

ROCKET 'ROUND THE CLOCK



Northrop Grumman Aerospace Systems

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OVERVIEW

Brief Description Of The Lesson

In *Rocket 'Round the Clock*, students will construct and launch paper rockets and investigate Newton's third law of motion as it applies to rocket propulsion.

Appropriate Ages

Rocket 'Round the Clock is appropriate for students in grades 3 Through 9.

Time

Rocket 'Round the Clock can be presented in approximately 1 hour.

Preparation Prior To Presentation

Assemble the rocket launchers that students will be using during the activity.

Practice assembling and launching rockets using both the launchers with and without bottles attached. Practice calculating the height of the rocket flight.

Practice swinging paper rockets over your head like a lasso to demonstrate how placing the center of pressure below the center of mass helps to prevent the rocket from tumbling.

Read and become familiar with the background information presented in this activity. Be able to explain how the air exiting the rocket causes the rocket to move in an opposite direction, and the usefulness of rocket fins in space and in air.

At Completion Of This Lesson, Students Should Know The Following Information

- 1) Forces come in pairs. Rockets move one direction because they push out material in the opposite direction.
- 2) Rockets don't need air around them to move forward. When rockets are in the air, fins help them fly straight.

During the presentation of *Rocket 'Round the Clock*, review the above concepts often with the students.

SUPPLIES

Materials For Each Student

- 1 rocket Worksheet
- 1 safety scissors
- 1 safety goggles
- 1 short or long rocket template
- 1 small or large fin template
- 1 set of colored pencils, 4 to 8 pencils per set
- 1 roll of scotch tape
- 1 empty film canister
- 1 paper-covered straw

Materials For The Presenter

- 1 deflated balloon
- 1 rocket height class worksheet
- 3 model rockets for demonstration
- 2 rocket launchers:
 - 2 plastic 1-liter bottles
 - 2 1 $\frac{1}{8}$ " to 1 $\frac{1}{4}$ " width bicycle tire inner tubes
 - 2 1 foot lengths of $\frac{3}{4}$ " PVC pipe
 - 4 zipping ties

Northrop Grumman Propulsion Posters

- 1 TR106 Engine
- 1 MEMS/Micro Propulsion

STANDARDS MATRIX

These activities support the following California Science Standards:

Grade 1

Investigation and Experimentation: 4 a

Grade 2

Physical Sciences: 1 c, e

Grade 3

Investigation and Experimentation: 4 d

Grade 4

Investigation and Experimentation: 6 c

Grade 8

Physical Sciences: Forces - 2 a, d

Grades 9-12

Physics: Motion and Forces -1 d

These activities support the following National Science Content Standards:

Grades K-4

Content Standard A: Science as Inquiry

Content Standard B: Physical Science

Grades 5-8

Content Standard A: Science as Inquiry

Content Standard B: Physical Science

Grades 9-12

Content Standard A: Science as Inquiry

Content Standard B: Physical Science

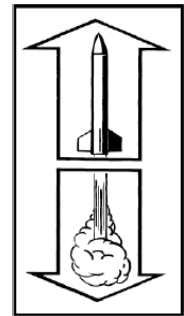
SCIENCE CONTENT

Forces Come in Pairs

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Another way to say this is that all forces come in pairs. A very clear way to demonstrate this is to think about touching. You can't touch without being touched. If you touch someone's hand, his hand touches you. If you lean against a wall, the wall holds you up by pushing against you. More examples that illustrate Newton's third law are sitting in a chair, and letting go of an inflated balloon. Rockets are also prime examples of Newton's third law.



When you sit in a chair, the chair is pressing up on your body, holding you above the ground. Your body is pressing down on the chair with the same amount of force that the chair is using to hold you up. The pair of forces in this example is the chair pushing your body up and your body pushing the chair down.



A rocket moves upward by expelling fuel downward. The rocket pushes the fuel in one direction, and the fuel pushes the rocket in the opposite direction. The pair of forces in this example is the rocket pushing the fuel down and the fuel pushing the rocket up. Rocket image from http://www.esteseducator.com/Pdf_files/Science.Model.Rocket.pdf

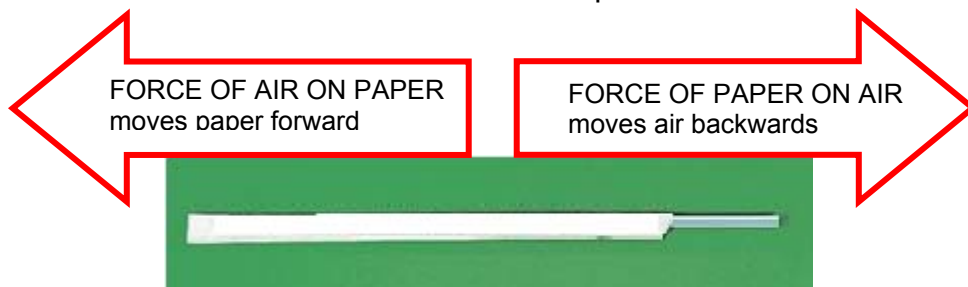
A balloon is an example of a rocket. When you blow a balloon up and then let it go, it zips around the room. What makes it move forward? Recalling that forces come in pairs, we see that the air that the balloon is pushing back is in fact pushing the balloon forward. In this case, the balloon rocket's fuel is the air you blew into the balloon.



