NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™

Engineering Design Challenge – Propellers

Students will learn about the Engineering Design Process, briefly learn of the importance of propellers, how they generate thrust, and work collaboratively to create a simple helicopter device.

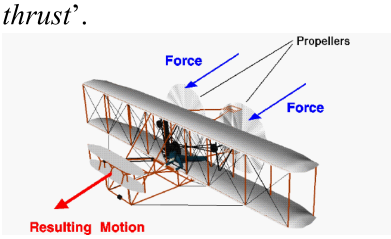
LESSON PLAN

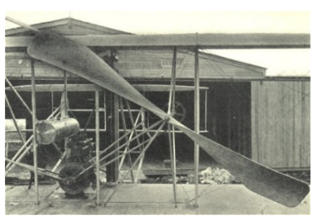
Learning Objectives

The students will
- Learn about propellers and about the importance of creative engineering to alter performance of propellers
- Learn about the dynamics of working within a team, while assisting their team with specific engineering design concepts and processes
- Learn about propeller vocabulary and the distinction of fixed-pitch as opposed to variable-pitch propellers
- Learn about the engineering design process

Background

Powered flight, as done first by the Wright brothers in 1903, would revolutionize the modern world. Pause and ponder to consider the considerable contributions to society that would not exist without airplanes! One of the facets of the Wright brothers' success was pioneering the development of propellers, which they realized '*if wings can generate lift, then they can also be used to generate thrust*'.





From the above images, one can see on the left the force that the propellers are creating, and the resultant 'pushing' motion that results, and on the right hand side, the actual image of the Wright brothers' propeller. As the Wright brothers' plane had two propellers that pushed the aircraft, they spun in opposing directions; this enhanced stability. This use of opposing rotating propellers can be seen in modern times in drones that have four propellers act opposite of those they neighbor. One difference is that some drones can modify the angle of the fin mid-flight, whereas the Wright brothers had a fixed angle (fixed-pitch)

The Engineering Design Process

This lesson uses the Engineering Design Process created by "Engineering is Elementary" which in turn was developed via the Museum of Science, Boston. No federal endorsement is implied. There are five steps to consider: Ask, Imagine, Plan, Create, Improve.

Grade Level: 5 – 6

Ohio Learning Standards/Technology (2017)
Design and Technology
3-5.DT.2.b.: Plan and implement a design process
3-5.DT.2.c.: Generate, develop and communicate design ideas and decisions
6-8.DT.1.c.: Define and categorize the requirements of a design as either criteria or constraints.
6-8.DT.2.a.: Apply a complete design process to solve a problem
6-8.DT.2.d.: Consider multiple factors, including criteria and constraints, (e.g., research, cost, time, materials, feedback, safety) to justify decisions when developing products and systems to solve problems.
6-8.DT.3.a.: Collaborate to solve a problem as an interdisciplinary team modeling different roles and functions.

Ohio Learning Standards/Science (2018)
Expectations for Learning
Nature of Science

Physical Science
5.PS.1: Force and Motion

Ohio Learning Standards/Mathematics (2017)
Statistics and Probability
6.SP.4: Display numerical data
6.SP.5: Summarize numerical data sets

Materials Required
- Heavy Cardstock or cardboard
- Drinking Straws – various sizes
- Tape
- Hole Punch
- Scissors
- Caution tape, string, 'flyzone' area creator
- Safety Glasses/ Eye Protection
- Measuring tape
- Pencil or pen

WHAT IS THE GOAL?

One of the most important parts of the engineering design process is that, sometimes, you may have to restart and go ‘back to the drawing board’. This may seem frustrating, but know that it is valuable that you had information you did not have before! If you ever feel like you have to start over, there are generally two governing constraints: time and money (or material). Understanding why certain things *don’t work* can at times be just as valuable as the reason why something *does work*.

1. **ASK:** What is the problem? What are your criteria? What are your constraints? What aspects of your experiment can change? How have people previously attempted solutions?
2. **IMAGINE:** What are some solutions? Brainstorm ideas, and collaborate with others. Think with other students about how your and their ideas may be improved, there are no bad ideas in this phase!
3. **PLAN:** Attempt to draw or model your ideas. Make a list of the required materials that you will need.
4. **CREATE:** Follow your plan and create something. Run several tests to see how it performs, and get an average performance for your prototype.
5. **IMPROVE:** What worked? What didn’t? Do you need to change your prototype or do you need to change the way the test is ran? How can you get the best performance out of your device?

It is important to note that there are many variations to the engineering design process. Some different models have many more steps, some are shorter, but the emphasis should be that the design process is not a clear-cut process. Sometimes, it may be more useful to assemble a quick model before devising all of the constraints or all of the materials, just to get a better idea of the problem at hand. Other times, when there is a bit more at stake, the ask phase may take the longest time: what safety concerns are there, what are the limitations, what is the cost, and other considerations. Assuredly, this will not be so critical!

LET’S GET STARTED

Working in teams of three or smaller, your goal is to design a simple propeller using the engineering design process mentioned above. The object is to try to maximize height, and by taking the average of test results, confidently make the argument of which propeller flew the best. It is important that a test can be repeated so that other engineers could replicate your results and give you credit for it too!

