Journal.

Research is done to learn more about the identified need or problem and potential solution strategies. Students can use resources from the internet, the library, or discussion with experts to examine how this problem or similar problems are currently being solved.


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?

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- Where can you find more information about the topic?
- What questions would you ask an expert or an engineer who is currently working on this problem?
- Who in our society will benefit from this problem being solved?

Instructional Procedure

1. Help students answer any questions they have about the challenge. Use the internet or a school library to research answers.
2. Write down any unanswered questions and save them to ask the NASA subject matter expert (SME) during live connections.
3. Have team members fill out the Research page in the Student Team Challenge Journal.

Differentiation Suggestions

Modifications

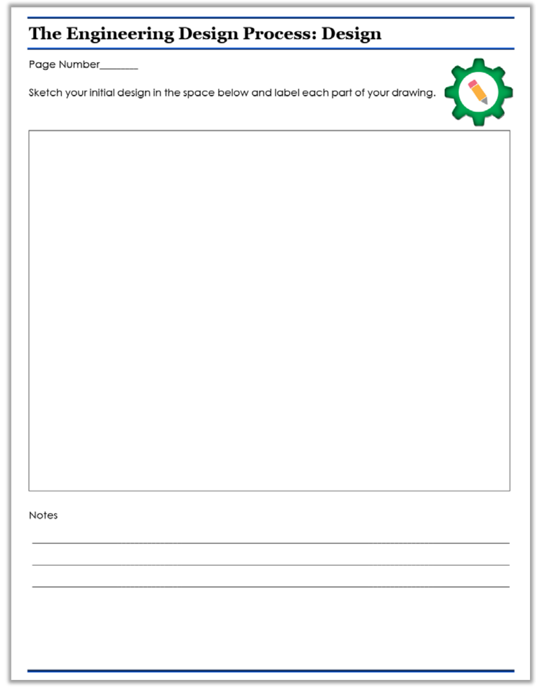
- Provide a list of reputable online resources students can use.
- Arrange a visit to a library.
- Pair up students to complete their research together.

Enrichment

- Have students provide a properly formatted citation for one or more resources.

Design

Students complete the Design pages from the Student Team Challenge Journal.


The Engineering Design Process: Design

Page Number______

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

Notes

The design stage includes modeling possible solutions, refining the models, and choosing the model that best meets the original need or problem.

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- What are all the different ways each member of the team can imagine to solve the problem?
- What do we need to add to the design?
- What could go wrong if we add to the design?
- Do the drawings address all the criteria and constraints?

Instructional Procedure

1. Ask each team member to brainstorm individually and make sketches representing ideas for a solution. Students must clearly label and identify each part of their drawing.
2. Each team member should make sure that designs meet all constraints and criteria.
3. Have students sketch their ideas on the Design page in the Student Team Challenge Journal.
4. Ask team members to discuss their ideas and drawings with the rest of the team.
5. Have students record the strengths of each of the designs.
6. Have students fill out the Best Possible Solution page in the Student Team Challenge Journal.

Differentiation Suggestions

Modifications

- Encourage students to create a series of storyboards rather than a single complete drawing.
- Show students the building materials to help them visualize their sketch prior to beginning the drawing.

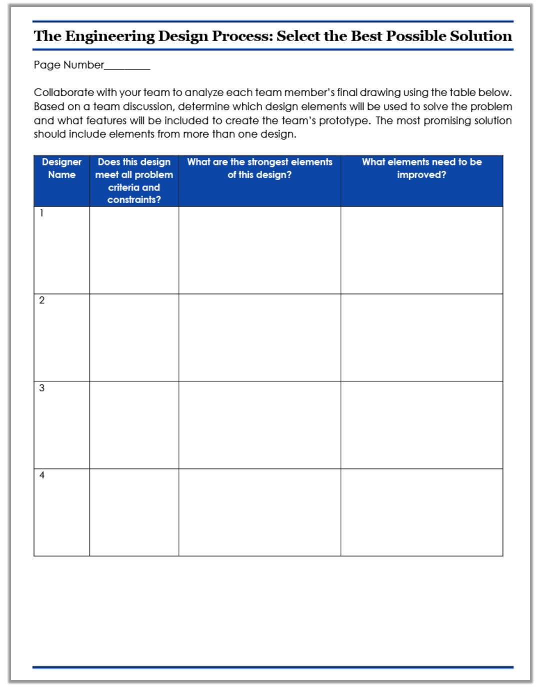
Enrichment

- Require students to specify measurements.

Analyzing the Designs

Team members analyze each member's final drawing using the table provided in the Student Team Challenge Journal.

Based on a team discussion, team members will 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.



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			

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- What is one strength of each student's individual design?
- How can that be incorporated into a group design?
- Are the strengths in each design related to the criteria and constraints of the challenge?
- Are elements from each team member's design represented in the final design?

Differentiation Suggestions

Modification

- Have students pick one aspect or characteristic at a time from each team member's drawing to discuss in the group.

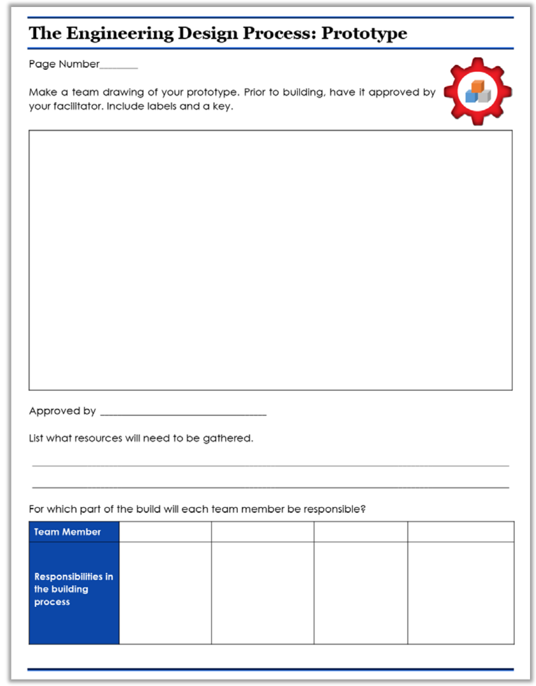
Enrichment

- Require students to draw one or more parts of the design to scale.

Prototype

Students complete the Prototype page from the Student Team Challenge Journal.

A prototype is constructed based on the design model and used to test the proposed solution. A final design should be drawn precisely and labeled with a key. Facilitators should approve final drawings before building begins. Facilitators are expected to assist students as necessary to ensure classroom safety.



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				

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- What resources does your team need to gather?
- What is the plan?
- Who is doing what?

Instructional Procedure

1. Ask each team to identify the design that appears to solve the problem.
2. A final diagram of the design should be drawn precisely and labeled with a key.
3. Have each team determine what materials they will need to build their design and assign responsibilities to team members for prototype completion.
4. Be sure to approve the final drawings before building begins.
5. After teams receive their materials to build their prototype, have them complete a budget sheet showing their building material costs.
6. Have teams construct their prototypes using their drawings.
7. Have teams fill out the Prototype page in the Student Team Challenge Journal.