Balloon image from <http://exploration.grc.nasa.gov/education/rocket/TRCRocket/IMAGES/balloon.gif>

The paper covering a plastic drinking straw is another example of a rocket that uses air blown into it as a fuel. If you curl up the end of a straw's paper covering and blow it off the straw, you have created a rocket. The air fills the cavity of the paper straw covering and is pushed backwards, resulting in an opposite force pushing the straw forwards.

The paper drinking straw cover is very similar to the paper rocket the students will be creating. The fuel in this case is the air pushed into the rocket from the plastic bottle and then pushed out of the rocket as the rocket fills up with air.



Does the rocket push down on the surrounding air?

A common misconception regarding rockets is that they push against the air surrounding them. In fact, rockets work best in a vacuum like outer space. There's no air or atmosphere in a vacuum. Fortunately for us, we are surrounded by a breathable atmosphere. Unfortunately for the rocket, our atmosphere pushes against its movement upwards.

Why do rockets have fins?

An adaptation we make to rockets launched in our atmosphere is to give them fins. Fins work to help stabilize the rocket by moving the center of pressure below the center of balance. Without fins, the rocket would want to spin about its center of balance as it launches into the air. Moving the fins below the center of balance provides a restoring force as the surrounding air strikes the fins. You may notice that many modern rockets don't have fins. Many modern models have steerable propulsion units that are used to stabilize and direct the rocket's flight path.

Does it help to make the rockets spin?

Some of your students may experiment with spinning the rockets, or setting their fins at an angle to help the rocket spin as it rises through the air. The spin will help the rocket fly straighter, but a spinning rocket may not rise as high as a non-spinning one. Just like a top or a gyroscope is very stable as it spins in place, a spinning rocket has a force acting towards the axis of rotation which helps prevent it from wobbling or spinning about its center of mass. As the rocket spins, however, the surrounding air strikes its fins. The energy transferred from moving upwards to striking the surrounding air results in the rocket not flying as high as it might have were it not spinning.

Altitude of Rocket Flight

We all want to know the maximum altitude that a rocket can reach. A simple way of estimating a rocket's altitude is by counting the seconds the rocket is flying through the air from launch until it reaches the ground. This is not the most accurate method for measuring altitude, since a rocket which has a prolonged glide back to the ground may be in the air longer than a rocket which traveled higher, but free-falls back to the ground. Nonetheless, counting seconds and working with a simple formula for predicting height with objects falling near the Earth's surface is useful pedagogically.

The formula is as follows, counting time from launch to the moment the rocket lands:

$$\text{Height (max altitude)} = \left(\frac{1}{2}\right)(32 \text{ ft/s}^2)(\text{time in sec}/2)^2.$$

Using meters, the formula is:

$$\text{Height (max altitude)} = (1/2)(10 \text{ meters/s}^2)(\text{time in sec}/2)^2 .$$

As an example, if the rocket is in the air for 2 seconds, the height it reached is approximately:

$$(1/2)(32 \text{ ft/s}^2)(2 \text{ s}/2)^2 = (16 \text{ m/s}^2)(1 \text{ s}^2) = 16 \text{ feet}$$

or

$$(1/2)(10 \text{ m/s}^2)(2 \text{ s}/2)^2 = (5 \text{ m/s}^2)(1 \text{ s}^2) = 5 \text{ meters.}$$

If the rocket is in the air for 4 seconds, the height it reached is approximately:

$$(1/2)(32 \text{ ft/s}^2)(4 \text{ s}/2)^2 = (16 \text{ ft/s}^2)(4 \text{ s}^2) = 64 \text{ feet}$$

or

$$(1/2)(10 \text{ m/s}^2)(4 \text{ s}/2)^2 = (5 \text{ m/s}^2)(4 \text{ s}^2) = 20 \text{ meters.}$$

ROCKET DESCRIPTIONS

TR106 Engine

Based on Northrop Grumman's Pintle Engine technology, Northrop Grumman's 650,000-pound thrust TR106 engine is one of the largest liquid rockets ever built. It was successfully test-fired at 100 percent of its rated thrust as well as 65 percent throttle condition in tests at NASA's John C. Stennis Space Center.



MEMS/Micro Propulsion

The Northrop Grumman-led Digital Micro-Propulsion Program is producing and demonstrating tiny thrusters to perform orbital insertion, station keeping and attitude control functions on micro-, nano- and pico-satellites.

The micro thruster design offers several advantages over conventional thrusters: it has no moving parts, uses a variety of propellants, is scalable, and eliminates the need for tanks, fuel lines and valves.

A micro thruster is very small in size as indicated in the picture to the right

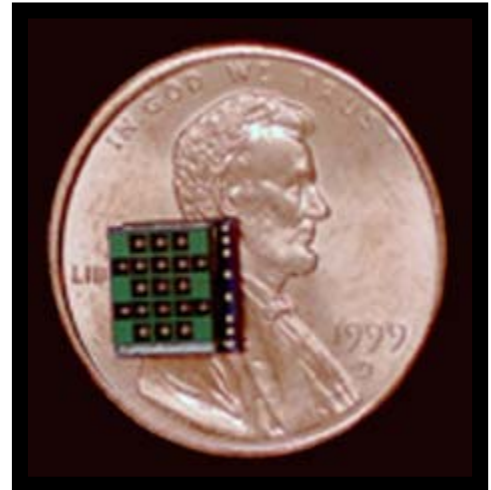


Photo courtesy of:
The Aerospace Corporation

Activity #1 – Balloons and Straws

The intent of this activity is for students to learn and investigate Newton's third law of motion through hand motions and by experimenting with balloons and straws.

