Project X51—Water Rocket Construction

LESSON DESCRIPTION
Teams of students will form "rocket companies" and compete in a commercial endeavor to construct a rocket capable of lifting payloads into Earth orbit. Through a strong interdisciplinary approach, balancing science with technology, engineering, and mathematics, they will develop a budget, purchase construction materials, and track expenditures while designing the rocket.

OBJECTIVES
Students will
Apply rocketry principles and design, construct, test, and launch a water rocket using a real-world problem-solving simulation.

NASA SUMMER OF INNOVATION

UNIT
Engineering—Design process

GRADE LEVELS
7 – 9

CONNECTION TO CURRICULUM
Physical Science and Technology

TEACHER PREPARATION TIME
2 hours

LESSON TIME NEEDED
2 weeks *Complexity:* ***Moderate***

NATIONAL STANDARDS

National Science Content Standards (NSTA)
Science as Inquiry
• Skills necessary to become independent inquirers about the natural world
• Dispositions to use the skills, abilities, and attitudes associated with science
Physical Science
• Motions and forces
• Transfer of energy
Science and Technology
• Abilities of technological design
Science in Personal and Social Perspectives
• Risks and benefits
• Science and technology in society

Common Core State Standards for Mathematics (NCTM)
Expressions and Equations
• Solve real-life and mathematical problems using numerical and algebraic expression
Geometry
• Solve real-life and mathematical problems involving angle measure, area, surface area, and volume

ISTE NETS and Performance Indicators for Students
Creativity and Innovation
- Apply existing knowledge to generate new ideas, products, or processes
- Use models and simulations to explore complex systems and issues

Research and Information Fluency
- Plan strategies to guide inquiry
- Process data and report results

Critical Thinking, Problem Solving, and Decision Making
- Plan and manage activities to develop a solution or complete a project

MANAGEMENT

Prior to this project, students should have the opportunity to design, construct, and launch water rockets using different water volumes and pressures to see the effect these variables have on the altitude. Students should also become proficient in altitude tracking (see article on page 141). Doing so will prepare them to employ Newton's laws of motion to maximize the flight properties of their rockets.

Divide the students into teams of three. They will form competing rocket companies in a request for proposal, issued by the United Space Authority (USA). Their objective is to construct the best payload transporting rocket. The team will select roles for each member: Project Manager, Budget Director, and Design and Launch Director. One of the student pages included contains badges for each student. The reverse side of the badges explains the duties for each job. Take digital head shot pictures of each student and print them. Instruct the students to trim the pictures and paste them on to their badges prior to laminating them.

The project takes approximately 2 weeks to complete and includes a daily schedule of tasks. Students may need additional time to complete daily tasks to keep on schedule. Collect all building materials and copy all reproducible items before beginning the activity. Make several copies of the order forms and blank checks for each group. Allow enough time on the first day for students to read and discuss all sheets and determine how the sheets apply to the project schedule. Focus on the student score sheet to ensure the students understand the criteria used to assess their performance.

MATERIALS
All supplies need to be available for each group.

- 2-liter soft drink bottle
- 1-liter water bottle
- One 1-inch-long by ¾-inch-diameter PVC segment
- Aluminum soft drink can
- Scrap cardboard, poster board, and tag board
- Large cardboard panels (about 3 by 1 foot) for silhouettes
- Duct tape
- Masking tape
- Glue stick
- Low-temperature glue gun
- Modeling clay
- Plastic grocery bag or garbage bag
- String
- Art supplies

The following are needed for launch day:

- Water rocket launcher (see page 109)
- Safety goggles
- Altitude tracker (see page 80)
- Tape measure

CONTENT RESEARCH

From the beginning of the space program, rockets, spacecraft, spacesuits, launch platforms, and much more have been built by contractors. The responsibility of NASA has been to manage the exploration of the atmosphere and space. When a particular space mission is decided upon, requests for proposals are issued to American industry to build the hardware. Corporate teams propose designs for rockets, space capsules, or whatever else NASA needs for its mission. After a competitive process, the winning corporation is chosen and money is awarded to begin construction. Often, when very large contracts are awarded, the winning companies will select other companies as subcontractors to build component systems. This contracting strategy has worked successfully for NASA for more than 50 years. It has enabled American astronauts to go to the Moon, conduct extensive scientific research in space, and construct the International Space Station.