Differentiation Suggestions

Modification

- Give students extra time to explore various materials prior to building the model.

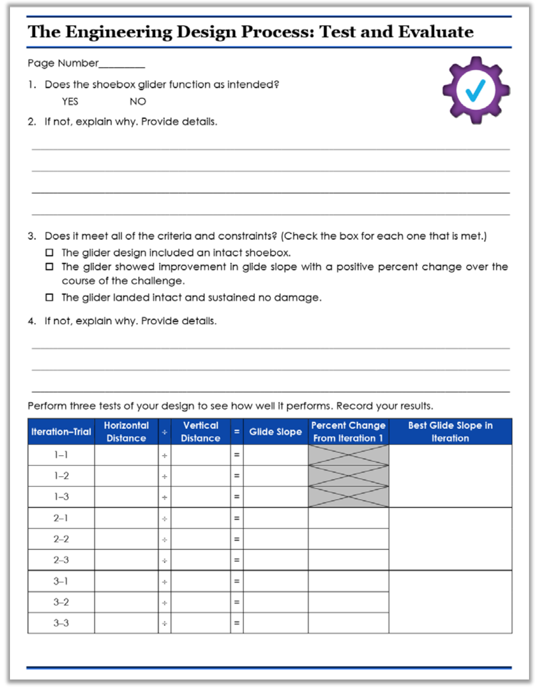
Enrichment

- Limit materials to add complexity (e.g., only 1 m of duct tape).

Test and Evaluate

Students complete the Test and Evaluate page from the Student Team Challenge Journal.

Student teams should test their prototypes to determine how effectively they addressed the need or problem and collect data to serve as evidence of their success or need for improvement. Remind students that they must test their prototypes a minimum of three times for each iteration to ensure the validity of their results.



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		÷		=			

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- Did the team collect enough data to analyze the design?
- How did the prototype perform when tested?
- Did the design meet or exceed the criteria and constraints?

Instructional Procedure

1. Visit each team and test their designs to ensure they meet all challenge criteria and constraints.
2. Have teams fill out the Test and Evaluate page in the Student Team Challenge Journal.

Differentiation Suggestions

Modification

- Encourage students to test only one criteria or constraint at a time rather than all of them at once.

Enrichment

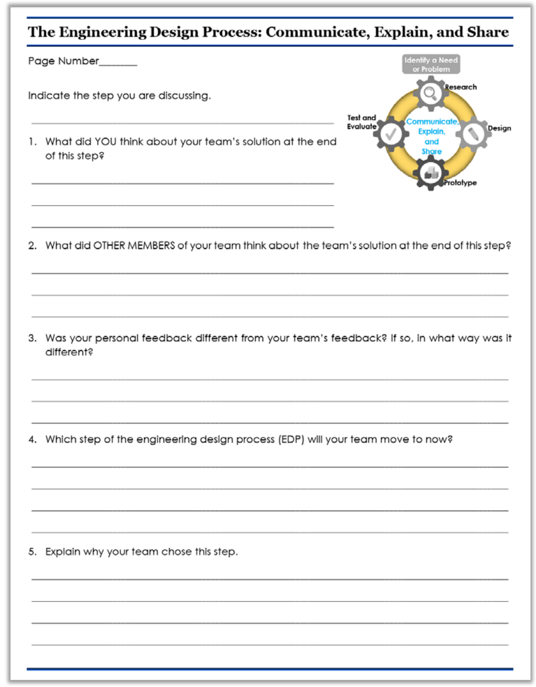
- Create a scatter plot of test results.

Communicate, Explain, and Share

Students complete the Communicate, Explain, and Share pages from the Student Team Challenge Journal.

Throughout the process, students will take time to reflect on their progress and consider what steps should be taken next. For this challenge, students will share with their peers, both one-on-one and as a classroom. Oral and written peer feedback will help students improve their solutions and designs. It is important for students to learn the peer-review process and to be accepting of others' suggestions.

Students will complete the Communicate, Explain, and Share pages after each step to maintain direction and focus during the engineering design process (EDP). Communicating, explaining, and sharing the solution and design is essential to conveying how it works, how it solves the identified need or problem, and how it meets the criteria and constraints. Using the Student Presentation Organizer will help students create the presentation that will be submitted when the challenge has been completed.

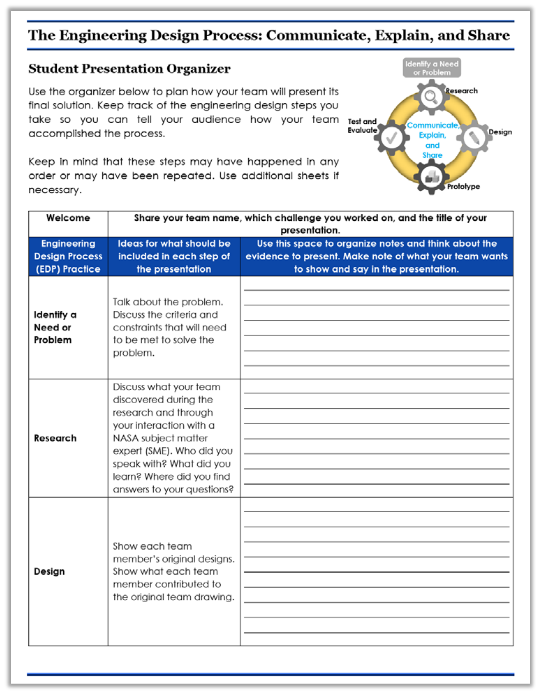


The Engineering Design Process: Communicate, Explain, and Share

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.	

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- What did or did not work in the latest iteration of the design? Why or why not?
- What are the pros and cons of this solution?
- Did each team show that they used all of the processes of the EDP?

Instructional Procedure

1. Ask team members to document and report the results of their designs.
2. Have students identify what changes were made with each iteration of the design and what the team believed caused the design to succeed or fail.

3. Students should complete the corresponding sheets in the Student Team Challenge Journal to help them think about how they completed each step of the EDP.
4. Students should use the Team Progress Chart to document progress as they work on their solutions.
5. Teams should use the Student Presentation Organizer to guide them through the creation of the team video or slide presentation.

Differentiation Suggestions

Modification

- Provide a few basic yes/no questions for students to answer to determine whether their design was successful or not.

Enrichment

- Have student teams use a variety of media to create their presentations.

Evaluation: Student Debriefing Questions

The following questions are designed to help start a discussion with your students. After the design challenge is complete, have teams work together to answer these questions.

1. Why did your team use this approach to solve the problem?
2. How did your research help you decide that this was the best solution?

   Encourage students to talk about their thought processes. How did they make their decisions? Was their approach logical and well reasoned? Do they understand the goals?

3. What changes did you make to your design during your iterations of redesign?
4. How could you further improve on your design?

