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# Festival of Flight Special: Opening Space for Next Generation Explorers

An Educator Guide with Activities in Mathematics, Science, and Technology





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# NASA CONNECT

# Festival of Flight Special: Opening Space for Next Generation Explorers

An Educator Guide with Activities in Mathematics, Science, and Technology

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**FOUNDATION** Registered users of NASA CONNECT<sup>™</sup> may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

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## **Program Overview**

## SUMMARY AND OBJECTIVES

In Festival of Flight Special: Opening Space for Next Generation Explorers, students will experience the dynamic skills and processes needed to design the next generation of launch vehicles. They will see how mathematics, science, and technology work together to improve human space flight, with increased safety and economy. Students will get an exciting "hands on" feel for the challenges facing the designers of tomorrow's launch systems and a greater appreciation for the accomplishments of the past. By conducting hands-on and Instructional Technology Activity, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

### STUDENT INVOLVEMENT

#### **Cue Card Questions**

Norbert, NASA CONNECT's<sup>™</sup> animated co-host, poses questions throughout the broadcast. These questions direct the instruction and encourage students to think about the concepts being presented. When viewing a videotaped version of NASA CONNECT<sup>™</sup>, educators have the option to use the Cue Card Review, which gives students an opportunity to reflect and record their answers on the Cue Cards (p.14). NASA CONNECT's<sup>™</sup> co-host, Jennifer Pulley, will indicate an appropriate time to pause the videotape and discuss the answers to the guestions.

#### **Hands-On Activity**

The hands-on activity is teacher created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science (NSE) Standards, and the International Technology Education (ITEA) Standards. Students will apply their problem–solving skills by using statistical data and mathematical modeling to determine the optimum propellant ratio for best vehicle performance of a chemical reaction rocket (CR<sup>2</sup>).

#### Instructional Technology Activity

Exploring Aeronautics, the instructional technology activity, is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science (NSE) Standards, and the International Technology Education (ITEA) Standards. This multimedia CD-ROM takes students on a journey to design their own aircraft. Students will learn about the history of flight, lift, drag, ratios, and other mathematics and science related concepts. Exploring Aeronautics is available through NASA Central Operation of Resources for Educators, <http://core.nasa.gov>.

## RESOURCES

Teacher and student resources support, enhance, and extend the NASA CONNECT<sup>™</sup> program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions. In addition to the resources listed in this educator guide, the NASA CONNECT<sup>™</sup> web site <http://connect.larc.nasa.gov> offers online resources for teachers, students, and parents.





# Hands-On Activity

## BACKGROUND

Despite the complexity of modern spacecraft, the rocket is one of the simplest of all machines. It uses the very basic principle that every action has an equal and opposite reaction. Each rocket is propelled forward by pushing material out of its tail. Nonetheless, people have been developing better and better rockets for more than 700 years. Rockets are now used for space exploration, military weaponry, rescue operations, and amusement.

A rocket obtains its thrust, the force that accelerates it forward even against the pull of gravity, by pushing gas out its tail. The rocket pushes on the gas so the gas pushes back: action and reaction. The more gas it ejects and the faster that gas moves away from its tail, the more thrust the rocket experiences. Even at room temperature, the molecules in the air are traveling at 1,800 km/hr. When exhaust gas molecules are heated to about 2800 degrees C, as they are in a liquid-fuel rocket engine, they move about three times that fast. A conventional rocket engine uses a chemical reaction to create very hot exhaust gas from fuels contained entirely within the rocket itself. What began as potential energy in the stored chemical fuels becomes thermal energy in the hot, burned gas. This thermal energy is mostly kinetic energy, hidden in the random motion of the tiny molecules themselves. The rocket engine's nozzle converts much of this random motion into directed motion by permitting only the gas molecules to leave the engine from one side. Like an anxious crowd of people streaming out of a sports stadium, the molecules pour out of the nozzle at high speed and head mostly in one direction.

