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Engineering Takes Flight

The Tech Challenge 2016 Flight Lesson 3:

Developed by The Tech Academies of Innovation

I. Lesson Overview

How can we design an aircraft that can deliver much needed medical supplies to a disaster area located on an island?

Lesson Description: During this lesson, students need to design an aircraft that can rescue people and deliver medical supplies to a flooded island. Students will test the flight characteristics of different materials and apply this knowledge to solve the given problem. Students will document and present their optimal aircraft design.

Grade Levels: 4-8

Education Outcomes:

Students will:
- identify the flight characteristics of materials
- find and document multiple solutions to a given design problem.
- describe their process and defend why their final solution is optimal.

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

Next Generation Science Standards (NGSS) Performance Expectations (PE)

3-5-ETS1-2: Generate and **compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem**

3-5-ETS1-3: **Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.**

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.**

NGSS Disciplinary Core Ideas (DCI)

3-5-ETS1.A: Defining and Delimiting Engineering Problems
- **Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria).** Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

3-5-ETS1.C: Optimizing the Design Solution
- **Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.**

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NGSS Science and Engineering Practices (SEP):

3-5 SEP 6: Constructing explanations and designing solutions

- **Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.**

6-8 SEP 7: Engaging in Argument from Evidence

- **Evaluate competing design solutions based on** jointly developed and agreed-upon **design criteria.**

NGSS Crosscutting Concepts (CCC):

3-5-CCC-6. Structure and Function - The way an object is shaped or structured determines many of its properties and functions.

- **Different materials** have different substructures, which can sometimes be observed.

6-8-CCC-6. Structure and Function - The way an object is shaped or structured determines many of its properties and functions.

- Complex and microscopic structures and **systems** can be visualized, modeled, and used to describe **how their function depends on the shapes, composition, and relationships among its parts**; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

Common Core Standards:

CCSS.ELA-Literacy.SL.4.4 Presentation of knowledge and ideas:

- Report on a topic or text, tell a story, or recount an experience in an organized manner, **using appropriate facts and relevant, descriptive details to support main ideas or themes**; speak clearly at an understandable pace.

CCSS.ELA-Literacy.SL.6.4 Presentation of knowledge and ideas:

- **Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details** to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

Common Core Standards:

CCSS.ELA-Literacy.L.4.6 Vocabulary Acquisition and Use

- Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal precise actions, emotions, or states of being (e.g., quizzed, whined, stammered) and that are basic to a particular topic (e.g., *wildlife, conservation,* and *endangered* when discussing animal preservation).

CCSS.ELA-Literacy.L.6.6 Vocabulary Acquisition and Use

- Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases; gather vocabulary knowledge when considering a word or phrase important to comprehension or expression.

CCSS.ELA-Literacy.W.4.7 Research to build and Present knowledge:

- Conduct short research projects that build knowledge through investigation of different aspects of topic.

CCSS.ELA-Literacy.W.6.7 Research to build and Present knowledge:

- Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

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English Language Development Standards:
Part 1A.1: Exchanging information and ideas with others through oral collaborative conversations on a range of social and academic topics

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II. Advanced Prep & Set-Up for Lesson

General Materials

The following is a list of supplies needed for a class of 36:

- Extra AA batteries
- Clear tape (10 cm. per pair) (Must be Invisible Tape 32953 or similar. Wide, not shiny)
- 1 stopwatch per team (extension for middle school)
- Scissors (1 per pair)
- Rulers (1 per pair)
- Protractor (to measure the angle of the electric launcher)
- Tape measure (to measure the height if the table platform where the launcher shall rest)

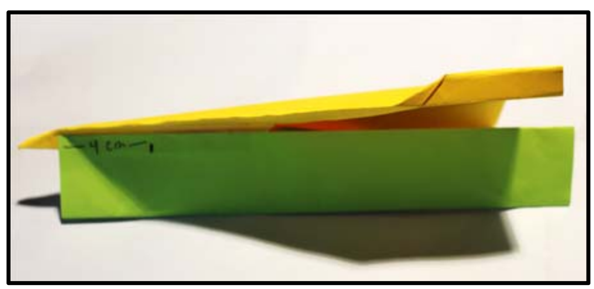
Aircraft Material Test Set-Up

Materials

- Wing materials to test, available for each group of 2-4 to choose from. (Each pair selects 1 material to test and all materials should be tested, so provide no more than 3 pieces of each of the following materials). All materials listed below must be pre-cut into 8.5 inch by 5.5 inch pieces.
  - Tissue paper
  - Newspaper print
  - Wax paper
  - Copy paper
  - Foil
  - Cardstock

- Paper cone to use to mark landing locations (1-2 depending on how many trials you want to allow for each material test.)

- Launch tool attachment paper – regular weight paper cut into 8.5 in. by 5.5 in. piece (1 per test material/ 2 per group) (This allows each aircraft, when mounted, to feed through the launcher easily. See "Aircraft Material Test Directions" in Appendix C on how to create the Launch Tool).