   Questions 3 and 4 will confirm that students have correctly identified the flaws in their designs and are working to correct them.

5. What were the greatest challenges for your team throughout this process?

   Emphasize to students that even the most successful engineers have setbacks.

6. What strategies did your team use that proved effective in overcoming challenges?

   Have students elaborate on why they chose certain options or strategies. Did collaborative discussion or debate help them generate more or better ideas?

7. How did you use the engineering design process (EDP) to help with your design?

   Make sure students talk about each practice and discuss how the process helped them complete the challenge.

8. What concerns must be considered in constructing a glider?

   Emphasize safety and meeting the criteria and constraints. Encourage students to utilize proper scientific terminology and the vocabulary embedded in this guide.

9. What specific problems did you have to address in designing the shoebox glider?

   This could include technical problems as well as interpersonal problems. Emphasize how the students worked to find a solution to each problem. Was test data consistent? Have students describe any unusual results and tell what might have happened to cause them.

10. If you were an astronaut heading to Mars, would you trust your team's shoebox glider to bring you safely to Earth after a mission? Why or why not?

    This question can serve two purposes. One allows students to visualize themselves as astronauts as a way to evaluate their solution in a real-world context. The other allows students to consider various career pathways such as electrical or mechanical engineer, repair technician, or payload scientist.

Creating Solution Presentations

For the final stage of the challenge, students will document their progress in a video or slide presentation to share with other groups who have completed this engineering design challenge. The Student Team Challenge Journal was designed to help document each stage of the engineering design process (EDP). Encourage students to use their journals to help build the presentation.

Submission Guidelines

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 should document every step students took to complete the challenge, including the Supporting Science Investigations.
- 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.

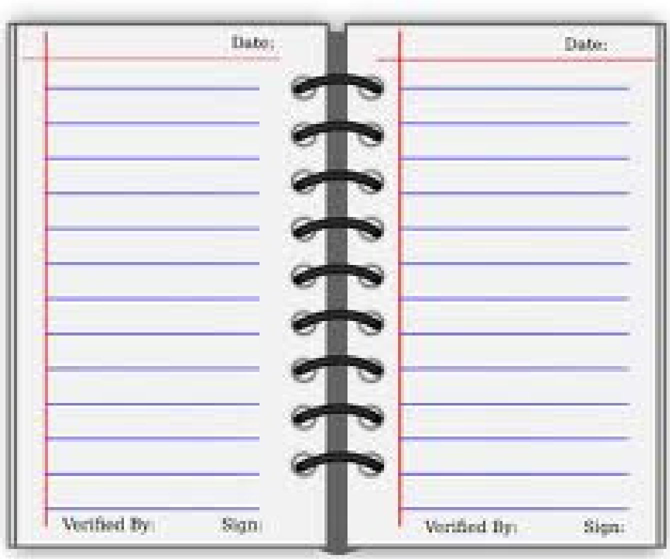
Once the video or slide document is complete, submit the presentations using the process explained on the Y4Y (You for Youth) website.

Budget Reporting Worksheet

Directions: As a team, complete the cost sheet below. Be sure to include all materials needed, unit cost, quantity, and the item total needed to complete your design. At the end, total up the entire cost of your solution.

Line Item Number	Material	Unit Cost	Quantity	Item Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
			Total Cost:	

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.

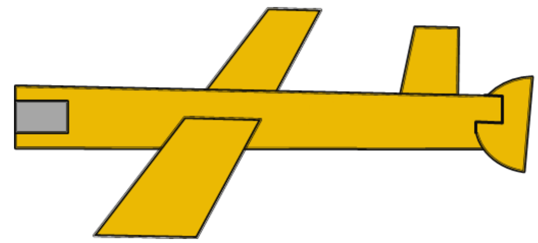


Figure 29. Illustration of a simple balsa wood glider.

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:

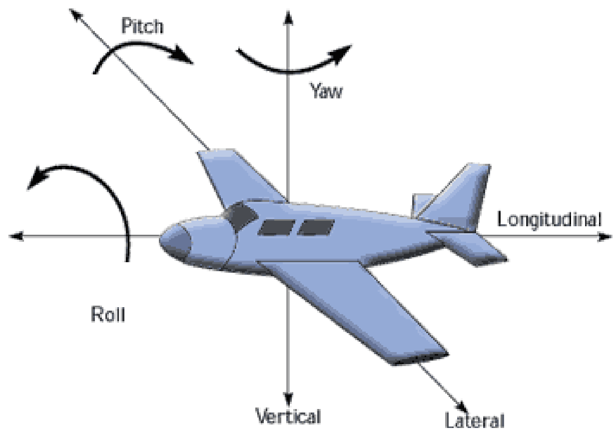


Figure 30. Illustration of the axes of rotation of an aircraft in three dimensions.

- 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

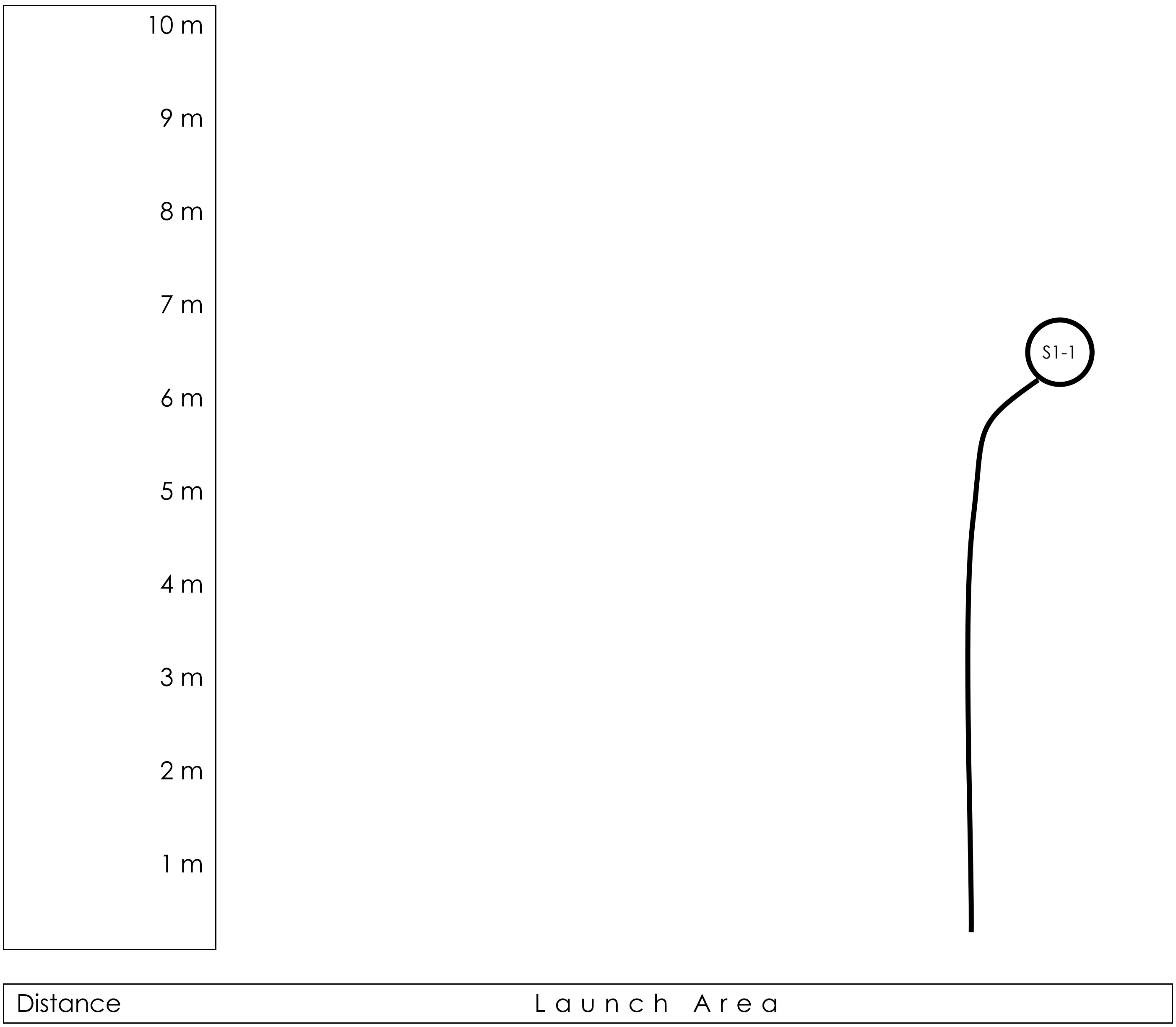
1. Assemble the glider per its instructions. Make sure that all pieces are centered and balanced for the initial control flights. Write your name on your glider to identify it.
2. Throw your glider three times to serve as control tests. Try to launch it with the same force and angle each time. This will 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.

