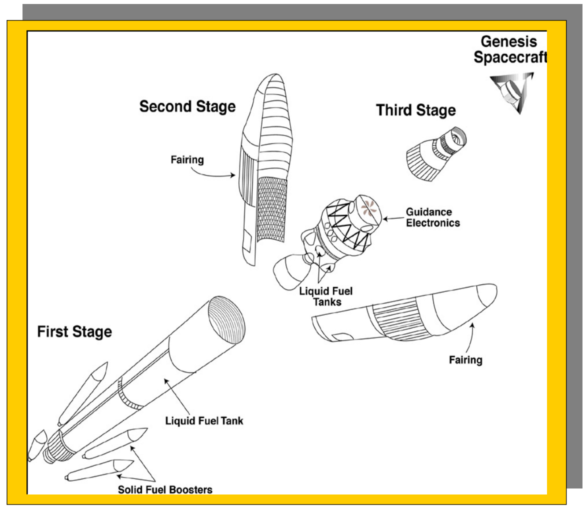
Dynamic Design: Launch and Propulsion

Launching Genesis

TEACHER GUIDE

BACKGROUND INFORMATION



In "Launching Genesis," students learn about the various facets of launching a spacecraft into space. In the first activity, "Choosing a Launch Vehicle," students look at the launch vehicle requirements for the Genesis spacecraft, then decide which rocket should be used from a list of several Delta rockets. The rocket chosen to launch the Genesis spacecraft was chosen to be the smallest possible launch vehicle that meets the volume and mass requirements of the spacecraft. The payload fairings protect the payloads during launch and ascent of flight. The fairing for the Genesis mission must be 9.5 feet (2.9 meters) in diameter in order to accommodate the spacecraft. The Genesis spacecraft requires mass capability of about 500 kilograms.

Sadly, the first Delta launch failed in 1960. However, since that time, the Delta series of rockets have been very successful launch vehicles. After reading about the history of the Delta rocket and the various early payloads that it lifted into orbit, students will determine the success rate of the Delta rocket using information taken from the text.

There are two types of propulsion involved in the Genesis launch and subsequent trip to L1. The first type of propulsion is the launch of the Genesis spacecraft aboard the Delta II rocket. This propulsion lifts the spacecraft beyond Earth's atmosphere. Once the spacecraft is launched, trajectory corrections must be completed to ensure that the spacecraft will reach L1. The propulsion subsystem is made up of eight 1 Newton thrusters and two 22 Newton thrusters that will be used for the corrections. In the first part of the propulsion activity, students model the Delta II rocket by using a balloon to launch a Ping-Pong ball to the ceiling of the classroom. In part two, students model the thrusters used for course corrections on the spacecraft, using a milk carton and water. In the third part of this activity, students investigate how the size of the exit nozzle affects the force of a thruster.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science As Inquiry
Abilities Necessary to do scientific inquiry

Physical Science
Motion and Forces

Science and Technology
Abilities of Technological Design
Understandings about science and technology

History and Nature of Science
History of science

Grades 9-12

Science As Inquiry
Abilities Necessary to do scientific inquiry

Physical Science

Motion and Forces

Science and Technology

Abilities of Technological Design

Understandings about science and technology

History and Nature of Science

Historical Perspectives

(View a full text of the National Science Education Standards.)

PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS ADDRESSED

Number and Operations Standard for Grades 6-8

Understand numbers, ways of representing numbers, relationships among numbers and number systems

Understand and use ratios and proportions to represent quantitative relationships

Compute fluently and make reasonable estimates

Select appropriate methods and tools for computing with fractions and decimals from among mental computations, estimation, calculators, or computers, and paper and pencil, depending on the situation, and apply the selected methods.

Measurement Standard for Grades 6-8

Understand measurable attributes of objects and the units, systems, and processes of measurement

Understand both metric and customary systems of measurement

Apply appropriate techniques, tools, and formulas to determine measurements

Select and apply techniques and tools to accurately find length to appropriate levels of precision

Problem Solving Standard for Grades 6-8

Solve problems that arise in mathematics and in other contexts

Number and Operation Standard for Grades 9-12

Compute fluently and make reasonable estimates

Develop fluency in operations with real numbers…using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.