- 20 copies of Directions for Aircraft Material Test in plastic sleeves (See "Directions for Aircraft Material Test," in Appendix C)

- 20 copies of aircraft construction directions *(see link here, or in Appendix B)*

- Electric Paper Airplane Launcher *(purchase here or see Appendix B)*

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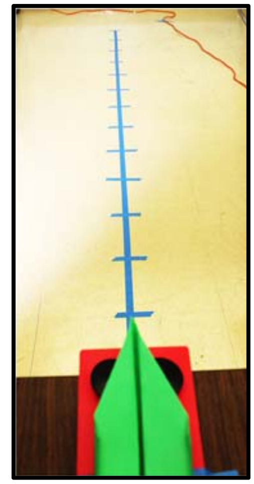
Aircraft Material Test Set-Up

1. Testing Set-Up
   - Launch point
     - Set Paper Airplane Launcher on table top (Standard table height ~71 cm/28 inches high)
     - Launcher front raised to a 35 degree angle relative to the table top
     - Secure the launcher feet with tape to keep the launcher stable
     - Cover front nut (directly in front of conveyor pieces) with tape to minimize "take off" obstruction
   - Tape measurements on the floor to measure flight distance (intervals in feet or meters) for a length of 15 feet or 5 meters.



2. Data collection – Create a whole class chart to chart flight results as a class, so that the class can compare materials and look for patterns. A hand-out of this sheet is also available so that students can each observe and document different flight characteristics. *("Aircraft Material Test Observations," Appendix C)* for collecting data as flight tests are performed. An example of a filled-in data table is below.

Observation Material Type	**Flight Stability**	**Flight Distance**	**Flight Orientation**	**Flight Path**
tissue paper	• horizontal spin (x2) • 1 vertical spin (x2)	• 5 ft. • 3.5 ft. • 5.5 ft. • 4 ft.	• top up/backwards (x1) • top down (x1) • top up/side-ways (x2)	• 10 cm. left • 15 cm. right • 34 cm. left • 20 cm. right
news print paper	• arc- no flips • hang time/gliding (x4)	• 5 ft. • 8 ft. • 7 ft. • 7.5 ft.	• top up/straight (x4)	• 31 cm. right • 14 cm. right • 40 cm. right • 20 cm. right
wax paper	• up/came down on tail (x1) • vertical flip (x2) • straight (x1)	• 4 ft. • 2 ft. • 4.24 ft. • 4 ft.	• top up/slightly sideway landing • top up/backward landing • top up/backwards/ sideway landing • top up/straight	• 8 cm. left • 11 cm. left • 12 cm. left • 9 cm. right
regular paper	• 1 vertical flip (x2) • 1 roll and horizontal flip (x1) • vertical and horizontal flip (x1)	• 7.25 ft. • 9.75ft. • 7.5 cm. • 6 ft.	• top up/backwards landing (x3) • top down (x1)	• 40 cm. left • 15 cm. right • 32 cm. left • 53 cm. left
foil	• vertical flips/glided back (x4)	• 7 ft. • 4.5 ft. • 3.5 ft. • 1 ft.	• top up/front (x1) • top down/sideways (x1) • top up/backwards (x2)	• 20 cm. left • 24 cm. left • 32 cm. left • 30 cm. left
card stock	• horizontal flip upon landing (x4)	• 7 ft. • 7 ft. • 7 ft. • 7.33 ft.	• top down/sideways landing (x4)	• 22 cm. right • 47 cm. right • 62 cm. right • 65 cm. right

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Aircraft Design Challenge Advanced Set-Up

Materials (for a class of 36)

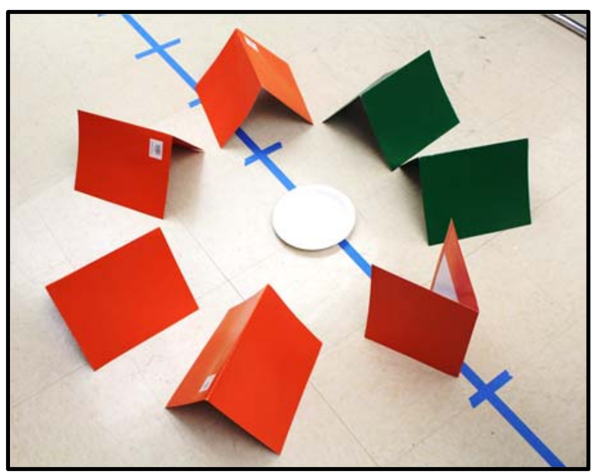
- Launch station supplies:
  - Electric paper airplane launcher *(purchase here or see Appendix B)*
  - Textbook (to hold electric launcher in place)
  - Measuring tape (to measure distance)
  - Masking tape (to mark distance)
  - 8 folders or binders (to act as mountain or bridge obstacles around the island)
  - Large Paper Plate (to be the island)
- Each student group of 3-4 will need:
  - 1 copy of the Design Challenge Journal ("Design Challenge Journal," Appendix C). (10 total)
  - 1 pencil (10 total)
  - 1 pair of scissors (10 total)
- Aircraft building materials table:
  - 2 rolls of scotch tape
  - 1 roll of masking tape
  - Roll of wax paper
  - Roll of foil
  - 20 sheets of newspaper
  - 100 sheets of white copy paper
  - 20 sheets of cardstock
  - 20 sheets of tissue paper
  - 100 plastic pony beads
  - 100 straws
  - 100 popsicle sticks
  - 100 paper clips
  - 100 pipe cleaners