Directions for the Presenter

1. Explain to the students that forces come in pairs that are separate and equal. Demonstrate this concept by running two model cars into each other on the table. Ask students to notice how the two cars each bounced back the same distance from the collision.
2. Demonstrate hand motions for each concept: Explain to students: "Just like your hands," *wave two hands*, "forces come in pairs that are equal." *Hold arms across your chest to form an equal sign* "and opposite." *Put two fists together with thumbs pointing in opposite directions* (one thumb up and the other down).
3. Ask the students to repeat the hand motions with regard to various objects around the classroom. For example: "when I push down on the desk, the desk pushes up on me. The forces come in a pair that is equal and opposite" (students' thumbs point up and down). "When I lean against the wall, the wall pushes against me. The forces come in a pair that is equal and opposite" (students' thumbs point side to side). "When I sit down on the chair, the chair pushes up on me. The forces come in a pair that is equal and opposite" (students' thumbs point up and down).
4. Hold up the balloon and ask students to guess what will happen with the balloon when you blow it up and let go. Explain that when you let go of the balloon, it will push the air out. Ask students which way the air will push the balloon. Repeat with hand motions: "When the balloon pushes out the air in one direction, the air pushes the balloon in the opposite direction. The forces come in a pair that is equal and opposite (students' thumbs point side to side).
5. Demonstrate with the balloon by blowing it up and letting go.
6. Ask students what happened and ask them to explain with hand motions.
7. Distribute the paper-covered straws to the students. Direct students to tear off the bottom of the paper covering

8. Ask students to guess what will happen with straw covering when they blow through the straw.
9. Have students point their straws towards the ceiling, instruct them to blow air through the straw.
10. Ask students to explain what happened with the air and the paper covering using the hand motions.
11. Distribute “The Pair of Forces Worksheet” and direct students to draw in arrows on the pairs of forces for the first four images.

Activity #2 – Fins

The intent of this activity is for students investigate the forces on a rocket in flight and how fin size and placement will affect their rocket's performance.

Directions for the Presenter

1. Display the three rockets with the different wing placement to the students. Explain that when the rocket flies, it wants to tumble about its center of mass. By placing fins behind the center of mass, the center of pressure stabilizes the rocket when it flies.
2. Use strings tied around the centers of mass of each of the rockets to demonstrate how the rockets with centers of pressure in front of their center of mass tend to tumble in the air when swinging the rockets over your head. The rockets without fins and with fins near the nose will tumble, fly tail-first, or be difficult to start moving through the air.
3. Ask students to choose if they want to make a short rocket or a long rocket. Explain that if they make a short rocket, they should use the smaller fins, and if they make a long rocket, they should use the larger fins.
4. Distribute the appropriate fin worksheet (large or small) and scissors.
5. Direct students to decorate and then cut out their fins.

Activity #3 – Making a Paper Rocket

The intent of this activity is for students to create a paper rocket and investigate Newton's Third Law of Motion.

Directions for the Presenter

1. Distribute the long or short rocket template to the students.
2. Direct students who are making short rockets to select the short rocket template. Direct students who are making long rockets select the long rocket template. Have the students decorate the box on their template.
3. Once students have completed decorating their rocket, demonstrate how to create the rocket tube by using a film canister and piece of paper. Have the students repeat the activity. Instruct students to tape the side of their paper rocket body so it does not unroll, being careful to not tape the rocket onto the film canister.
4. Direct students to remove the film canister from their rockets. Demonstrate pinching and taping one end of the rocket closed.. Have students complete the steps demonstrated on their own rockets..
5. Demonstrate taping the fins to the side of the rocket. Direct students to complete the steps demonstrated on their own rockets.



Completed Rockets

Activity #4 – Launch!

The intent of this activity is for students to launch their rockets using the soda-bottle launcher.

Preparation Needed Prior to the Activity

The presenter needs to make a rocket launcher. The directions are on page 16

Directions for the Presenter

1. Walk with one student to the launch site, at least 5 feet from the other students. Ask the student to bring his/her rocket. The other students should stay out of the launch site until it is their turn.
2. Demonstrate to the class how they will launch, count the amount of time their rocket is in the air and how to record their findings.
3. Inflate the soda bottle by wrapping your hand over the open end of the PVC pipe and blowing through your hand into the pipe.
4. Slip the student's rocket over the open end of the PVC pipe. Check to see that the students wear safety goggles when they launch their rockets.
5. Hold the PVC pipe vertical to the ground and ask the student to jump or stomp on the soda bottle. If the rocket is very loose on the PVC pipe, lightly grasp the bottom of the rocket so little air escapes as the rocket launches.
6. The moment the student jumps or stomps on the soda bottle start counting (1 Mississippi, 2 Mississippi, etc.) out loud till the rocket falls to the ground.
7. Have the student record his/her flight time on the Rocket Height Worksheet and then make the appropriate calculations.
8. Explain to the students that they will be working in pairs: one student times the flight of the other's rocket, while the student whose rocket is being launched stomps on the plastic bottle to launch the rocket.

9. Assist students with calculating approximately how high their rockets flew using the formula: $\text{height} = (\frac{1}{2})(32 \text{ ft/s}^2)(\text{time}/2)^2$, and write their answers on the class worksheet.

10. After all the students have launched their rockets return to the classroom. Discuss the data results with the students. You may find that the tall rockets tended to go higher than the short rockets. Since the tall rockets are on the launch tube for a longer time than the short rockets, the tall rockets experience a larger initial thrust enabling a higher maximum altitude, even though the amount of force is the same for each launch. Discuss what students expected to see and what was recorded.