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

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

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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).

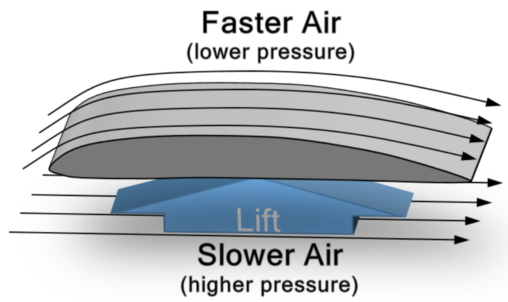

Figure 31. Illustration of Bernoulli's principle.

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.

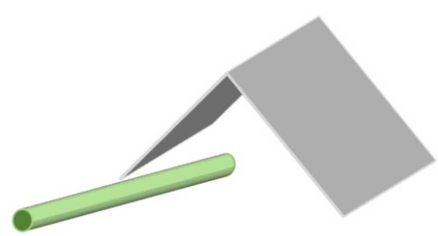

Figure 32. Index card tent with a straw for Investigation A.

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.

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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.

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

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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.

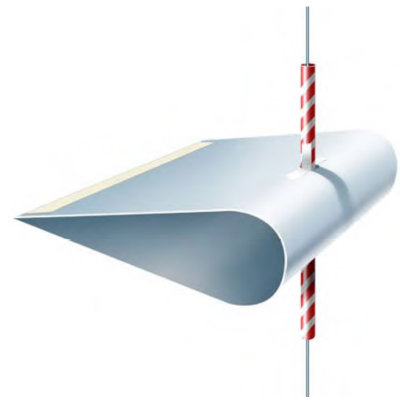


Figure 35. The airfoil on a string for this investigation.

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.

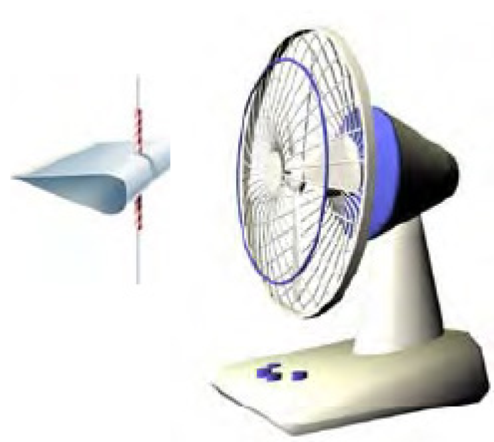
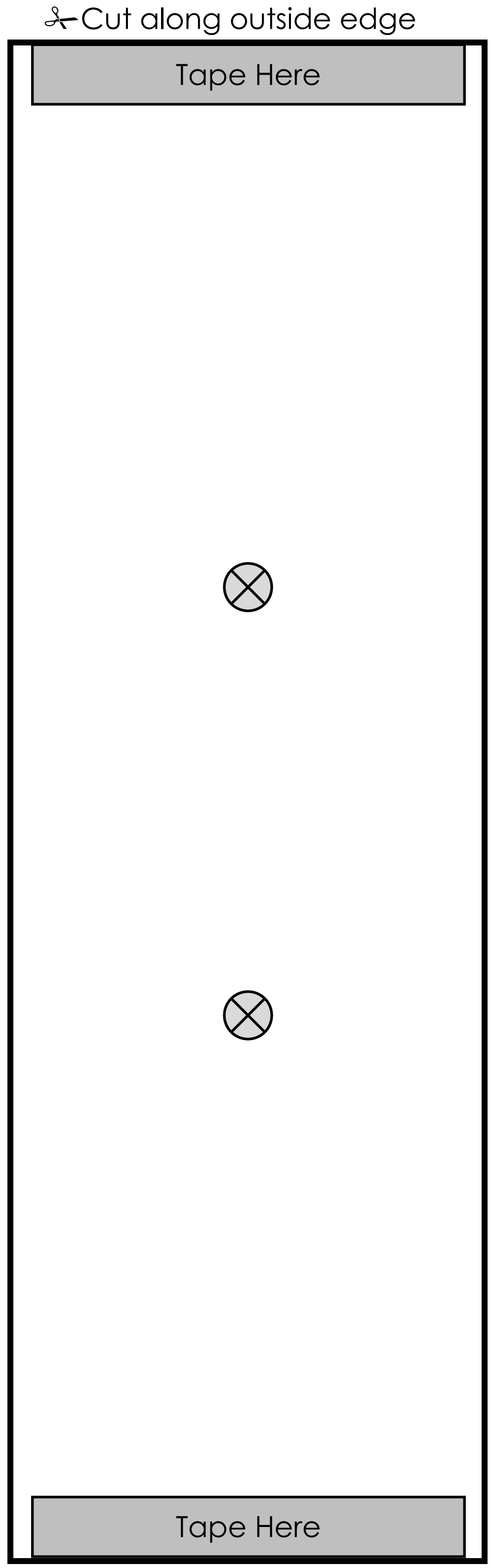


Figure 36. Proper placement of the airfoil in front of the fan.

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.

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:

____

____

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____

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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?

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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?