Aircraft Design Challenge Set-Up

1. Student Group Stations Set-Up: Set up a table for each group with the listed materials and handouts.

2. Set up a materials table that has all the materials listed above available to teams for building.

3. Launch Station Set-Up
   - Launch point
     - Set paper airplane launcher on table top (Standard table height ~71 cm/28 inches high)
     - Launcher front raised to a 35 degree angle relative to the table top
     - Secure the launcher feet with tape to keep the launcher stable
     - Cover front nut (directly in front of conveyor pieces) with tape to minimize "take off" obstruction
   - Place a paper plate 3 feet away from the table (to represent the island)
   - Place 8 folders or binders in a 1-2 foot radius around the paper plate (to represent mountain and bridge obstacles)



4. Data Collection: Distribute a copy of the Design Challenge Journal to each group and have teams fill out the information as they complete prototypes of their design ("Design Challenge Journal," Appendix C).

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III. Engineering Takes Flight Lesson Guide

Guiding Question: How can we design an aircraft that can deliver much needed medical supplies to a disaster area located on an island?

A. Introduction (30 minutes)

1. Introduce the big challenge. Suggested talking points might include:
   - In the near future, we may experience extreme weather in the Bay Area. One potential danger may be flooding.
   - The National Guard needs our help to design an aircraft that can rescue people and deliver medical supplies to cities in need.
   - As we work towards this challenge, we will explore and experiment with materials to build an aircraft.

2. Lead a discussion that draws on students' prior knowledge of forces acting on an aircraft and the engineering design process. Sample questions might include:
   - How does gravity act on an aircraft in flight?
   - How do forces act on an aircraft to allow it to fly?
   - How might we use the engineering design process to explore flight?

3. Discuss materials testing and introduce core vocabulary for this lesson
   - How might engineers decide what materials to build with?
   - Why is this important? (Materials testing is important because it allows engineers to pick the optimal materials for their aircraft designs (material or solution that works best within the limitations of the design). It also lets engineers test the materials under different variables and conditions so that they can anticipate any weaknesses in the design or structure of an aircraft).
   - Some additional engineering vocabulary that we will be using today are:
     - **Design criteria**: The requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
     - **Constraints:** The limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions.
   - Some examples of **criteria**:
     - purpose
     - goal of the product
     - how well it will perform
     - reliability
     - aesthetics
   - Some examples of **constraints**:
     - budget (cost)
     - time (delivery dates, deadlines)
     - legal codes/ethical constraints
     - practical real-world physical constraints (size, weight, power)

Facilitator Notes:
Discussion Tips and Suggestions
- Through this discussion, review with students that in order for an aircraft to fly, the force of lift must be greater than gravity and thrust must be greater than drag. These concepts are taught in the second Tech Challenge 2016 Lesson: Lighter than Aircraft Design.
- When introducing the concept of **optimal** materials, ask students what the optimal way to get to school is? If you live down the street, it might be optimal to walk. If you live a few miles away, it might be optimal to take the bus. Depending on your situation, the optimal mode of transportation will change.
- One way to help students understand the difference between **criteria** and **constraints** is to introduce a real-world problem. You might want to have students sort criteria and constraints on a T-chart. One example would be "Design a Healthy School Lunch:"
  - Criteria (Desired Features):
    - Less than 1,000 calories *(Note: students might think of this as a limitation, but it is a desired feature of the design so is not a limitation or constraint.)*
    - Includes a serving of fruit, vegetables, protein, fat, carbohydrates, and dairy.
  - Constraints (Limitations within which we must work):
    - Cost - not more than $2.00 per school lunch
    - Must be able to be prepared in 2 hours
- Possible NASA Real World design challenge extension focusing on criteria and constraints *(link here, or see Appendix B)*

B. Aircraft Material Test Experiment (20 minute build + 40 minute whole class launch and recording of data and observations)

1. Introduce the aircraft material test: *Today, as engineers, you will all be exploring various materials and how they affect their flight.*
   - Introduce the materials that will be used during this experiment: tissue paper, wax paper, aluminum foil, regular paper, cardstock and newspaper.
   - Point out that all materials are the same size.
   - Have students make some observations about the materials and invite pairs to choose a specific material to test.

2. Discuss **variables**: *When engineers test a material, scientists conduct a fair test to ensure that everything stays exactly the same except for the condition or variable that they are testing. A variable is anything that can change during an experiment.* Sample questions might include:
   - What can change in this experiment? (e.g. Where the aircraft is taped on the launch tool. How precisely a material is folded. How an aircraft is placed in the launcher, etc.)
   - Which variable are we intentionally changing? (Material type)

Facilitator Notes:
Experiment Tips
- Remind students that they are merely observing the behavior of the different materials according to flight stability, flight distance, flight path and flight orientation, and not looking for the "optimal material." Save judgment and recommendations after all materials have been tested and the engineering challenge has been presented.
- If a mis-launch occurs, the group must relaunch their aircraft to establish valid data compared to other trials that were done for the same aircraft material.
- All students must observe all groups' launches and record data for each.
- Ensure that at least 2 groups work on each material suggested to provide redundancy.
  - Each group tests their aircraft at least 2 times.
  - Each class must then expect at least 4 launches to make observations and record data for each material.