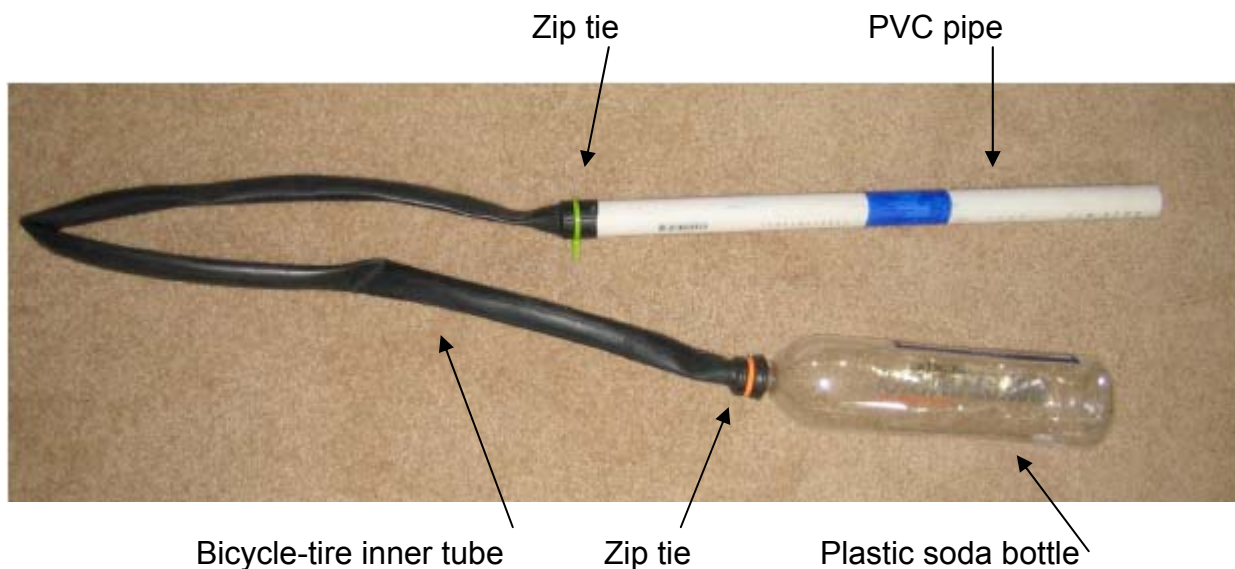
Rocket Launcher Construction

Materials for one launcher:

- 1 1liter or larger plastic soda bottle
- 1 piece of $\frac{3}{4}$ " PVC pipe, approximately 1 foot long
- 1 bicycle-tire inner tubing, cut once to form a long tube
- 2 zip ties to attach the inner tube to the bottle and the PVC pipe

Procedures:

- Step 1 : Slip one end of the inner tube over the neck of the soda bottle.
- Step 2 : Attach a zipping tie around the tube and bottle neck and tighten as firmly as possible.
- Step 3 : Slip the other end of the inner tube over one end of the PVC pipe
- Step 4 : Attach a zipping tie around the tube and pipe and tighten as firmly as possible.
- Step 5 : To inflate the soda bottle, hold one hand over the open end of the PVC pipe and blow through your hand. The bottle should inflate quickly. If the bottle doesn't inflate immediately, check to make sure the inner tube is not twisted or stuck together.



The Pair of Forces Worksheet

Name: _____

Draw arrows indicating the forces in the following pictures:

A: Cat on the table

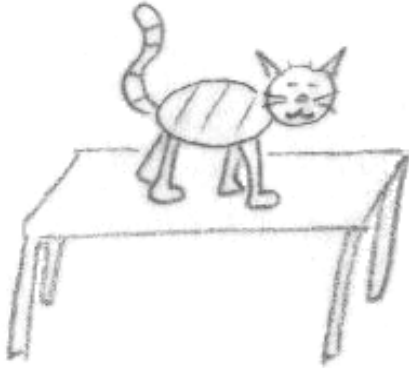


Table on the cat

B: Pencil on the paper



Paper on the pencil

C: Board on the wall



Wall on the board

D: Fuel on the rocket



Rocket on the fuel

E: Ball on the ground



Ground on the ball

F: Straw cover on the air



Air on the straw cover

1. Draw your rocket here.
Draw arrows and label the force of the rocket pushing down on its fuel and the fuel pushing up on your rocket.

2. Which rocket length do you think will go the highest, a short rocket or a tall rocket? Explain your reasoning.

3. How many feet in the air did your rocket go?

4. How high did the highest rocket in the class go?

5. What was the average height for the short rockets in the class?

6. What was the average height for the long rockets in the class?

7. Which rocket reached a greater height – the short rocket or the long rocket?

8. How could you make your rocket go higher or stay in the air longer?

The Pair of Forces Worksheet

Name: Answers

Draw arrows indicating the forces in the following pictures:

A: Cat on the table

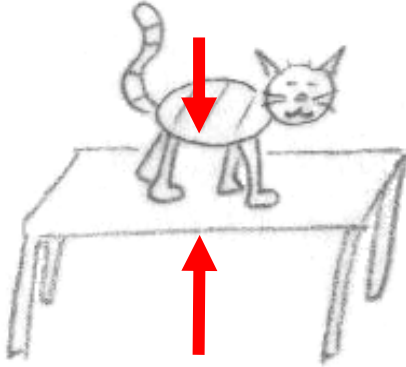
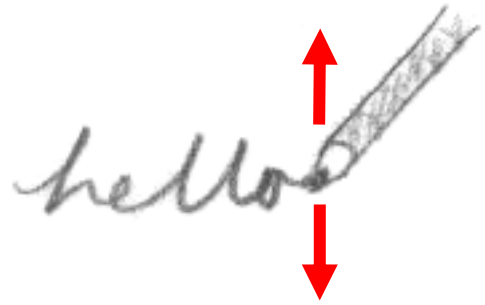