In directing the rush of exhaust out its nozzle, the rocket is exerting a substantial force on the gas. After all, the gas starts out stationary and ends up moving rapidly in one direction. The rocket nozzle exerts a force on the gas to increase the momentum and the gas pushes back to complete the transfer. Overall, the rocket is pushed forward by its own exhaust. It doesn't need anything outside to push "against" and will operate perfectly well in empty space. The thrust exerted on the rocket by its exhaust plume causes it to accelerate, and if the exhaust gas exerts enough thrust on the rocket, that upward force can exceed the rocket's downward weight so that the rocket feels an upward net force. The rocket begins to accelerate upward. For example, the Space Shuttle weighs about 20 million N (newtons) at launch but its thrust is about 30 million N. The shuttle cannot only support its own weight, it can also accelerate upward at about half the acceleration due to gravity! As the shuttle consumes its fuel, so that its weight and mass diminish, it can accelerate upward even more rapidly.

As long as the engine keeps pushing material backward, the rocket will continue to accelerate. However, to reach extremely high speed, the rocket must push the vast majority of its initial mass backward as exhaust. But there is a problem with trying to burn up and eject a huge fraction of the rocket's original mass as exhaust. It's difficult to construct a rocket that is 99.99% fuel. Instead, space-bound rockets use several separate stages, each stage much smaller than the previous stage. Once the first stage has used all its fuel, the whole stage is discarded and a new, smaller rocket begins to operate.

In February 2001, the U.S. government began a program–The Space Launch Initiative (SLI)–to develop a reusable rocket vehicle that could achieve Earth orbit with only a single stage. Nothing but fuel would be jettisoned during launch so that the vehicle could travel to and from orbit repeatedly, with only refueling and minimal maintenance between flights. The challenges facing this program are formidable. Even with liquid hydrogen and oxygen as its fuels, almost 90% of this vehicle's launch weight must be fuel. Nonetheless, construction and testing of such reusable launch vehicles (RLVs) is proceeding rapidly and test vehicles have already shown the feasibility of the ideas. RLVs, because they are re-used, will dramatically reduce the cost of access to space that is required to bring about extensive human exploration and colonization of the solar system.



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The power and speed required to reach low-Earth orbit, let alone travel to other worlds, demand a highly sophisticated propulsion system with a much greater level of simplicity, dependability, and low cost than today's rockets provide. Space propulsion, by definition, encompasses the energy storage, transfer, and conversion subsystems and components required to propel a space transportation system or maneuver a vehicle. Propulsion is the single largest contributor to unreliability during ascent, requires the largest expenditure of time for maintenance, and takes the longest time to develop; therefore, propulsion is the key to meeting the safety, reliability, and cost goals of the SLI program. When vinegar (an acid) reacts with baking soda (a base), carbon dioxide is formed. The chemical reaction created by vinegar and baking soda is used as a simple propulsion system that will enable students to investigate the optimum ratio of the two reactants as shown by the distance CR<sup>2</sup> (Chemical Reaction Rocket) travels.





## NATIONAL STANDARDS

#### **Mathematics (NCTM) Standards**

- Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic rules.
- Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations.
- Model and solve contextual problems using various representations such as graphs, tables, and equations.
- Use graphs to analyze the nature of changes in quantities in linear relationships.
- Understand both metric and customary systems of measurement.
- Understand and use units of appropriate size and type to measure.
- Solve simple problems involving rates and derived measurements for such attributes as velocity and density.
- Build new mathematical knowledge through problem solving.
- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Monitor and reflect on the process of mathematical problem solving.
- Organize and consolidate mathematical thinking through communication.
- Use representations to model and interpret physical, social, and mathematical phenomena.

#### Science (NSE) Standards

- Unifying Concepts and Processes
- Science as Inquiry
- Physical Science
- Science and Technology
- Science in Personal and Social Perspectives
- History and Nature of Science

#### Technology (ITEA) Standards

#### Abilities for a technological world

- Specify criteria and constraints for the design.
- Operate and maintain systems to achieve a given purpose.
- Design and use instruments to gather data.
- Use data collected to analyze and interpret trends to identify the positive or negative effects of a technology.

#### The Design World

- Power systems are used to drive and provide propulsion to other technological products and systems.
- Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.

#### The Nature of Technology

• Systems thinking involves considering how every part relates to others.