3. Introduce the experiment question, design criteria, constraints, and directions.

   Experimental Question:
   - What are the flight characteristics of 6 different possible wing materials?

   Control Variables:
   - Use standard aircraft design provided *(see link here, or in Appendix B)*
   - All aircraft must be mounted on a predetermined launcher tool in the same configuration using clear tape. (See "Directions for Aircraft Material Test," in Appendix C)
   - All aircraft must launch from a standard launcher and launch starting point.

   Independent Variable:
   - Six different materials used for aircraft wings:
     - Foil
     - News print
     - Cardstock
     - Wax Paper
     - Copy Paper
     - Tissue Paper

   Constraints (Design Limitations):
   - Budget: Build 1 aircraft per pair, using only 1 of the materials provided in class per aircraft.
   - Schedule: To be built within 20 minutes

Facilitator Notes:
Experiment Tips
- Prepare an indoor space that will allow up to 10 ft. of flight space and limit or avoid turbulence that will affect flight.
- In order to have all materials tested, have no more than 2-3 sheets of each material so that ideally there are at least 2 sets of pairs testing each material. Invite each pair to select 1 material to test from those provided.

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Testing:

- Teacher launches from a height of 71 cm/28 inches (standard table top), with the launcher pointed 35 degrees
- Flight Observation: During all tests, observe and document how each aircraft design behaves during flight.
- All students observe all aircraft materials tested.
- Considering the 6 different materials named in this section, it is assumed that there will be 2 aircraft built by 2 different pairs for any given material, creating the necessary redundancy.

4. While the students are choosing their aircraft material and folding them according to the provided aircraft directions *(see link here, or in Appendix B)* walk around and ask questions. Some suggested questions are:
   - What material did you choose? Why?
   - How do you predict your material will fly? Why do you think so?
   - What will your team look for/observe during the testing? What will you document?
   - How will you document? (Will different team members observe/document different things? Who will document what?)
   - What variables are you trying to control? How?
   - Why is it important to keep all variables the same except for the experimental variable?

5. Prior to testing as a whole class, go over launch/safety procedures.
   - Have all students move to the launch end of the testing area so that airplanes are launched away from observers.
   - To control launch variables, the teacher should launch all aircraft.
   - For each launch, be sure to use the same launcher position and angle.
   - The launcher will yell, "Clear the launch way," prior to each launch and will only launch when there are no people in the launch path.
   - Each student must be ready to record their observations in the data observation tool before each launch.

6. Before the tests, identify these observation points.
   - **Flight distance**: Using the prepared measurements in feet on the floor, record the approximate length traveled from the launcher to the touch down.
   - **Flight orientation**: Record the position of the aircraft nose when the aircraft lands (position of nose, e.g. right side up, or upside down; final position of aircraft, e.g. backwards facing, facing front, or sideways facing).

Facilitator Notes:
Data and Results

- Sample conclusions: According to the data gathered during the development of this activity, given the specific materials used, the conditions in the testing room and the controls set, the following generalizations were drawn. **(Please note that because variations in construction, launch height, force, angle, room conditions etc., your classroom results may not be identical or similar to the sample data given.** It's important to help students point out evidence to their claims based on the data they collect.)
- *Stability: Newspaper resulted in the most stable flight of the materials tested. Our evidence is that the aircraft made of newspaper never flipped or rolled.*
- *Distance: The cardstock material was the most consistent in traveling the furthest distance. Our evidence is that the aircraft made of cardstock travelled 7 ft. for 3 trials and 7.33 ft. for the last trial. (See sample table in Section II)*
- *Orientation: Newspaper was most consistent in its flight orientation performance. Our evidence is that all 4 trials landed top up with no flips.*
- *Path: Wax paper showed the least amount of deviation from the center path. Our evidence is that our data shows a deviation range of 8-12 cm. from the center path for all 4 trials.*
- Because 2 groups will construct the aircraft with the same material, possible inconsistencies may come up because of differences in construction or quality of build. If data appears inconsistent, 3rd and 4th trial for the same exact aircraft might be necessary to draw conclusions.

- **Flight path**: The actual course of an aircraft through the air. This must be recorded by measuring, in cm or inches the flight deviation of the aircraft relative to the center, straight flight path. Record the shortest distance from the final landing site of the aircraft to the center, straight flight path. Visual, qualitative statements of flight path may also be included in this section (e.g. turned around, glided backwards, glided in a circular path, flight went off path but came back, etc.)
- **Flight stability**: The tendency of an airplane in flight to remain in straight, level, and upright flight. This may also be described by recording flips or rolls (horizontal- parallel to the ground or vertical- perpendicular to the ground). Landing observations may also be recorded in this section (landed on nose or landed on tail).