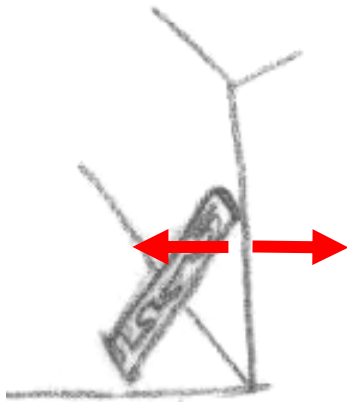
Table on the cat

B: Pencil on the paper



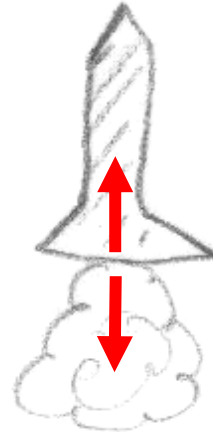
Paper on the pencil

C: Board on the wall



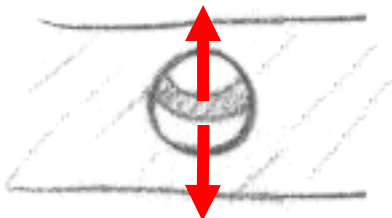
Wall on the board

D: Fuel on the rocket



Rocket on the fuel

E: Ball on the ground



Ground on the ball

F: Straw cover on the air



Air on the straw cover

Sample Answers

1. Draw your rocket here.
Draw arrows and label the force of the rocket pushing down on its fuel and the fuel pushing up on your rocket.

2. Which rocket length do you think will go the highest, a short rocket or a tall rocket? Explain your reasoning.

3. How many feet in the air did your rocket go?

4. How high did the highest rocket in the class go?

5. What was the average height for the short rockets in the class?

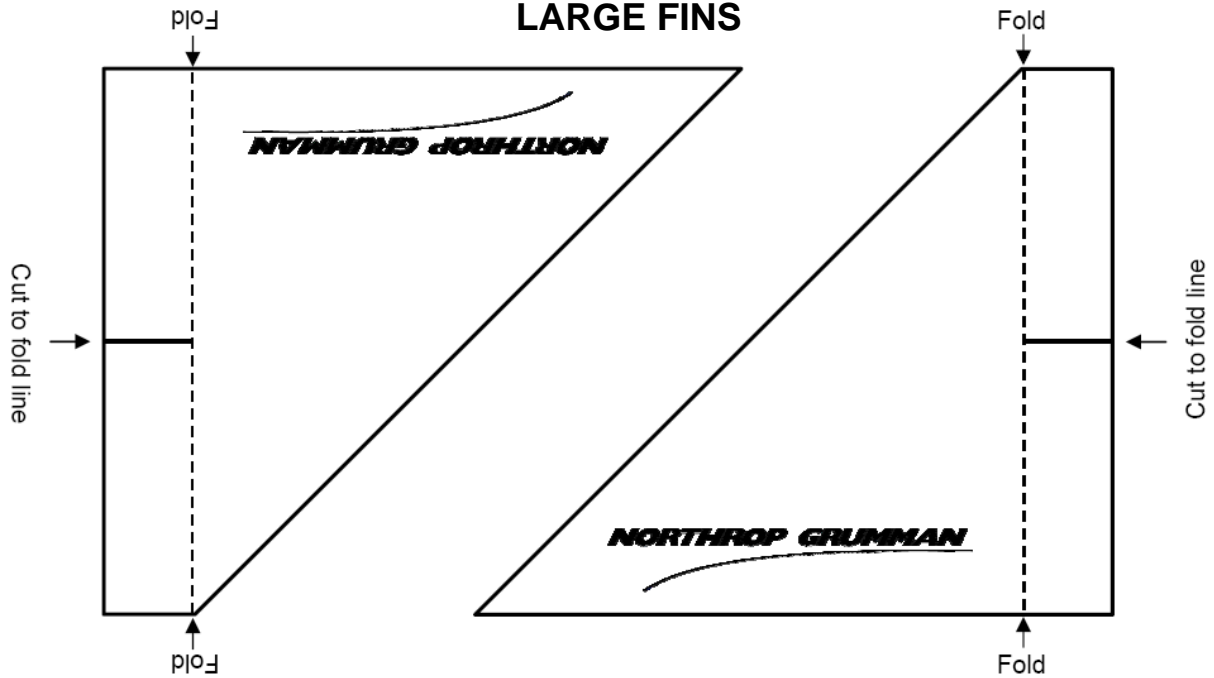
6. What was the average height for the long rockets in the class?