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

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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.

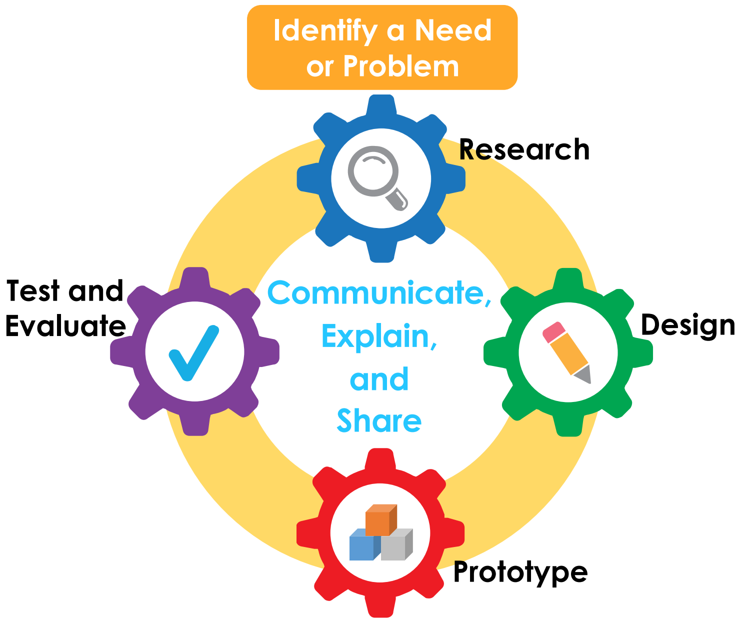


Figure 37. Engineering design process model. Model and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

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.

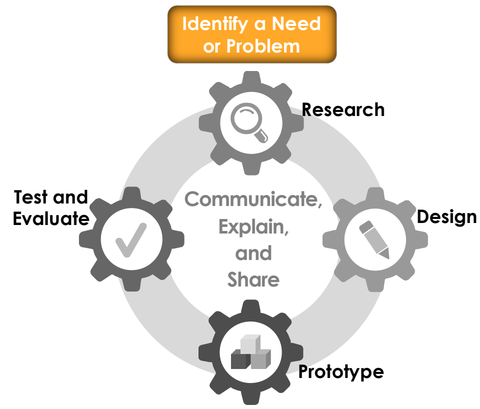
Prototype. Construct a prototype, or physical model, based on the design model(s). Prototypes are used to test proposed solutions.

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.

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

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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

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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.

____

____

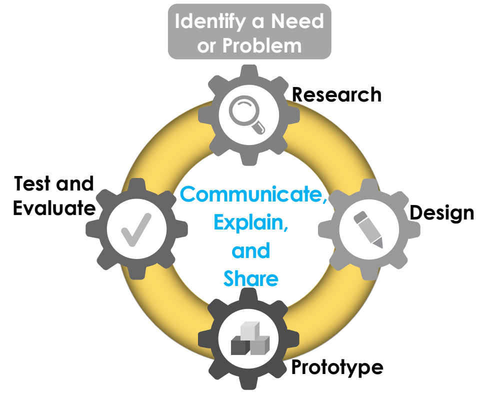
____

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.

____

____

____

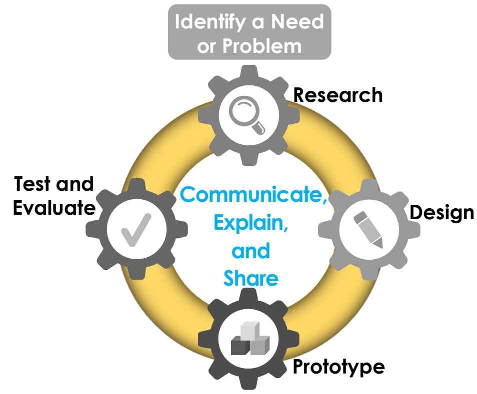
____

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.

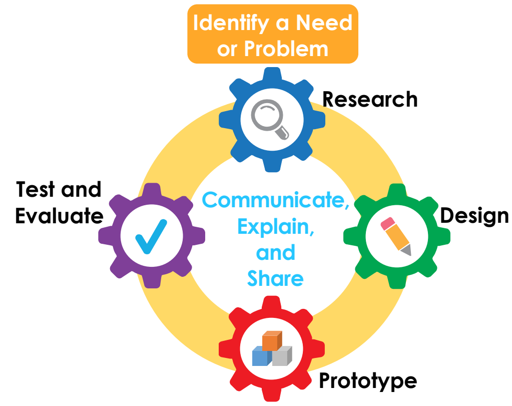


Welcome	Share your team name, which challenge you worked on, and the title of your presentation.	
Engineering Design Process (EDP) Practice	**Ideas for what should be included in each step of the presentation**	**Use this space to organize notes and think about the evidence to present. Make note of what 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.

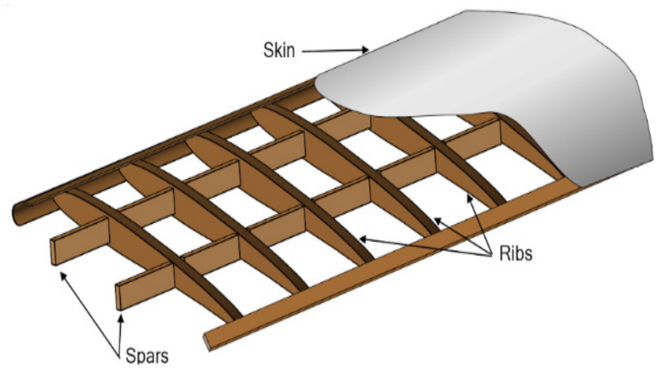


Figure 39. Illustration of the inside of a basic wing.

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.