#### **Technology and Society**

- Throughout history, new technologies have resulted from the demands, values, and interest of individuals, businesses, industries, and societies.
- The design and construction of structures for service or convenience have evolved from the development of techniques for measurement, controlling systems, and the understanding of spatial relationships.

#### Design

- Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.
- Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.



## **INSTRUCTIONAL OBJECTIVES**

The student will

- gather statistical data
- find the optimum ratio of propellant for best vehicle performance
- measure the distance traveled by using metric units
- explore mathematical problem solving
- explore mathematical models through graphing

## VOCABULARY

**chemical energy** – potential energy stored in chemical bonds that hold chemical compounds together

**chemical reaction** – a change in which one or more kinds of matter are transformed into a new kind of matter or several new kinds of matter

kinetic energy - energy that is in motion

**momentum** – a vector quantity that measures an object's motion; the product of an object's mass times its velocity

**newton** – the force that gives to a mass of 1 kilogram (kg) an acceleration of 1 meter per second squared (1m/s<sup>2</sup>); one newton is about the weight of 10 US quarters.

**potential energy** - the stored form of energy that can produce motion. Potential energy is stored in the forces between or within objects.

propulsion - the act of driving forward or away

**thermal energy** – a disordered form of energy contained in the kinetic and potential energies of the individual atoms and molecules that make up a substance; other names for thermal energy include internal energy and heat.

**thrust** – a force that can be produced by a rocket in reaction to a high–speed jet of exhausted air





## PREPARING FOR THE ACTIVITY

#### **Student Materials**

5-10 empty bottles (500 ml / 16.9 oz) cork/test tube stopper to fit bottle pushpin shoe box or other small box aluminum foil (enough to cover box) baking soda vinegar (4 liters or 1 gallon) 10 tissue paper squares (11 cm x 11 cm) measuring cup or 150-ml beaker funnel masking tape (to mark track) meter stick or measuring tape triple beam balance Distance Data Chart (p. 12) CR<sup>2</sup> Charts (p. 13) transparency marker safety goggles

#### **Teacher Materials/Notes**

- 1. For best results, presoak corks in water overnight.
- Suggest to students that it is advisable to wear clothes that won't be damaged by vinegar that might splash on them when bottles are launched. Students should also wear safety goggles to avoid vinegar entering the eyes.
- 3. Pre-select an outside launching area that is paved and flat and free of trash, such as the tennis court or bus parking area.
- 4. Copy blank chart on transparency so that results can be compared easily on the overhead projector.
- 5. If measuring of baking soda is done the day before testing, place labeled packages into a plastic bag to retain freshness.

#### Time

Discussion of the activity	10 minutes
Preparing for the activity	15 minutes
Conducting the activity	30 minutes

#### **Focus Questions**

- 1. What pushes a rocket forward?
- 2. What propels your vehicle forward?
- 3. What are the advantages of having a reusable vehicle rather than a single use vehicle?
- 4. Why find the optimum ratio for fuel consumption?

#### **Advanced Preparation**

- 1. Presoak the corks in water overnight for best fit into the bottles.
- 2. Rinse the bottles to be used so that nothing will interfere with the chemical reaction.
- 3. Cut the tissue paper squares and write the trial number on the tissue paper.
- 4. Place each tissue square onto the triple beam balance and carefully weigh the baking soda. Check Distance Data Chart (p. 12) for amounts.
- 5. Enclose the baking soda by bringing opposite sides of the tissue paper together. Fold over twice and twist the ends of the tissue paper so that the baking soda does not escape. See diagram 1.



- 6. Cover the shoe box or other small box with foil so that the escaping liquid does not soak the box as the rockets (bottles) are launched.
- 7. Measure 115 ml of vinegar and use a funnel to pour it into the bottles.
- 8. If groups have less than 10 bottles each, take a container of water to rinse used bottles before filling and reusing.
- 9. Proceed to the test area.