NASA continues to use this very effective process for its U.S. Space Exploration Policy that will establish a permanent presence on the Moon and future human expeditions. Background content needed for teachers to understand the lesson is included with each activity. This content will be reviewed and discussed with students to ensure understanding that will allow students to explore the data results to explain their answers and outcomes.

Key Concepts:

Aeronautics: The science of flight: the science, art, theory, and practice of designing, building, and operating aircraft.
Atmosphere: The air surrounding the Earth, described as a series of shells or layers of different characteristics. The atmosphere composed mainly of nitrogen and oxygen with traces of carbon dioxide, water vapor, and other gases, acts as a buffer between the Earth and Sun. The layers, troposphere, stratosphere, mesosphere, thermosphere, and the exosphere, vary around the globe and in response to seasonal changes.
Contractor: Responsible for the day-to-day oversight of the construction site, and management of vendors and trades. In addition, they keep communication between the general contractor and the involved parties open and clear throughout the course of project. Sometimes they are called the project manager.
Engineers: Use math and science to design new tools and devices to solve practical problems.
Launch Platform: Mobile Launcher Platform or MLP is one of three two-story structures used by NASA to support the Space Shuttle during its transportation from the Vehicle Assembly Building (VAB) to Launch Pad 39-A at the Kennedy Space Center as well as serve as the vehicle's launch platform. NASA's three MLPs were originally constructed for the Apollo Program to launch the Saturn V rockets in the 1960s and 1970s, and have remained in service to this day, with substantial alterations.
Proposal: Suggested idea or plan; especially one put forward on paper or presented officially.
Prototype: Original or model on which something is based.
Rockets: Space vehicles designed for space travel, propelled by rocket engines.
Subcontractor: Individual or a business that signs a contract to perform part or all of the obligations of another's contract and hired by the general contractor to perform a specific task due to an expertise.

LESSON ACTIVITIES

http://www.nasa.gov/pdf/153416main_Rockets_Project_X51.pdf

1. Write a Request for Proposal. Form a rocket company. Pick company officers. Brainstorm ideas for design and budget. Sketch a preliminary rocket.
2. Using graph paper, draw side, top, and bottom views of your rocket to scale (1 square = 2 cm), based on the measurements recorded above. Attach your drawings to this paper. If you make changes during construction, your scale drawing and measurement sheet should reflect them.
3. Develop a budget for the project and stay within the allotted funds.
4. Build a test rocket using the budget and plans developed by your team. List rocket specifications and evaluate your rocket's stability by determining its center of mass and center of pressure and by conducting a string test.
5. Successfully test launch your rocket with a 250-gram payload of simulated fuel.
6. Develop a cost analysis for your vehicle and demonstrate the most economically efficient launch.

ADDITIONAL RESOURCES

Rockets Educator Guide: http://www.nasa.gov/pdf/280754main_Rockets.Guide.pdf
All about water rockets: http://exploration.grc.nasa.gov/education/rocket/BottleRocket/about.htm
Beginners guide to rockets: http://exploration.grc.nasa.gov/education/rocket/bgmr.html
NASA's Water rocket construction:
http://www.nasa.gov/pdf/153406main_Rockets_Water_Rocket_Construction.pdf
Preparing to Launch Ares 1 NASA eClips Video:
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=Rockets&category=0100&disp=grid

DISCUSSION QUESTIONS

What did you learn about running a company? *Answers will vary.*
How might you have done things differently? *Answers will vary.*
What was the most difficult part of the 2 weeks? What do you understand now that you were not sure or aware of before? *Answers will vary.*
What is the process NASA uses to complete a mission? *The Design Process used in this activity. Brainstorm, write proposal, design, build, test, redesign, test, and share.*

ASSESSMENT ACTIVITIES

Base the assessment of team performance on their documentation: Project journal, silhouette, and launch results. Refer to the Project X–51 Score Sheet for details

ENRICHMENT

Large space missions often require a wide range of subcontractors across the United States to provide the expertise needed to build the launch and vehicle systems. Learn about the contributions contractors in your state make towards the exploration of outer space. A good place to start is with the Space Grant Consortium for your state. Consortium members (colleges and universities) promote space research and educational activities in their home states and work with local space industries. The following Web site contains a listing of Space Grant colleges by state:
http://www.nasa.gov/audience/foreducators/postsecondary/grants/Space_Grant.html.