7. Which rocket reached a greater height – the short rocket or the long rocket?

8. How could you make your rocket go higher or stay in the air longer?

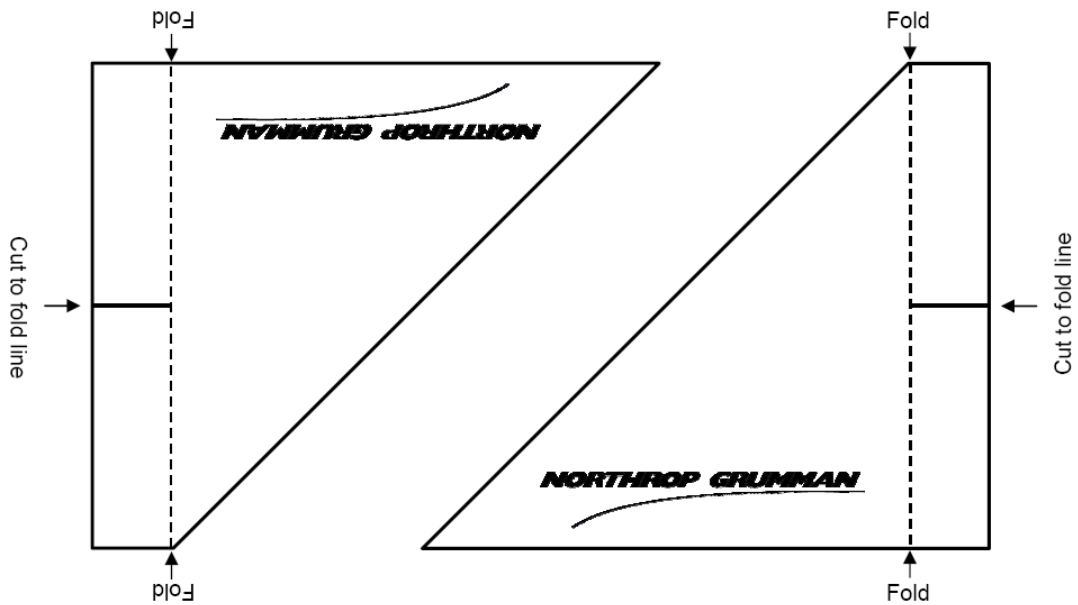
Fin Template

LARGE FINS



- A. Decorate and cut out these shapes for your fins.
- B. Cut into tab and fold on dotted lines in opposite directions.
- C. Tape tabs to rocket body.

SMALL FINS



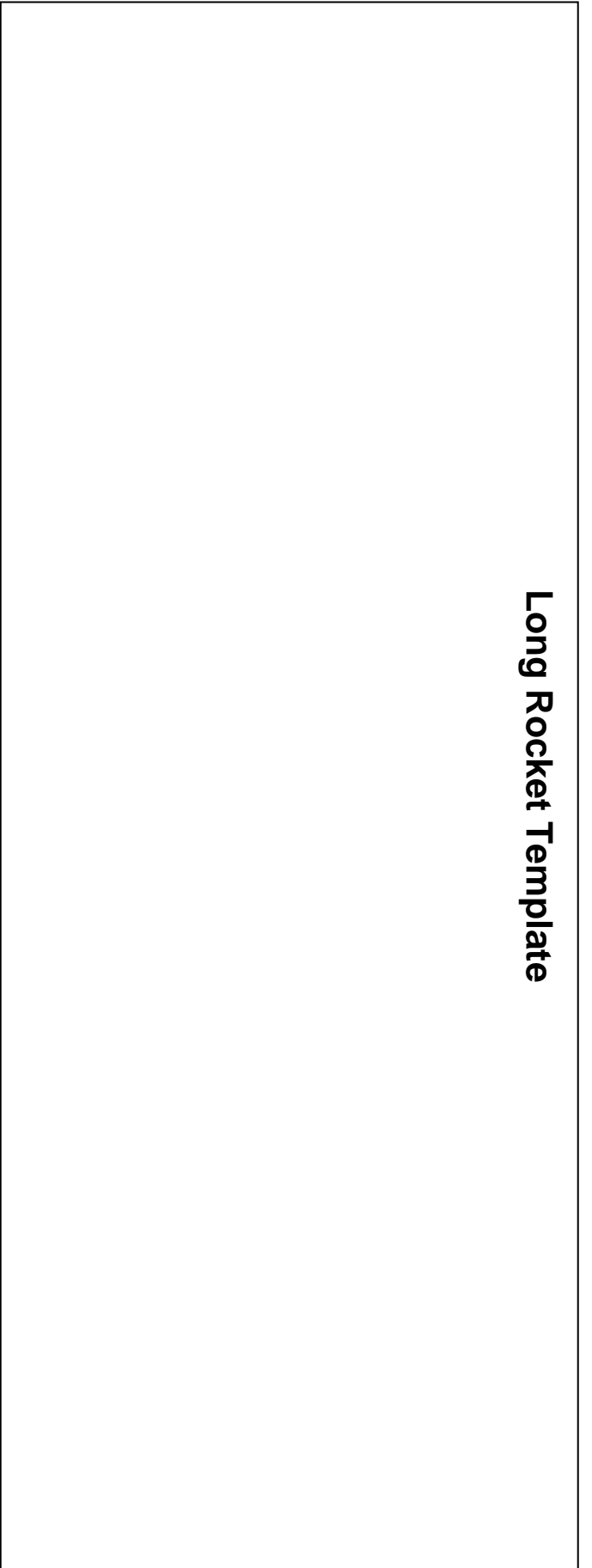
- A. Decorate and cut out these shapes for your fins.
- B. Cut into tab and fold on dotted lines in opposite directions.
- C. Tape tabs to rocket body.