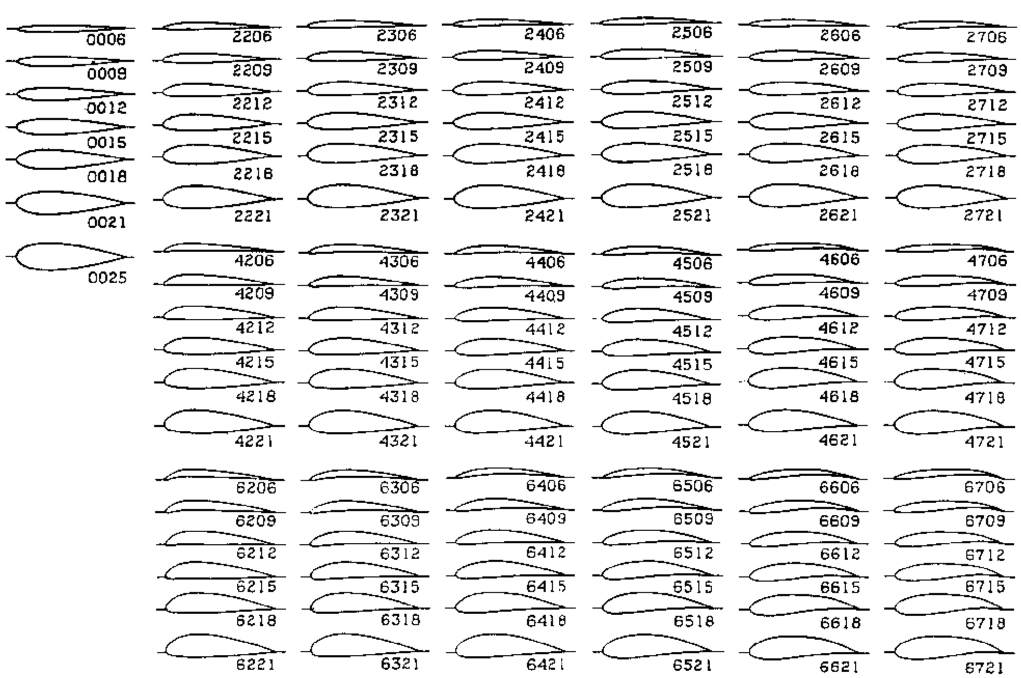


Figure 40. Illustration featuring a group of related NACA airfoils. Each design was proportioned with the same chord length for purposes of controlled testing.

Instructions for Wing Assembly

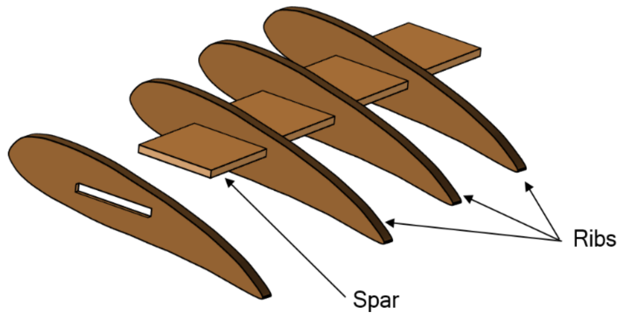


Figure 41. Sample wing structure made from engineering design challenge rib templates.

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.

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

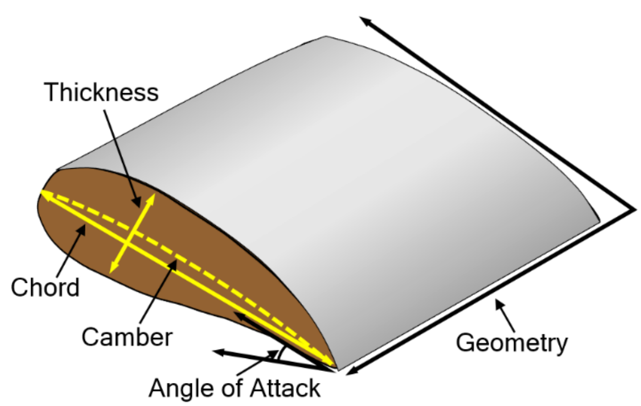
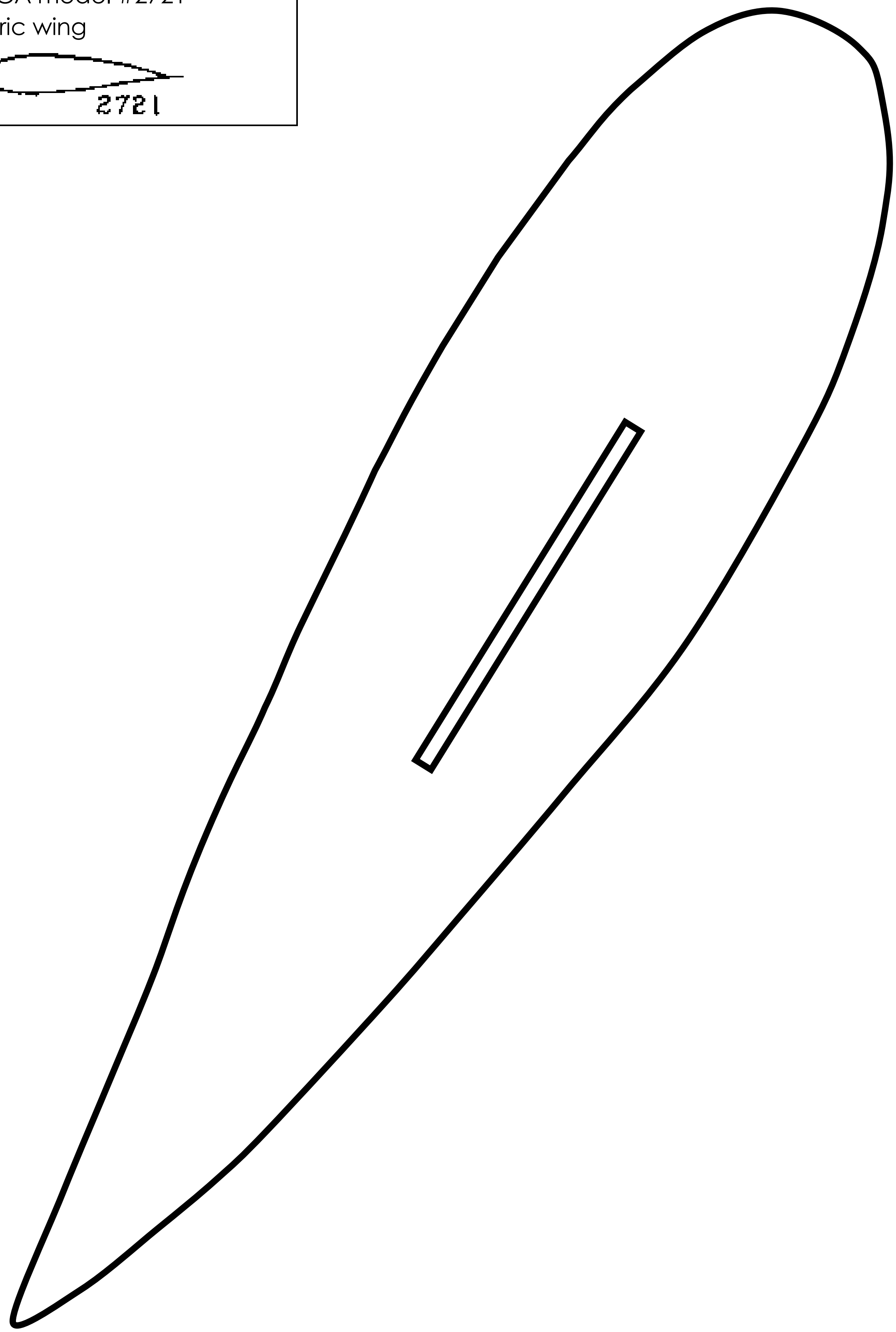


Figure 42. Wing features that can be modified to affect lift.