Measurement Standard for Grades 9-12

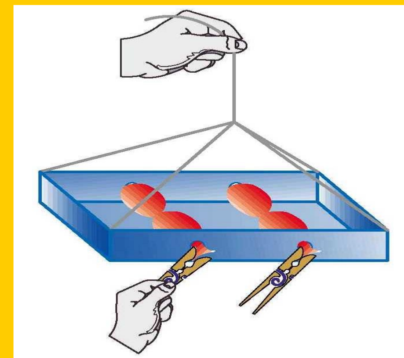
Understand measurable attributes of objects and the units, systems, and processes of measurement

Make decisions about units and scales that are appropriate for problem situations involving measurement

Problem Solving for Grades 9-12

Solve problems that arise in mathematics and in other contexts

(View a full text of the Principles and Standards for School Mathematics.)



MATERIALS

For each student:

Choosing a Launch Vehicle:
- Student Activity, "Launching Genesis: Choosing a Launch Vehicle"
- Student Text, "Genesis Launch Vehicle: The Delta Rocket"
- (Optional) *Newton In Space* Liftoff to Learning Video

How Do You Spell Success?
- Student Activity, "Launching Genesis: How Do You Spell Success?"
- Calculator (Optional)

Propulsion
- Student Activity, "Launching Genesis: Propulsion"
- Teacher Text, "Propulsion" (Optional)

For each group of students:

Part 1: Launch
- Long, thin balloon (see diagram on student sheet)
- Fishing line (3 meters)
- Paperclip
- Straw
- Small paper cup
- Ping-Pong ball
- Clothes pin

Part 2: Propulsion
- String (strong enough to support a full milk carton)
- Pint-sized milk carton
- Nail
- Tape
- Water

Demonstration (Optional)
- Balloons
- String
- Clothespins
- Lid from a copier paper box
- Scissors

Part 3: The Exit Nozzle
- Hair dryer (with a cool setting)
- Construction paper
- Cotton ball
- Meter stick
- Electrical tape

PROCEDURE

Choosing a Launch Vehicle

1. Distribute the Student Activity, "Launching Genesis: Choosing a Launch Vehicle." While working individually, instruct the students to look at the second page, which shows several Delta rockets. Ask your students to name some reasons why there are so

Alternate Strategy Tip
Propulsion Demonstration for Part 2

Materials:

Box lid (lid from copier paper box works well)
Roll of string
4 small balloons
4 clothespins
Scissors

- Obtain the lid from a box of copier paper and four small balloons. Using a pair of scissors, cut two holes on each long side of the lid, sizing each one the same, and locating them in the same place on each of the two sides. The size of the holes should be approximately ¼ inch. (Air must be able to exit through the balloon opening in the hole, but the hole cannot be so large as the entire balloon could escape.)
- After blowing up each balloon, thread the rolled balloon end (pinched with your finger to keep the air inside) through one of the four holes. The inflated part of the balloon will be inside of the lid, with the rolled end protruding outside of the lid. Attach a clothespin to the end of the balloon, securing it in place.
- After all four balloons are inflated and secure, attach a string to each corner of the lid. (Poke a hole in each corner, thread the string through, and knot it.) Tie the four ends of the string together, and ask a student volunteer to hold the lid by the string, extending it outward while another volunteer releases the clothespins one at a time. Ask a third volunteer to record the resulting movement on the chalkboard as each balloon (thruster) fires, using diagrams and arrows to show the movement of the lid.
- Once all thruster movements are recorded, repeat the experiment. This time fire two thrusters at the same time. Again, ask a volunteer to record the results using diagrams and arrows.
- Ask your students to conceptualize and write an experimental procedure for testing all of the various combinations of thrusters. After the procedure is recorded, ask the students to write a plan that could be used by someone who would navigate the spacecraft.

many different types of launch vehicles. (Students might suggest that larger payload requires larger rockets. If the students mention mass and volume, go to procedure 4.)