Short Rocket Template

Decorate your short rocket inside this box

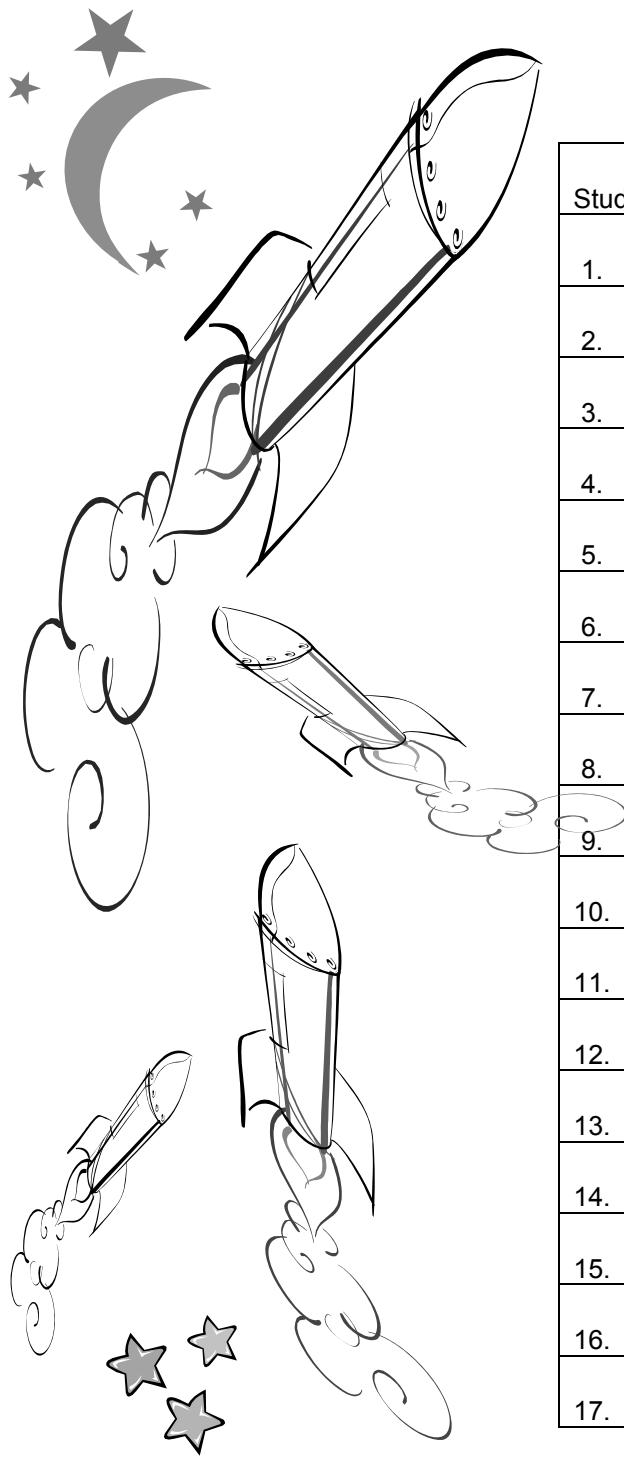


Long Rocket Template



Decorate your long rocket inside this box

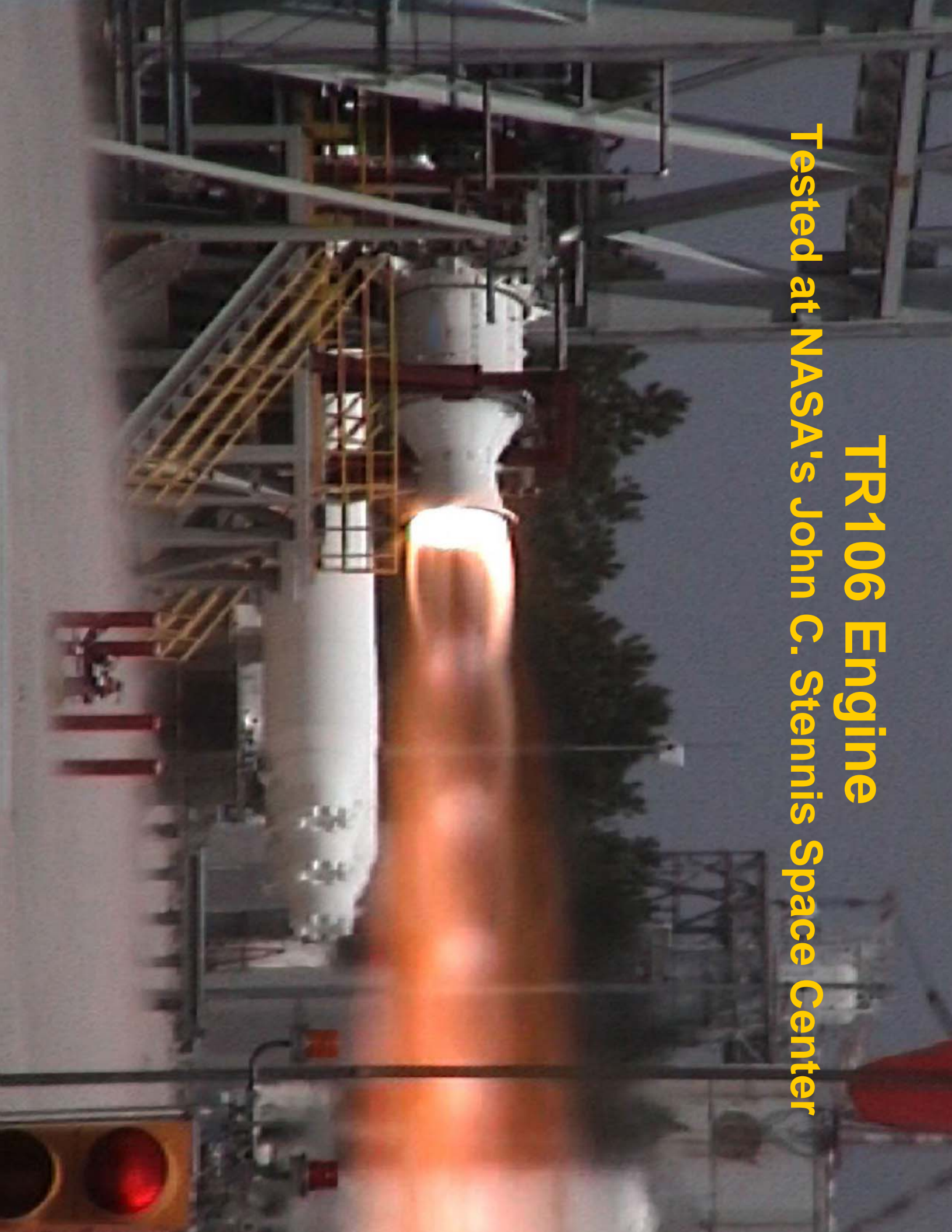
Rocket Height Worksheet



Student Name	Short or Long Rocket	$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\text{time in sec} \div 2)^2$	Height
1.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
2.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
3.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
4.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
5.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
6.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
7.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
