**Details-Design Process**

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| **Duration** | 45 minutes |
| **Group Size** | 1 |
| **Primary Concepts or Objectives** | * Describe thrust and what factors can affect it. * Identify some factors that engineers must consider when designing real rockets, including safety. * Define a simple design problem reflecting a need or a want. * 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. |

**Materials:**

**Each student needs:**

1. 1 piece of letter-sized paper (8.5 x 11 inches), cut in half, resulting in 2 half-sized pieces each measuring 8.5 × 5.5 inches
2. 1 pencil
3. 1 drinking straw
4. 1 cotton ball
5. Thrust Quiz
6. Thrust Analysis Worksheet
7. Results from the Earth Math Sheet or Results from the Earth Math Sheet

**For the entire class to share:**

1. target pictures of each of the nine planets: Inner Planets Target and Outer Planets Target
2. Colored pencils, crayons, or markers
3. cellophane tape provided in several dispensers
4. tape or string, to mark a starting line
5. Launch from the Earth Handout or Launch from the Sun Handout
6. Results from the Earth Math Sheet or Results from the Sun Math Sheet

**Introduction:**

* How does a rocket make it all the way into space? It's not as easy as it looks. Rockets that fly into space are very heavy and require something powerful to "push" them. Engineers design rocket engines to do just that!
* The push that a rocket engine provides is called thrust.
* Do you remember which law helps us describe thrust?
  + Newton's third law of motion states that for every action, there is an equal and opposite reaction. That means that as the rocket engine pushes hot gases (mass) out of the rocket, the rocket propels (pushes) forward into space. That forward push is called thrust.
* In order to create a successful rocket for Tess, her engineering team must understand thrust and know how much force (push) it is creating.
* What do you think could affect the thrust of a rocket?
  + Perhaps a bigger engine? Well, there are some other things that engineers can do to affect thrust as well.
* How an engineer designs the shape of the rocket nozzle is very important to the performance and thrust of the rocket.
  + The size and shape of the nozzle effects how fast the exhaust will leave the rocket as well as how much pressure it will have.
  + Tess' engineering team must perform many complex mathematical calculations in order to design a nozzle that will create enough thrust to launch the rocket into space.
* Today, we are going to design two paper rockets with different nozzle shapes.
* Although we will not be performing all the math calculations, we will still understand how the different sized nozzles affect thrust.
* We will use our own mouths as rocket engines! By blowing air out of our mouths, we can launch our paper rockets into the air.
* We are also going to put cotton balls on the end of our paper rockets. For what reason, do you think, the cotton is added?
  + Engineers have to take safety into consideration when designing rockets as well, no matter what the size of the rocket.
  + Today, with our small paper rockets, we will be taking safety into account by adding a soft cotton ball to the front of the rocket to protect its landing.

**Come on, let's go build some rockets!**  
**Vocabulary/Definitions**  
**thrust:** To push (someone or something) with force. The forward-directed force of a rocket engine or jet as a reaction to the ejection of exhaust gases.

**Procedure**

**Before the Activity**

1. Gather materials and make copies of the Thrust Quiz and Thrust Analysis Worksheet.
2. Print out the planet targets, Inner and Outer. If possible, do so in color and laminate for reuse.
3. Cut enough pieces of letter-sized paper into halves so that each student receives two halves. Note: Almost any size paper can be used as long as it is not longer than the straw.
4. Remove the straws from their paper wrappers, if necessary.
5. Mark a starting line on the floor with tape or string.
6. Lay out the planet targets on the floor beyond the starting line.
   1. For a somewhat realistic layout, use one of the attached patterns: Launch from the Earth or Launch from the Sun. Note: Refer to the Planet Comparison Datasheet for actual planet diameters and distances.

**With the Students**

1. Present to the class the Introduction/Motivation content.
2. Hand out materials.
3. Have students wrap one half-sheet of paper around a pencil, starting from the eraser end and working up to the graphite tip.
   1. When wrapping, spiral the paper to make a cone shape (see Figure 2)
   2. it helps to hold it tighter at the eraser end and wrap upward.

Figure 2. A cone-shaped paper tube.

1. Have students tape the paper tube near each end so it keeps its shape.
2. Then remove the pencil.
3. Check the final length of paper tubing to make sure it is at least a few centimeters shorter than the straws; otherwise, students will have nothing to hold onto for the launch.
   1. If necessary, use scissors to cut the paper tube shorter.
4. Have students pinch and fold the smaller end of the tube over and tape it so it is airtight. This end is the "nose" of the strawket.
5. Because engineers always consider safety measures in their designs, direct students to tape a cotton ball to the nose of each strawket.
6. To prevent the cotton from falling off the strawket, place the tape over the top of the cotton ball (that is, not wrapped inside/out and placed underneath the cotton ball as it sits on the nose of the paper tubing).
7. Note: Some cotton balls are big enough to pull apart; only use as much cotton as necessary to provide some protective padding.
8. Have students personalize their strawkets. Suggest they write their names or draw designs on them so they know which one is theirs.
9. Have students sketch their strawket on their worksheets.
10. Have each student launch from the Earth or Sun (depending on the pattern you selected before the activity) using the Launch from the Earth or Launch from the Sun Sheets. To do this, have students insert their straws into their strawkets—holding onto the straw, not the paper part of their strawket—aim at a planet, and blow.
11. After retrieving their strawkets, direct students to answer the three worksheet questions for the strawket they just launched.
12. Next, have students make a new strawket.
    1. Take another half-sheet paper and wrap it tightly around a pencil—without spiraling into a cone shape—to make a tight paper tube that is more even in diameter along the length of the tube. See Figure 3.
    2. Again, be sure the final length is a few centimeters shorter than the straws to leave available some length of the straw to hold onto for the launch!
    3. Note: If students have trouble wrapping this tube, assure them that a slight cone-shape is acceptable as long as the tube is tighter than their first designs.
    4. Repeat steps 19 and 20.

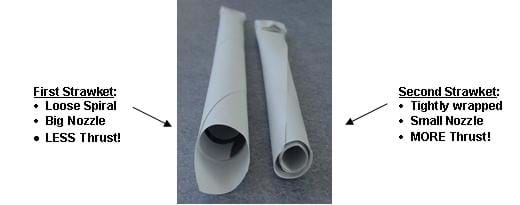


Figure 3. Strawket design comparison.

**Assessment or Summation**

* Allow the students to finish their Thrust Quiz and their Thrust Analysis Worksheet.
* Guide students to create graphs, and then revisit their quiz answers.
* Graphing Practice: Have students create bar graphs of the class results using either the Results from Earth or Results from Sun math sheet (depending on where the students started their rocket from in step 7, either the Earth or the Sun).
* Ask the students the following question:
  + Could you change the strawket nozzle (the tail end) any other way to get more thrust? (Answer: Use a smaller diameter straw and tighter paper wrap while blowing as hard as before. Another idea is to plug the back with something so the air pressure builds up before launch and then "pull the plug.")

**Troubleshooting Tips**

* Make a strawket or two in advance to confirm that your materials are suitable.
* Also, it is a good idea to have some extra strawkets in case someone's gets lost or crushed during the activity.
* If you do not have access to enough pencils, use extra drinking straws instead to help wrap the paper cone.
* Distributing tape to each student can be difficult while demonstrating how to build. If possible, have have several helpers pass out the tape or have pieces stuck on the table edges in advance.
* The tape used to secure the cotton balls should be fairly long so they are adhered properly.
* Make sure kids are not holding onto the bottom of the rocket when they blow through the straw!