See the last two pages of this document if your students need help with the design process.

Procedure: ***Safety FIRST! When flying your prototypes, make sure to wear eye protection and avoid flying close to others to avoid injuries. Prior to beginning flights, indicate an area as a ‘Flight Zone’, and upon a nearby wall, make approximate markings on the wall using tape for equidistant marks for ease of measuring.***

We will walk through the engineering design process.

1. **ASK:** What is the problem? What is the criteria?
    - We need to create a propeller driven propeller, which we hope to get to fly as high as possible. Review the virtual tour on http://www.nationalmuseum.af.mil/visit/virtual-tour to see examples of propellers.

    What are some constraints?
    - We only have the materials as specified. There may also be a time limitation.

What have other people tried?

- Again, consider reviewing the virtual tour, as well as page one with the Wright Flyer propeller.

2. **IMAGINE:** What are some solutions? Brainstorm ideas. Choose the best one.
    - Encourage students to think outside the box. What might be the best shape? Are multiple fins better? Should the blades be bent? What direction?
3. **PLAN:** Draw a diagram. Make a list of materials you will need.
4. **CREATE**: Follow your plan and create something. Develop a test and follow it! Remember to follow safety procedures.
5. **IMPROVE:** Observe how your, and your peers' prototypes perform and repeat the engineering process a few times until satisfied with your flyer. Remember, you will need to record your observations of the height of your aircraft in the following tables. You will also need to try to keep each test identical to the last to make it fair for each design!

Resources

Sample images of propellers:
https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196934/test-propellers/
https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196426/salmson-two-blade-wood-propeller/
https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196411/north-american-f-82b-twin-mustang/
https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196672/a-mission-remembered/

Information on propellers:
https://www.explainthatstuff.com/how-propellers-work.html#:~:text=How%20does%20a%20propeller%20work,it's%20easy%20to%20see%20why.
https://science.howstuffworks.com/transport/flight/modern/airplanes8.htm
https://howthingsfly.si.edu/propulsion/propellers
https://www.grc.nasa.gov/www/k-12/airplane/propeller.html

Information on the Engineering Design Process:
https://stemactivitiesforkids.com/2016/02/22/the-engineering-design-process/
https://www.engineergirl.org/128119/engineering-design
https://www.nasa.gov/audience/foreducators/best/edp.html
https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps
https://www.teachengineering.org/k12engineering/designprocess
https://www.eie.org/overview/engineering-design-process
https://www.eie.org/engineering-adventures/engineering-design-process

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NAME________________________

DATE_________________________

Instructions: Record observed height within the tables and calculate the average height of each of the designs. The average we are after is the mean, which as a reminder, is the sum (add all of the trials up) divided by the number of trials, (in our case, 3). An example calculation is shown below.

Design Name Ultra-High Sky-Soarer Mk.5000

UHSS Mk.5000	*Trial 1*	*Trial 2*	*Trial 3*	*Average*
Estimated Height	30 cm	40 cm	50 cm	$\frac{30+40+50}{3}$ = 40 cm

Design 1 Name ______________________________________

Design 1	*Trial 1*	*Trial 2*	*Trial 3*	*Average*
Estimated Height				

How will you change the design to increase the height flown?

Design 2 Name ______________________________________

Design 2	*Trial 1*	*Trial 2*	*Trial 3*	*Average*
Estimated Height				

Did your change improve the performance?
How will you change the design to increase the height flown?

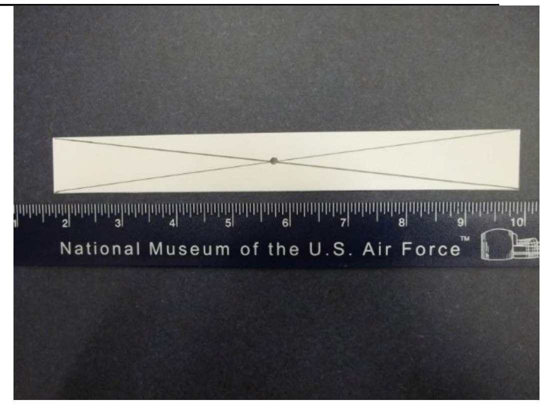
Design 3 Name ______________________________________

Design 3	*Trial 1*	*Trial 2*	*Trial 3*	*Average*
Estimated Height				

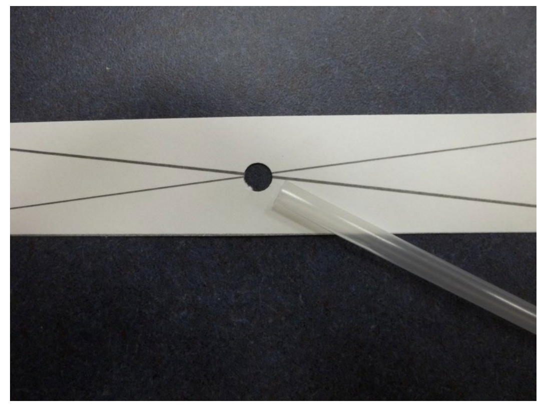
Did your change improve the performance?
Which design flew the best?