2. If your students do not mention mass as a constraint, tell them to look at the first stage (bottom) of these rockets, focusing specifically on the Delta II rockets. Ask them to identify differences among the Delta II rockets. (Students may mention that there are different numbers of boosters attached to various rockets.) Ask students, "Why are there different number of attached boosters to the first stage of the Delta II?" (Students might suggest that rockets that have a greater number of boosters can lift greater mass of payload [spacecraft]).

3. If your students do not mention volume as a constraint, tell them to study the fairings on the first page. Ask students, "What is the purpose of a fairing?" Allow reasonable responses. Explain that a fairing is a structure whose primary function is to produce a smooth outline and to reduce drag and to contain the payload. Ask them why there are different dimensions of fairings. (Students may state that spacecraft or payload takes up various amounts of space.)

4. Explain to students that they are going to look at the mass and volume requirements of the Genesis spacecraft and use that information to select the smallest rocket that can be used. Ask students why the mission planners would want the smallest spacecraft? (Students may suggest that the smaller the rocket, the less it would cost to launch).

Teaching Tip

If students need help converting from the English to metric system, you may direct them to this Web site that has a metric-to-English calculator.

http://www.psinvention.com/zoetic/convert.htm

5. After forming students into groups, ask them to compare choices and make adaptations. Circulate around the room providing feedback and answering questions as needed. Encourage students to write their reasons in complete sentences.

6. Student activity procedure 1 deals with the volume of the spacecraft. The Genesis spacecraft has a diameter of 2.9 meters and which would make fairing number 2 the smallest that it could fit into. Student activity procedure 2 deals with the mass. Since the mass of the Genesis spacecraft is 500 kilograms, it could be launched on Delta 7326, the smallest rocket shown.

7. In procedure 3 on the student activity, students are given the masses of the different Discovery mission spacecraft. Students are instructed to list the potential launch vehicle for each. Only Delta rockets are shown as possibilities. The following chart shows the possible answers and the actual launch vehicle used.

Discovery Mission	Spacecraft Mass	Potential Launch Vehicle (Based on GTO Destinations)	Actual Launch Vehicle
NEAR	805 kg	Delta 7326	Delta 7925
Mars Pathfinder	890 kg	Delta 7326	Delta 7925
Lunar Prospector	1,896 kg	Delta 7925	Athena II
Stardust	380 kg	Delta 7326	Delta 7425
Genesis	494 kg	Delta 7326	Delta 7326

8. Explain to students that rockets are chosen based on mass and the destination of the spacecraft. Therefore, there are two variables that would affect the results, and they would need to research the destinations of the other missions. Discovery mission Web sites are listed in the teacher resources on page 7 of this teacher guide.

9. For student activity procedure 4, provide graph paper for the students to graph the mass of each of the spacecraft. Explain to students that a bar graph would be the appropriate graph since the data is categorical. That is to say, the x-axis has categories (missions) not numbers.

10. Distribute the Student Text, "Genesis Launch Vehicle: The Delta Rocket," for the students to read as a homework assignment. Ask them to read up to and including Table 3 on page 4 before beginning the discussion session. This text presents information about the history of the Delta rocket.

How Do You Spell Success?

1. Begin this session by asking students critical questions about “The Delta Rocket” student text. Some questions are listed below.
   a. The second paragraph explains the code that is used by the Delta launch vehicles. Did you crack the code? What can you tell about the Delta launch vehicles used by these Discovery missions?
   Suggested answers:
      - All of the rockets are the latest version of the Delta.
      - Genesis has three solid boosters attached, Stardust had four, and NEAR and Mars Pathfinder had nine.
      - All of the rockets have the second version of the second stage.
      - All of the rockets had the same third stage except Genesis.

   b. Can you summarize some of the early payloads carried by the Delta that are mentioned in the text?
   Suggested answers:
      - Echo I satellite was launched on Delta 2 in 1960.
      - The Orbiting Solar Observatory was launched on Delta 8 in 1962.
      - Arial 1 international satellite that studied the ionosphere launched on Delta 9 in 1962.
      - Telstar I communications satellite was launched on Delta 11 in 1962.