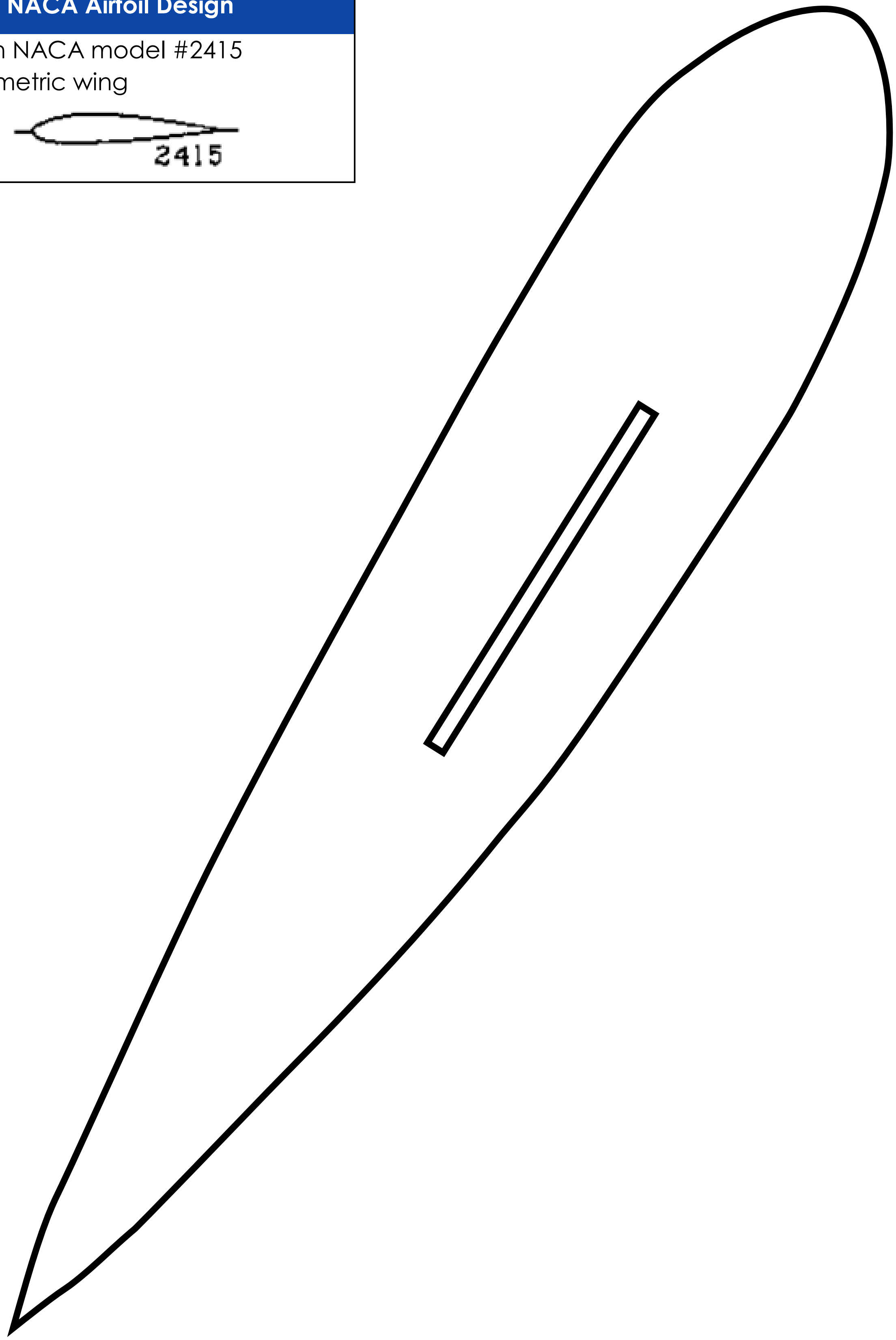
NACA Airfoil Design

Based on NACA model #2721
Thick symmetric wing

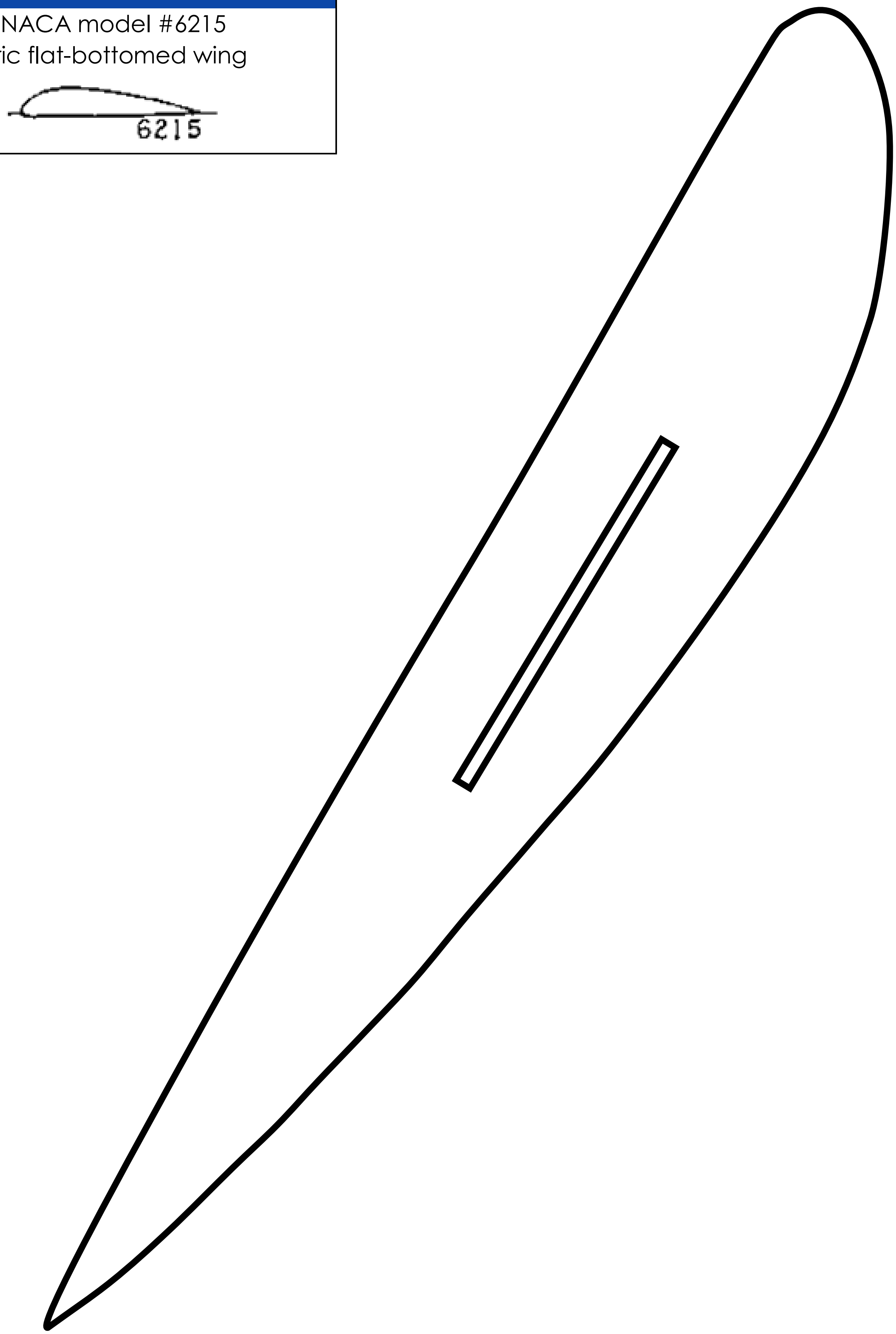
2721



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

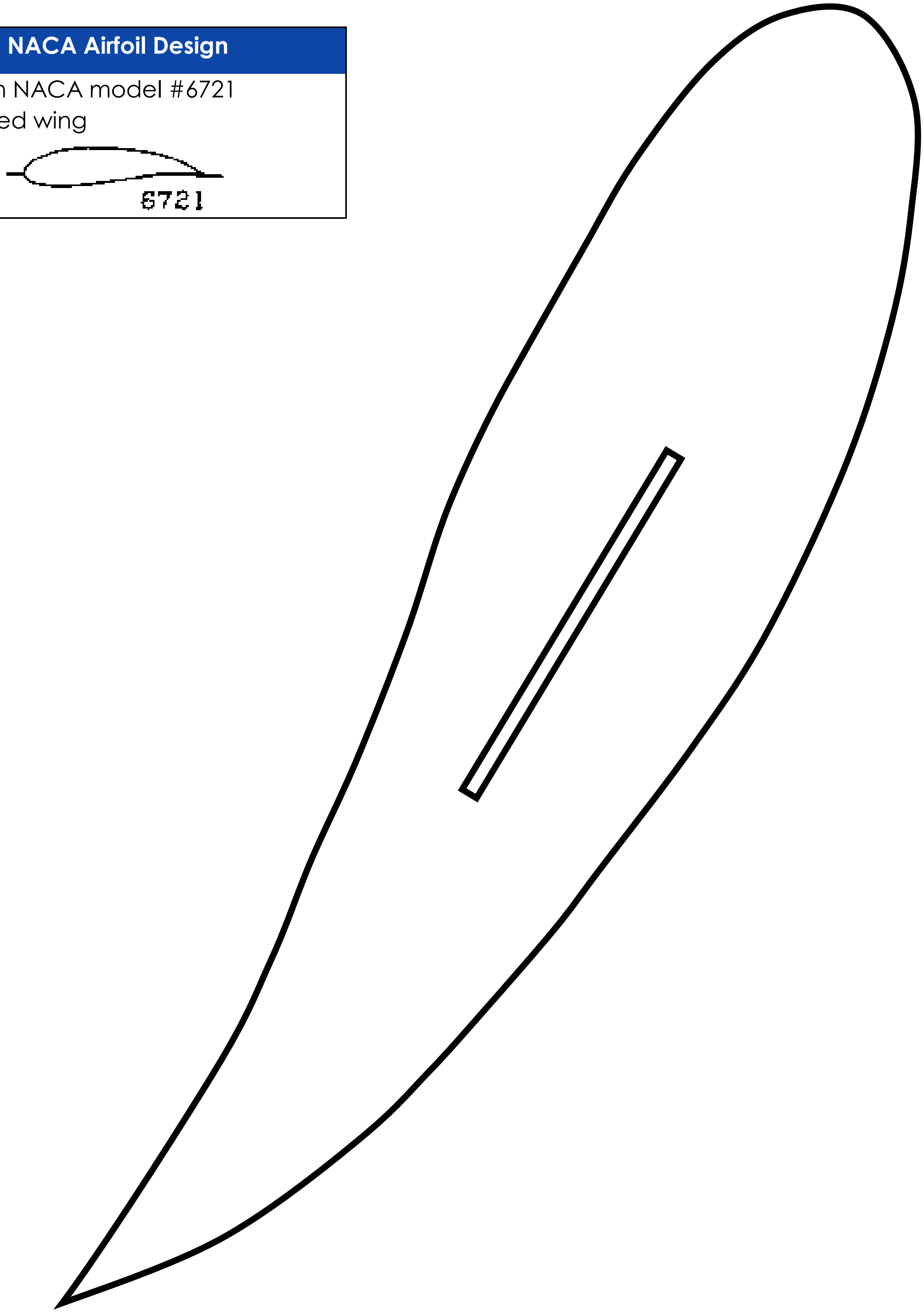


NACA Airfoil Design
Based on NACA model #6215 Asymmetric flat-bottomed wing



NACA Airfoil Design

Based on NACA model #6721
Cambered wing



NASA Resources

Online Resources

Airfoils. Through design and construction, students learn how airfoils create lift.
http://www.nasa.gov/pdf/544371main_PS1_Airfoils_C4.pdf

Aerodynamics Index. This index compiles slides and scientific explanations regarding flight.
http://www.grc.nasa.gov/WWW/K-12/airplane/short.html

Beginner's Guide to Aerodynamics. Study aerodynamics at your own pace and to your own level of interest.
http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html

NACA 100 Years. Provides a complete overview of the last 100 years of flight, including images, articles, and artifacts.
http://www.nasa.gov/naca100

Paper Airplane Activity. Students select and build one of five different paper airplane designs and test them for distance and time aloft.
https://www.grc.nasa.gov/www/k-12/aerosim/LessonHS97/paperairplaneac.html

Parts of an Airplane. Students analyze the individual components of an aircraft, learn how to identify them, and develop an understanding of how each component works.