7. Have a whole class discussion.
    - How do you predict each material will fly? Why?

8. Run the tests and have students record data from experiment. You may want to use a whole class flight characteristics data collection table for documenting the class observations. Have a whole class discussion.
    - What do you notice about the characteristics of each material? What's similar? What's different?
    - Can you describe the flight path of each?
    - Do you see any differences in the way they flew?
    - What do you notice about how each flies? How would you describe the:
        - Flight stability?
        - Flight orientation?
        - Flight path?
        - Flight distance?
    - What conclusions can you draw? What evidence do you have from your data table to support this?

C. Content Learning (25 minutes)

1. Introduce key engineering vocabulary as revisiting the Design Challenge question (10 minutes)
    - **Payload**: goods carried by a vehicle
    - **Prototyping:** creating a full-scale model/demo of a new type or design of a construction used for testing. (Not the final product)
    - **Failure point:** a design element that can cause an unsuccessful result. This is the point in a system that if it fails, the whole system fails.
    - **Design process**: a series of steps that engineers use to guide them as they solve problems. The process is non-linear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating.

2. Discuss documentation and journal writing process as an engineering tool.
    - The purpose of journaling is to record and document the design process, solutions and testing results so that the optimal solution can be identified and replicated.
    - Information that should be included:
        - What should/can we record while conducting this challenge?,
        - Is there additional information that you want to record in your journal? Why?
    - Examples of what you might document, includes:
        - Sketches and photos of design ideas and prototype
        - Materials list
        - Data from prototyping

- ○ Careful documentation of the variables that are changed in each design (of materials, shapes, sizes, load placement, etc.)
- ○ Documentation of both successful and unsuccessful designs and failure points—so that they can be remedied in future designs
- ○ The process you went through to develop your solution
- ○ All the designs you tried and how you changed them
- ○ Your final design including measurements and materials used
- ○ What you learned through the process
- ○ Specific details that will set you apart from other teams (sketches, specific materials, budgets, number of designs, testing procedures, attendance at Test Trials, meeting minutes, etc.)
- ○ Real world applicability (how would your device work in real life?)

3. Introduce four roles for documentation and have team members select roles. Students in a team may switch roles for each test.
   - **Data collector**: during prototype, pay attention to and take notes on successful and unsuccessful points of an aircraft flight
   - **Design illustrator:** Sketch an aircraft with details as much as possible
   - **Materials manager**: Manage and record all materials used for an aircraft design
   - **Journal writer**: in collaboration with the team, make sure all parts of journal are complete using the sentence frames.

D. Aircraft Design Challenge (about 120 minutes)

1. Review Questions about Materials from the Aircraft Materials Experiment:
   - What did we learn about the materials that we tested?
   - How can we use this knowledge to create an aircraft that will land safely and accurately?

2. Review key engineering vocabulary
   - **Optimal Design**: The most desirable solution (design) that best meets the constraints and criteria.

3. Introduce the Engineering Design Challenge:
   Design Problem:
   - In the near future, we may experience extreme weather in the Bay Area. One potential danger may be flooding. The National Guard needs our help to design an aircraft that can land in a specific area to rescue people and deliver a payload of medical supplies to cities in need.

   Criteria (Design Requirements/Desired Features):
   The aircraft must:
   - be made out of at least two different materials
   - land as close to the target as possible
   - clear the mountain and bridge obstacles)
   - carry a payload of 6 pony beads (medical supplies)
   - land right side up on the island.
   - have a stable flight (no rolling or flipping)

Facilitator Notes:
Design Challenge
- For design process, it may be helpful to refer to The Tech's Design Challenge Learning resources *(see link here, or Appendix B)*
- To introduce these vocabulary, you may need to make connections between the vocabulary and the actual situational words: payload-medical supplies, model/demo-aircraft
- In order to facilitate students' documentation and journal process, let each team write the vocabulary on cardstocks and place them on a table.
- In addition, students might need to identify aircraft parts vocabulary as well. If you post a picture with the vocabulary on the wall, students may easily refer to it. (For a picture, see link here, or Appendix B)
- See the Appendix B for the definitions of the following aircraft parts vocabulary:
  - Nose
  - Fuselage
  - Tail
  - Wing
  - Elevator
  - Aileron
  - Pitch
  - Roll
  - Rudder
  - Yaw

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Constraints (Design Limitations):

- Schedule - must be completed within 2 class periods
- Documentation - at least 3 different aircraft prototypes documented in the Design Challenge Journal ("Design Challenge Journal Writing," Appendix C)
- Budget - must use the building materials and tools provided
- Physical - must mount aircraft on launch tool

Testing:

- Teacher launches from a height of 71 cm/28 inches (standard table top), with the launcher pointed 35 degrees
- Flight Observation: During all tests, observe and document how each prototype aircraft design behaves during flight and how closely it meets the design criteria.

4. Review key vocabulary words. One option is to use the online Kahoot game created just for this lesson *(see link here, or Appendix B)*

5. Explain to students that they will work with their group to create three different prototypes using the materials provided. They will need to use at least 2 different materials in their design and they must deliver their payload of six beads to the target area safely.
   - Before testing each prototype, they will need to show their completed design sketch with materials on the Design Challenge Journal *("Design Challenge Journal Writing," Appendix C)*. Students may have different roles for each prototype: Data Collector, Design Illustrator, Materials Manager, and Journal Writer.