Build a hand-launched Propeller Flying Toy
Instruction Sheet

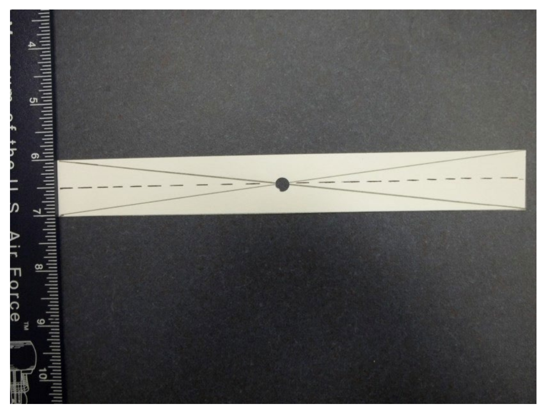
Step 1
Cut a piece of cardboard or heavy card stock (1 inch x 8 1/4 inches). This will be the propeller blade. Draw a line from the opposite corners to make an “x”. This will be the center point. Mark it with a dot.



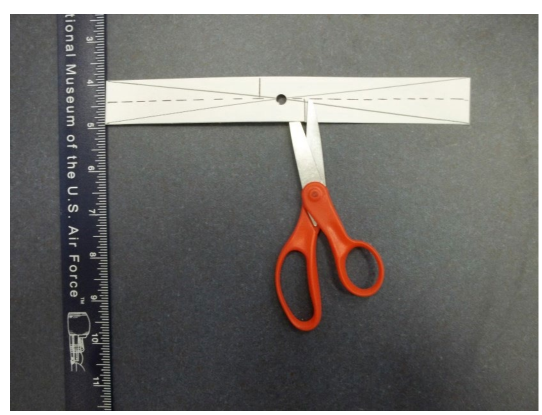
Step 2
At the dot, use a hole punch and make a hole that is slightly bigger than the diameter of the straw.

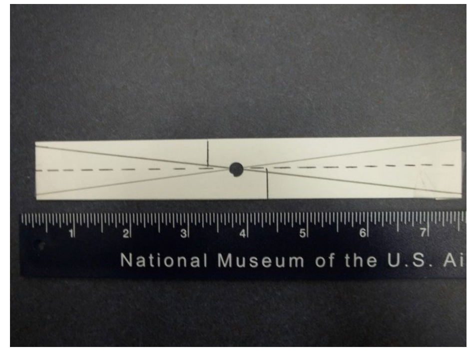


Step 3
Place the propeller blade long ways and measure 1/2 inch up from the bottom and mark a dotted line along the length. (This should be the center line of the rectangle).



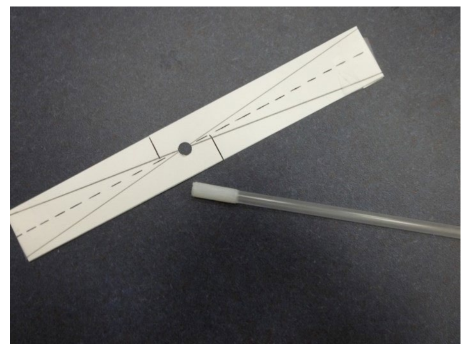
Step 4
Measure 1/2 inch from either side of the hole. One the left side, mark from the top down to the dotted center line. On the right side, mark from the bottom up to the dotted center line. Now make a cut up to the center line at these two marks as shown.



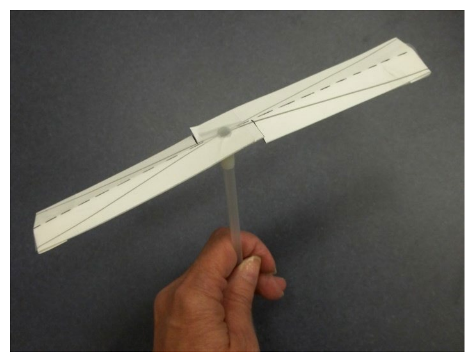


Step 5
Measure 1/2 inch from each tip of the blade and fold the tips under. Tape these folds down. This will add extra weight to the blade tips and increase the momentum as the blade spins.

Step 6
From the small cuts outward, gently bend the blades down slightly along the fold line. Do not bend down too far. This should be a gentle curve. Make sure both ends are bent down the same amount.



Step 7
To attach the straw, wrap tape around one end, so the wrapped end fits tightly when inserted into the hole of the propeller blade. If the propeller blade wobbles, tape the straw to the blade to hold it in place.



Step 8
Ready to Fly! Wearing eye protection, hold the straw between your palms. (Blade on top.) Roll your palms together so the propeller blade rotates rapidly counterclockwise. Now let go! The propeller will spin out of your hand and go up!

Flying Tips!
If the blade spins but won't climb, try bending the edges down more. If it climbs rapidly but stops spinning almost immediately, try reducing the amount of bend at the blade edge. Experiment to find the settings that work best for you. You may need to add a paper clip to the bottom of the straw for stability. Sometimes "pilots" release it too soon. Also, keep your thumbs out of the way while releasing it.
Keep practicing!