http://www.aeronautics.nasa.gov/pdf/parts_of_an_airplane_5-8.pdf

Informational Videos

Get It Wright—Podcasts. In this series of short videos, actors portraying Orville and Wilbur Wright discuss scientific concepts that led to the invention of the modern airplane.
http://www.grc.nasa.gov/WWW/K-12/airplane/podcast.html

Launchpad: Bernoulli's Principle On-Board the International Space Station. See how Bernoulli's principle can be applied aboard the International Space Station.
https://www.youtube.com/watch?v=J4WRd7OAt0A

NASA Aeronautics: A New Strategic Vision. Learn about NASA's vision for aeronautics research.
https://www.youtube.com/watch?v=TesfgMtIGQ0

NACA–NASA 1915–2015: "We Fly, We Explore, We Measure, We Reveal, We Discover." This video highlights 100 years of flight history.
https://www.youtube.com/watch?v=UKBPxRAGMBA

NASA 360: **NASA and the Future of Aeronautics.** This 24-minute feature discusses NASA's work in aeronautics and testing using scale models.
https://www.youtube.com/watch?v=DOSE7JxsKB0

Real World: The Silent Airliner. Learn how NASA engineers are working to design safer, faster, quieter aircraft that have less impact on the environment.
https://www.youtube.com/watch?v=J43ejj92Das

Back cover: N3–X hybrid wing body turboelectric plane concept. (NASA)

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