6. While the students are working on their design prototypes, teacher should walk around and ask questions. Some suggested questions are:
   - What materials did you choose? Why?
   - How do you predict your aircraft will fly? Why do you think so?
   - Why do you think the materials you chose would be optimal for your aircraft?
   - What will your team look for/observe during the testing? What will you document?
   - What variables are you trying to control? How?

Facilitator Notes:
Optimal Design
- To help students further understand optimal design, share a few more scenarios that your class can think about together:
  - Your team has been contracted to design a safe race car for NASCAR. What would be the most important criteria to consider when deciding on the optimal design?
    - A. cost of the design
    - B. selecting the fastest car
    - C. color of the car
    - D. reliable seat belts for the car

7. Teacher will be at the launch testing site to launch each completed prototype.
   - Go over launch/safety procedures.
   - Have all students move to the launch end of the testing area so that airplanes are launched away from observers.
   - Teacher will be the only one to launch the airplanes.
   - For each launch, be sure to use the same launcher position and angle.
   - The launcher will yell, "Clear the launch way," prior to each launch and will only launch when there are no people in the launch path.

Facilitator Notes:
Prototyping
- To help students further understand prototyping, share that it is similar to creating several drafts of a paper or project.
  - a first draft is similar to Prototype 1
  - a second draft is similar to Prototype 2
  - a third draft is similar to Prototype 3
  - a final product/draft is similar to Optimal Design

8. Have students fill in the sentence stems for prototype 1 *(see "Design Challenge Journal" in Appendix C)*.

9. Repeat the above process with Prototype 2 and 3.

10. Final testing of optimal designs:
    - When students are finished, they should share these observations with the teacher. Then they will collaborate with their group to select and provide evidence for their optimal design. Their optimal design should be the design that best meets the constraints and design criteria.
    - Have groups present in front of the class. Test all optimal group designs.
    - Suggested discussion questions:
        - (4-5th grades) How well does each design solution meet the criteria and constraints?
        - (6-8th) Which design best meets the criteria and constraints? How do you know?
        - (4-5th) What materials did you use on your aircraft and how did they affect the flight? What is the function of each material?
        - (6-8th) How did the different materials in your aircraft work together to fly?
        - What do you notice about the design of each airplane that might contribute to these flight characteristics?
        - After seeing all of the class prototypes, which do you think is the optimal design? Why?
        - What trade-offs might an engineer make when designing an aircraft?

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IV. Appendices

A. Vocabulary and Background Information

The following is the start of a suggested list of words to discuss as you read and discuss with students.

1. Flight Vocabulary

flight distance	The length traveled by the aircraft from launch to the touch down
flight orientation	How an aircraft faces when it lands (position of nose, e.g. pointing down, right side up, and upside down).
flight path	The path that an aircraft or device takes when it flies.
flight stability	The tendency of an aircraft in fight to remain in straight, level and upright flight.
payload	The goods carried by a vehicle.

2. Engineering Vocabulary

constraint	The limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions.
criteria	The requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
engineering or design process	A series of steps that engineers use to guide them as they solve problems. The process is non-linear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating.
failure point	The part of a system that, if it fails, will cause the entire system to stop working.
optimal design	The most desirable solution (design) that best meets the constraints and criteria of a design problem.

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prototype — A first model of something, from which other forms are developed or copied.

variable — Any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled. The independent variable is the one that is changed by the scientist.

3. Aircraft Vocabulary

aileron — A hinged flight control surface usually on the back edge of each wing of a fixed-wing aircraft. Moving an aircraft's ailerons up or down controls the aircrafts roll.

elevator — A control surface at the rear (tail) of an aircraft, making it climb or descend (affects pitch).

fuselage — The main part of an airplane that holds cargo, crew and/or passengers.

nose — The forward end of an aircraft, usually cone shaped.

pitch — The movement of the aircraft's nose up or down causing the plane to descend or climb (see image here)

roll — When an aircraft's wings tilt left or right (see image here)

rudder — A control surface on the fixed fin on the tail of an aircraft moving left and right that affects the side-to-side movement (yaw) of the aircraft

tail — The rear portion of an aircraft, which usually includes a horizontal stabilizer and elevators that control the up and down motion (pitch) of the aircraft

wing — One of the long flat parts on both sides of an airplane that allow it to fly

yaw — The turning of an aircraft, when the aircraft's nose turns side to side (see image here)

B. References

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C. Lesson Handouts

Handout	**Page(s)**
Directions for Aircraft Material Test	18-19
Materials Test Observations	20
Design Challenge Journal Writing (4^{th}-5^{th})	21-24
Design Challenge Journal Writing (6^{th}-8^{th})	25-28
Assessment Rubric	29

Name: ______________________________

Date: __________ Class: ______________

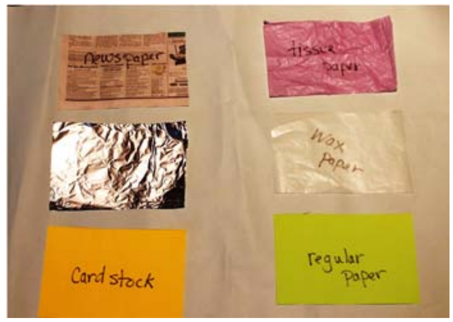
Directions for Aircraft Material Test

Students will be grouped in pairs. Assign a role for each student in the pair:

- **Aircraft Engineer**- Aircraft construction
- **Launch Tool Engineer**- Launcher tool builder and aircraft mounting

Building Your Aircraft:

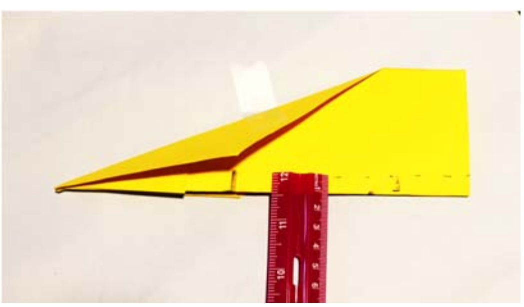
1. Select 1 kind of material from those provided in class



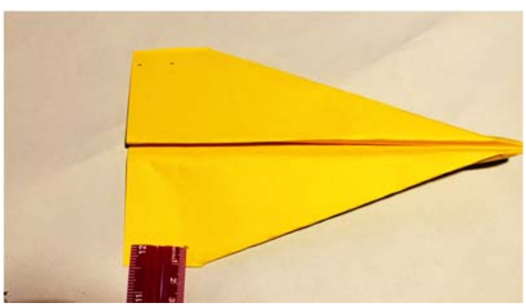
2. Cut your material to 8.5 in. x 5.5 in. (standard copy paper folded in half and cut across the width)

3. Fold your material according to the folding instructions for the Falcon F-16 *(see futureflight.arc.nasa.gov/designs/F16.html for full instructions)*. To ensure consistency of all aircraft, some specifics are included here for the wing folds:

   A. Fold each wing 1 cm. from the bottom fold:

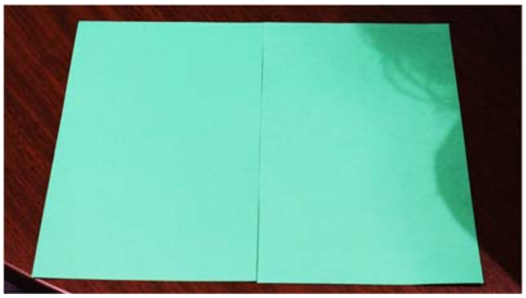


   B. Fold a 1 cm. elevator pointing up, on each wing:



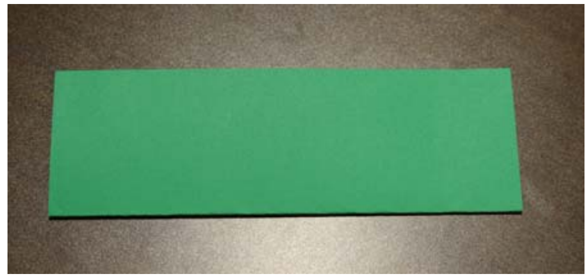
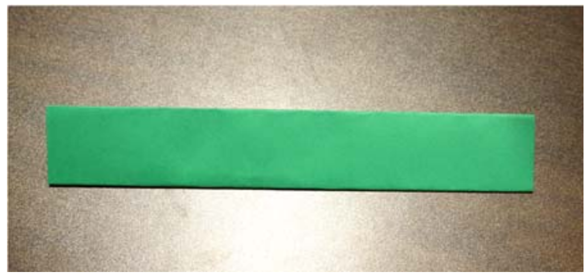
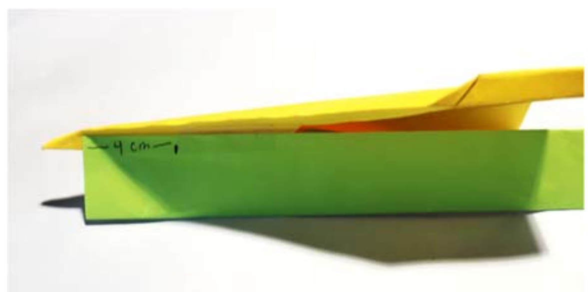
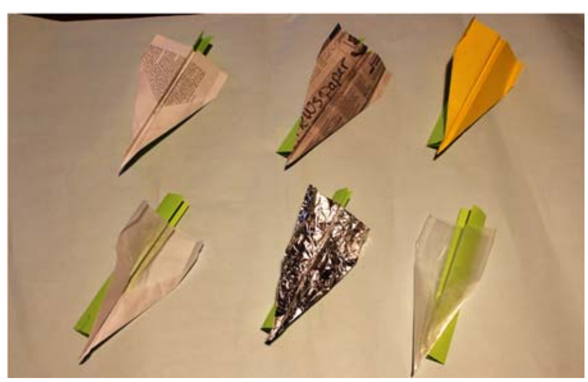
Tool for Electric Launcher – Each pair must construct 1 tool for launching their aircraft

1. Start with piece of paper cut in half to 8.5 in x 5.5 in.



Name: ______________________________

Date: __________ Class: ______________

2. Fold the half sheet in half, lengthwise (hot dog)	
3. Fold the long sides in, towards the center crease, like doors, and crease.	
4. Position the aircraft on your launch tool by tucking the folded bottom of the body of the aircraft into the long open side of the launcher tool. 5. Line the front edge of the launcher tool with the point where the front corner of the wing is folded from the body of the aircraft.	
6. Use 4 cm (~1.5 inches) of clear tape to attach the aircraft to the launch tool on both sides.	
7. Get ready to launch your aircraft and observe how it flies!	