8.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
9.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
10.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
11.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
12.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
13.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
14.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
15.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
16.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft
17.		$(\frac{1}{2})(32 \text{ ft/s}^2)$	x	$(\div 2)^2$	ft

TR106 Engine

Tested at NASA's John C. Stennis Space Center



Micro Propulsion

MEMS

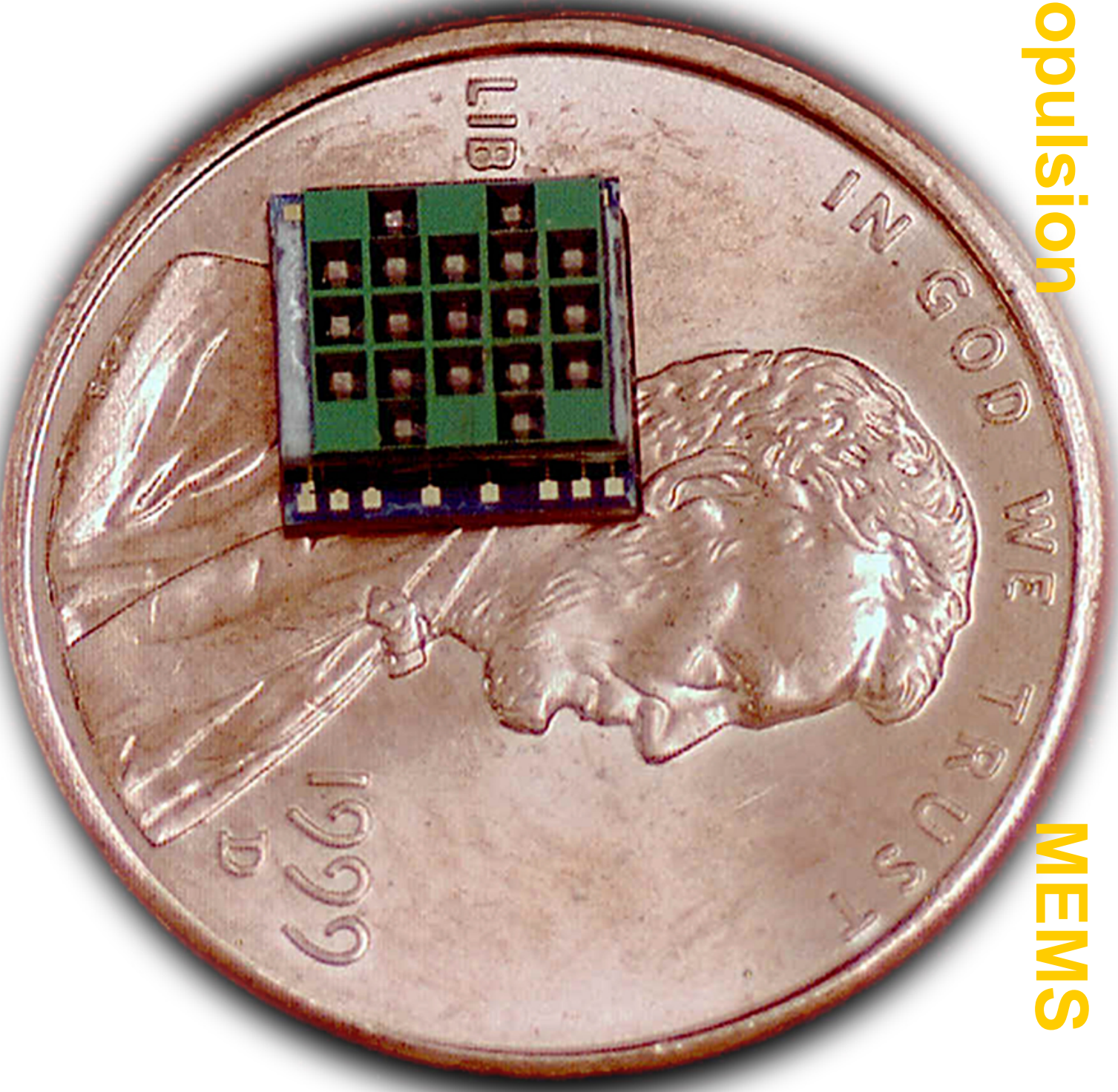


Photo courtesy of:
The Aerospace Corporation