## THE ACTIVITY

### Step 1 Conducting the Activity

A. Have each group place 20-m of masking tape in a straight line and place a mark at 10-cm intervals.

mark

10-cm

intervals

- B. Place the shoe box at one end of the masking tape. The corked bottle will be placed against it each time. It may be necessary for one student in the group to place his or her foot inside the box to stabilize it. See diagram 1.
- C. Begin testing by using the pushpin to attach the 2-cm packet to the bottom of the cork. See diagram 2.



cork

**Diagram 3** 

baking soda

bottle

baking soda

20-m masking

tape

shoe box

your foot

Diagram 1

- D. Slide the packet/cork into the neck of the bottle firmly. See diagram 3.
- E. Shake the bottle quickly three times to start the chemical reaction.
- F. Quickly place the corked end of the bottle against the shoe box and move away. See diagram 4.



- G.Record the distance traveled on the Distance Data Chart (p. 12).
- H.Retrieve and rinse the bottle with water, then repeat the procedure or test the next prepared bottle with the next measured test packet.
- I. Repeat until all trials have been completed.
- J. Have each group plot the data onto the CR<sup>2</sup> Group Chart (p. 13).

### Step 2 Analysis

R

- A.Compare groups' data by overlaying transparency graphs.
- B. Have students average data of each gram weight for all groups and plot the results on the CR<sup>2</sup> Class Chart (p. 13).
- C. Discuss the shape of the graph(s) and determine the optimum ratio of baking soda to vinegar.

### Step 3 Discussion

- 1. Why do you think that 2 grams of baking soda is the smallest amount tested?
- 2. In comparing the data, at what point did the recorded distances stop increasing?
- 3. At what point did the recorded distances decrease?
- 4. What does this mean in terms of fuel consumption?
- 5. Why would it be important to find the optimum amount of fuel for any launch vehicle?

#### Extensions

1. Change the volume of vinegar or size of the bottle. Use a graphing calculator to collect, plot, and analyze the data.



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## Student Worksheets

Name : \_\_\_\_\_ Date: \_\_\_\_\_

Trial	Baking Soda Weight (g)	Distance (m)
1	2g	
2	3g	
3	4g	
4	4.5g	
5	5g	
6	5.5g	
7	6g	
8	7g	
9	8g	
10		



## Student Worksheets

Name : \_\_\_\_

Date: \_\_\_\_\_





CR<sup>2</sup> Chart Class





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Kathy Kynar	d, Engineer, NAS	A Marshall Space	e Flight Center	
What is a reusal launch vehicle o RLV?	ole or			
Why do spaced need to be lightweight?	raft			
How is the RLV protected duri reentry?	ng			
What is a computer simulation?				
How are compu- simulations use design spacecra	d to			
How are math and science use to plan for the Next Generatio	ed			



Cue Cards

# **Teacher Materials**









## **BOOKS, PAMPHLETS, AND PERIODICALS**

Banks, Michael: *Second Stage: Advanced Rocketry*. Kalmbach Publishers, 1998.

Freeman, Marsha: *How We Got to the Moon: The Story of the German Space Pioneers*. 21st Century Science, 1994.

Hutchings, Robert: Rockets. Dover Books, 2002

Nielson, Lee and Nielson, Lianna: *Blast Off: Rocketry for the Elementary and Middle School Student*. Teacher Ideas, 1997.

Richardson, Hazel: *How to Build a Rocket*. Franklin Watts, Inc., 2001.

Stine, G. Harry: *Handbook of Model Rocketry*. John Wiley & Sons, 1994.

#### Videos

3 – 2 – 1 Lift Off: Basic Model Rocketry

## WEB SITES

www.physics4kids.com/

http://www.nasaexplores.com/lessons/03-015/index.html

http://www.nasaexplorers.com/lessons/01-047/5-8\_index.html

http://kids.msfc.nasa.gov/Rockets/

#### **Figure This!**

Offers mathematics challenges that middle school students can do at home with their families to emphasize the importance of a high-quality mathematics education for all. http://www.figurethis.org

#### **Engineer Girl**

Part of the National Academy of Engineering's Celebration of Women in the Engineering project. The project brings national attention to the opportunity that engineering represents to people of all ages, but particularly to women and girls. http://www/engineergirl.org

National Council of Teachers of Mathematics (NCTM) http://www.nctm.org

NASA