Name: ____________________________________

Date: ____________ Class: __________________

Aircraft Material Test Observations

Material Type	Flight Stability	Flight Orientation	Flight Path	Flight Distance

Name: ____________________

Date: ________ Class: __________

Design Challenge Journal– <u>Prototype 1</u>

(4-5th)

Team Members: ______________________________ Team Number: ____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 1** (remember to label materials!)

The materials we used were ______________________________

____

The optimal behaviors were ______________________________

____

The failure points were ______________________________

____

We will improve our next prototype design by ______________________________

____

____

Name: ______________________________

Date: __________ Class: ______________

Design Challenge Journal– <u>Prototype 2</u>

Team Members: ____ Team Number: _____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 2** (remember to label materials!)

The materials we used were ____

____

The optimal behaviors were ____

____

The failure points were ____

____

We will improve our next prototype design by _______________________________

____

____

Name: ___________________________

Date: __________ Class: ______________

Design Challenge Journal– <u>Prototype 3</u>

Team Members: ____________________________________ Team Number: ____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 3** (remember to label materials!)

The materials we used were ____

____

The optimal behaviors were ____

____

The failure points were ____

____

We will improve our next prototype design by ______________________________

____

____

Name: ______________________________

Date: __________ Class: ______________

Design Challenge Journal– <u>Optimal Design</u>

Team Members: ____ Team Number: ____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Optimal Design** (remember to label materials!)

Our optimal design is Prototype #____, because it best meets the criteria in the following ways: ____

____ and because it meets the constraints in of the following ways: ______________________________

____.

The materials we used were ____

____

The materials helped our design by ____

____

____

Name: ___________________________________

Date: ____________ Class: _________________

Design Challenge Journal– Prototype 1

(6-8th)

Team Members: ____ Team Number: _____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 1** (remember to label materials!)

The materials we used were ____

____

The optimal behaviors were ____

____

The failure points were ____

____

We will improve our next prototype design by ____

____

____

Name: ____________________

Date: __________ Class: __________

Design Challenge Journal– <u>Prototype 2</u>

Team Members: ______________________________ Team Number: _____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 2** (remember to label materials!)

The materials we used were ______________________________

____

The optimal behaviors were ______________________________

____

The failure points were ______________________________

____

We will improve our next prototype design by ______________________________

____

____

Name: ______________________

Date: __________ Class: ____________

Design Challenge Journal– Prototype 3

Team Members: ______________________________ Team Number: _____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Prototype 3** (remember to label materials!)

The materials we used were ______________________________

____

The optimal behaviors were ______________________________

____

The failure points were ______________________________

____

We will improve our next prototype design by ______________________________

____

____

Name: ______________________________

Date: __________ Class: ______________

Design Challenge Journal– <u>Optimal Design</u>

Team Members: ____ Team Number: ____

Team Roles:

Data Collector:	Design Illustrator:	Materials Manager:	Journal Writer:

Sketch of **Optimal Design** (remember to label materials!)

Our optimal design is Prototype #____, when we compare it to the other prototypes, it meets the criteria and constraints better. It meets the criteria in terms of ______________________

____ and the constraints in terms of ____

____.

The materials we used were ____

____

The materials helped our design by ____

____

____

Name: ______________________

Date: __________ Class: ____________

Engineering Takes Flight Assessment Rubric

	4	3	2	1
Academic Vocabulary	- All three, criteria, constraints and optimal design, are used accurately.	- Two of three, criteria, constraints and optimal design, are used accurately.	- One of three, criteria, constraints and optimal design, is used accurately. - Other terms not used or not used accurately.	- No identified key vocab terms used accurately.
Content Accuracy	- Students will determine and accurately explain an optimal design, materials used, and how these materials functioned together.	- Students will determine and accurately explain an optimal design and materials used.	- Students will determine and explain an optimal design and materials used.	- Students will determine and explain an optimal design.
Claims and Evidence	- The claim is stated clearly. - Relevant evidence is given to justify design decision	- The claim is stated. - Evidence provided is not justified with relevant evidence	- Claim is alluded to. - Justification is not relevant to the claim.	- Weak or no claim is stated. - No justification is provided.
Engineering Process	- Multiple, systematic tests were performed. - The final solution meets all criteria and constraints. - Evidence clearly demonstrates how each tested solution met the criteria and constraints and why the solution chosen best meets these parameters.	- Multiple tests were performed. - The final solution meets most criteria and constraints. - Evidence is provided to support a selected solution and how it meets the criteria and constraints; however, data provided does not clearly show that the chosen solution best meets these parameters.	- Only one or two designs were tried. - The final solution meets few of the criteria and constraints. - Little or no evidence is provided to support design decisions.	- Only one design solution was tried. - The final solution doesn't meet the criteria and constraints. - No evidence is provided to support design decisions.