   c. Why was the Delta rocket not used from 1984-1986? What caused it to be used again?
   Suggested answer:
      - The space shuttle had taken all of NASA’s medium-to-heavy satellites into orbit. Once the shuttle fleet was grounded after the *Challenger* explosion, the Delta was used to meet the need.

   d. Look at Table 2: Delta Rockets 1959-2002. Can you write a statement that indicates that the payload capacity has increased over time? Make sure the statement uses information from the table.
   Suggested answer:
      - Answers will vary. Students should write a statement that the payload capacity has increased over time. One way to incorporate information from the table would be to say that since 1959, the capacity of the Delta rocket to launch a payload into a low-Earth orbit has increased 508 times, from 45.36 kg in 1959 to 23,042 in 2002.

2. Distribute the Student Activity, "Launching Genesis: How Do You Spell Success?” Allow students to work in small groups to calculate the success rate of the Delta rocket for each decade since 1960, and then for the last forty years. If an entire group needs assistance in completing this assignment, explain the concept of a rate. A rate is a quantity, amount, or degree of something measured per unit of something else. Give an example of speed as the number of miles traveled in one hour. For this exercise, ask them how they might calculate the success rate of the Delta. You may want to use the first decade as an example. There were 69 successful launches during the sixties and 5 failures, for a total of 74 total launches. If students take 69 divided by 74 they will get a success rate of 0.9718 or about 97 percent. The table below provides the answers for your use.

Alternate Strategy Tip

Begin this activity by asking students to list some examples of success rates in everyday life. One example is that of a baseball hitter’s batting average. Batting average is calculated dividing the number of balls hit fair by the total number of at bats.

Year	Success	Failure	Success Rate	Question Answers
1960-1969	69	5	0.932 or about 93 percent	
1970-1979	70	5	0.933 or about 93 percent	Lowest success rate decade
1980-1989	38	1	0.974 or about 97 percent	Highest success rate decade
1990-1999	81	3	0.964 or about 96 percent	Most launches in a decade
2000-2001	9	0	1.000 or 100 percent	
Total	267	14	0.95 or 95 percent	

3. Discuss the difference between the terms "success rate" and "successful" with the class. Ask students why the eighties had the highest success rate and yet may not be considered the most successful decade. (Students may suggest that although the eighties had the highest success rate, it also had the fewest number of launches.) Explain to students that successful would need to be defined before being able to state which decade was the most successful for the Delta.

4. Bring this session to a close by asking students to finish reading the Student Text, "Genesis Launch Vehicle: The Delta Rocket" that details the launch of the Genesis spacecraft.

Propulsion

Part 1: Launch

1. Explain to students that this session involves three activities. The first is a challenge to launch a Ping-Pong ball so that it touches the ceiling using a balloon, fishing line, and a straw. In the second activity, students model the propulsion system of the Genesis spacecraft. In the third activity, students investigate various exit nozzles.

2. Distribute the Student Activity, "Launching Genesis: Propulsion" to each student. Explain that they are to work in their small groups to meet the challenge. Provide the materials (see page 3) and allow the students to begin. Encourage students to try different strategies and to use trial and error to launch the Ping-Pong ball so that it touches the ceiling. Clarify any procedures that are not clear to the students.

> **Safety Note**
> Safety goggles should be worn according to local regulations.

Part 2: Propulsion

3. (Optional) Once students have completed the activity, distribute the Teacher Text, "Propulsion," which highlights various methods of propulsion from the squid to future of interstellar propulsion.

4. For Part 2 of the "Propulsion" activity, have the students read the procedure. You may want to model the procedure and complete the first five steps of the procedure as a demonstration before asking the students to finish steps 6-11. As students work on steps 10 and 11, you may want to demonstrate the propulsion system as stated in the alternate strategy tip located on page 3 of this teacher guide. You may use either this propulsion demonstration, the milk carton activity, or both, to enhance your students' understanding of propulsion.

> **Teaching Tip**
>
> If it is a nice day, you may want to complete this activity outside. If you must do this inside, provide a large basin or sink for the students to work over so they do not make a mess.
>
> **Caution!** Students must be careful when using nails.

Part 3: The Exit Nozzle

5. For the Exit Nozzle activity, start by reviewing with students what was read in the "Propulsion" teacher text about the exit nozzle. Review the fact that high velocity flow exits the engine through the exit nozzle and generates thrust. The shape of the exit nozzle is designed so that the velocity of the exhaust gases continually increases as they exit the engine. Some fighter aircraft have the ability to adjust the shape of the exit nozzle in order to meet certain flight needs.

6. Instruct students to complete the first two steps for this investigation by observing the exit nozzles of the Genesis thrusters, and describing the shape and size of the two types of thrusters.

7. Explain to students that in this investigation, they will explore how the size of the exit nozzle affects thrust. They will begin by writing a research question that deals with the size of the exit nozzle. Encourage students to avoid writing questions that can be answered with a "yes" or "no" response. Also, students should include the variables that are to be tested. An example of a research question for this investigation is, "How does the size of the exit nozzle affect the amount of thrust produced?"

8. Once you have approved the research questions, provide the materials listed in the materials section on page 3 of this teacher guide to the small groups. Monitor students so that they are working safely with the materials. Offer any assistance that they might need to complete the procedure.

9. Provide the space for the student groups to test their exit nozzles. Instruct students to record their results in the data table. Once students have completed the testing, ask them to complete the questions 9-12. Emphasize that their conclusions should answer the research question and include data from the table.

10. Draw a chart on the board similar to the one provided here. Ask a representative from each group to come to the board and record their group's average distances.

Group	Average Long Nozzle Distance	Average Short Nozzle Distance
1		
2		
3		
4		
5		
6		
Average (mean)		

11. Once the chart on the board is complete, ask questions similar to the following:
    a. Why are the average distances different? (Each student group used different materials.)
    b. What would cause some of these differences? (Students should list variables that were not kept constant.)
    c. How do the averages compare with your group's distances? (Answers will vary.)

12. Challenge students to complete an investigation similar to this one, only this time, ask the students to change the shape of the exit nozzle. Students can complete an investigation similar to this, or design their own.

TEACHER RESOURCES

Publications

Ellis, Richard. (1999). *In Search of the Giant Squid.* Penguin Books. London, England.

Lee, Wayne. (1996). *To Rise from the Earth, An Easy-to-Understand Guide to Spaceflight*. Checkmark Books. New York, New York.

National Aeronautics and Space Administration. (1996). *Rockets: A Teacher's Guide with Activities in Science Mathematics, and Technology*. Office of Human Resources and Education. Washington, DC.

Taylor, L.B. (1968). *Liftoff! …The Story of Americas Spaceport.* E.P. Dutton & Co.,Inc. New York.

Winter, Frank H. (1990). *Rockets Into Space.* Harvard University Press. Cambridge, Massachusetts, and London England.

Web sites

http://discovery.jpl.nasa.gov/
NASA Web site of all the Discovery missions

http://nmp.jpl.nasa.gov/ds1/
NASA's Deep Space 1 (ion propulsion)

http://users.commkey.net/Braeunig/space/basics.htm
Basics of space flight

http://wings.avkids.com/Book/Propulsion/instructor/index.html
Propulsion background information

http://www.boeing.com/defense-space/space/delta/deltahome.htm
Boeing Web site with information about Delta rockets

http://www.finds-space.org/beamedpropulsion.html
Press release about beamed energy propulsion

http://www.hydrazine.com/hydrazine/home.asp
About hydrazine

http://www.ksc.nasa.gov/elv/launchcomplex17.htm
Launch complex 17

http://www.grc.nasa.gov/Other_Groups/K-12/TRC/TRCactivities.html
Glenn Learning Technologies Projects (Experiments and Lesson Plans)

http://www.nasm.edu/nasm/dsh/artifacts/SS-ariel1.htm
Ariel 1

http://www.nasm.edu/nasm/dsh/artifacts/SS-OSO1.htm
Orbiting Solar Observatory

http://www-spof.gsfc.nasa.gov/stargaze/Sintro.htm#q4
From Star Gazers to Star Ships (lessons and activities)

http://www.thetech.org/exhibits_events/traveling/robotzoo/guide/giant_squid_jets.html
Propulsion and the squid