Prelaunch

Readiness Review

	Test Launch	Final Launch
Total Mass	__________ oz (mL)	__________ oz (mL)
Total Length	__________ in (cm)	__________ in (cm)
Width (at widest part)	__________ in (cm)	__________ in (cm)
Number of Fins	__________	__________
Length of Nose Cone	__________ in (cm)	__________ in (cm)
Volume of Water (fuel)	__________ oz (mL)	__________ oz (mL)
Center of Mass (from Nose Cone)	__________ in (cm)	__________ in (cm)
Center of Pressure	__________ in (cm)	__________ in (cm)
Does rocket pass swing test?	_____Yes_____No	_____Yes _____No

Flight Log

Company Name: ____

Safety Officer: ____

Loading Officer: ____

Principal Investigator/Launch Officer: ____

Downrange Officer: ____

Teacher: ____

Launch Conditions:

Test Launch **Final Launch**

Launch Location: ______________________________

Time: ______________________________

Temperature: ______________________________

Wind Conditions: ______________________________

Launch Direction: ______________________________

Maximum Altitude: ______________________________

Notes from Day of Launch:

Recommendations for Future Launches:

After Test Launch

After Final Launch

Teacher Guide

You Get What You Pay For

Background Information

This optional activity incorporates an economic component into the module and can be conducted prior to the other activities in the Interaction/Synthesis sections or with the assessment section of this module. Students will be given a budget of $150,000 and an approved subcontractor list that has a listing of the materials and costs for construction. Teachers completing this aspect of the module should decide on either using "play" money, checks, or giving the student groups a spreadsheet that they can organize to keep track of their expenditures. Students are cautioned to spend their money wisely and thus save the teacher real money on materials used in this unit. Students are also warned that in order to participate in the final launch they must pay $20,000, plus money for fuel. Students will not receive salary or benefits during this activity. Insurance will not be included either.

National Science Standards Addressed

Grades 5–8

Science and Technology

Understandings about science and technology.

Grades 9–12

Science and Technology

Understandings about science and technology.

Economic Standards Addressed

Grades 6–8

Understands that scarcity of productive resources requires choices that generate opportunity costs.

Knows that all decisions involve opportunity costs and that effective economic decision-making involves weighing the costs and benefits associated with alternative choices.

Understands that the evaluation of choices and opportunity costs is subjective and differs across individuals and societies.

Materials

- Spreadsheet or balance sheet.
- Calculator.
- Student activity, "You Get What You Pay For," page 105.

Procedure

1. Distribute the student activity "You Get What You Pay For." Have the students read over the directions at the top of the page. Instruct them to respond in writing to the group discussion question about their money-managing experiences. Then, ask them to share their answers with the rest of their group. Once students have had a chance to share within their groups, ask one or more students in each group to share with the class.
2. Prior to the group activities, have students complete the budgets for their expert group work, and the competition on their student activity sheet. They will need to build a preliminary budget for the activities. Since this is the first time to "spend money," and they have little experience in building a water rocket, encourage students to keep their costs down. Students may use this time to consider the materials they would like to use for the expert group work.
3. If this activity is being done with the Interaction/Synthesis section, tell students that they will be working in groups to test various aspects of the rocket. Different groups will experiment with nose cone design, propulsion, and fin design. Since each person will be representing a different "competing team," each person should be given a certain amount of "money" to contribute to the expert group to cover the costs of the materials used in testing. Students should then complete the expert group activities outlined in the Teacher Guide.
4. Make it clear to the students that each design group has the same budget. Though not realistic, it will give each group the same resources. Explain to the students that each person is expected to contribute funds to support the work done in the expert groups.
5. Finally, explain that the bulk of their budget should be geared for the launch of the water rocket. Make it clear that $20,000 needs to be budgeted for the two launches (trial and official launches), and they need to have budgeted projected fuel costs.
6. Distribute expert group sheets to the groups. The groups can use these sheets to help them estimate their group budget.
7. Allow time for students to create their budgets. Circulate around the room assisting where necessary.
8. Encourage students to keep good records of their expenditures during the activities. At the completion of the activity, students should take the time to re-evaluate their actual payments versus their budgeted amounts. They should record whether they are over or under budget during each part and then reallocate funds appropriately.
9. You may want to assign the primary budget responsibilities to the Principal Investigators, as they will be responsible for acquiring materials throughout the module. You may also want to check the design groups' budgets periodically to see how each group is handling their funds.
10. At the end of the activity, you may want to recognize the groups with a certificate for being fiscally responsible.

Student Activity

You Get What You Pay For

Background Information

In this activity, you will plan a budget for the construction and launch of your water rocket. Each group will be given a budget of $150,000 and an approved subcontractor list that identifies materials and their costs for your consideration. Use your funds wisely and keep accurate records of all you spend. To pay for the use of the launcher, your group must have a minimum of $20,000 for the last two launches (the test and final launches). Your group must also have money budgeted for fuel costs. (Fuel will cost $30 per milliliter.) If your group has less than $20,000 at the time of launch, your group will not be permitted to launch and will be disqualified. Complete the following activity in your group to create a budget that helps you to manage your funds.

Group Discussion

Think about any experiences you have had in managing money. Describe your successes and failures in the space below and then share with your group.

Part 1: Final Launch Budget

Below is the list of required materials needed for the final launch. Using a spreadsheet or balance sheet, plan the funds you would like to allocate for the first launch. You may use materials found on the Approved Subcontractor List in addition to the materials listed below. Create a budget for the final launch and testing. The budget for test and final launches should total at least $20,000.

- One or more two-liter plastic soft drink bottles.
- Water for fuel.
- Safety goggles.
- Glue or tape.
- Cardboard or thick paper.
- Modeling clay.
- Scissors.
- Pens and decorating supplies.
- Materials for protecting the payload.
- Use of launcher.

Part 2: Expert Group Budget

Each person in your group should be allotted a certain budget that they can spend on materials, construction, and launching their rockets. The payload and propulsion groups should be given at least $5,000 to purchase a bottle (with the labels removed) for their tests. Launch pad fees will not be assessed during the expert phase. Create a budget for each expert team. The expert groups will use funds for testing different aspects of the rocket. Since it is unknown at this time exactly what costs are, you will need to estimate. Use the expert group sheets to help estimate your group's costs.

Budget	
Propulsion	
Nose cone	
Fin shape/size	
Fin number/placement	
Total	

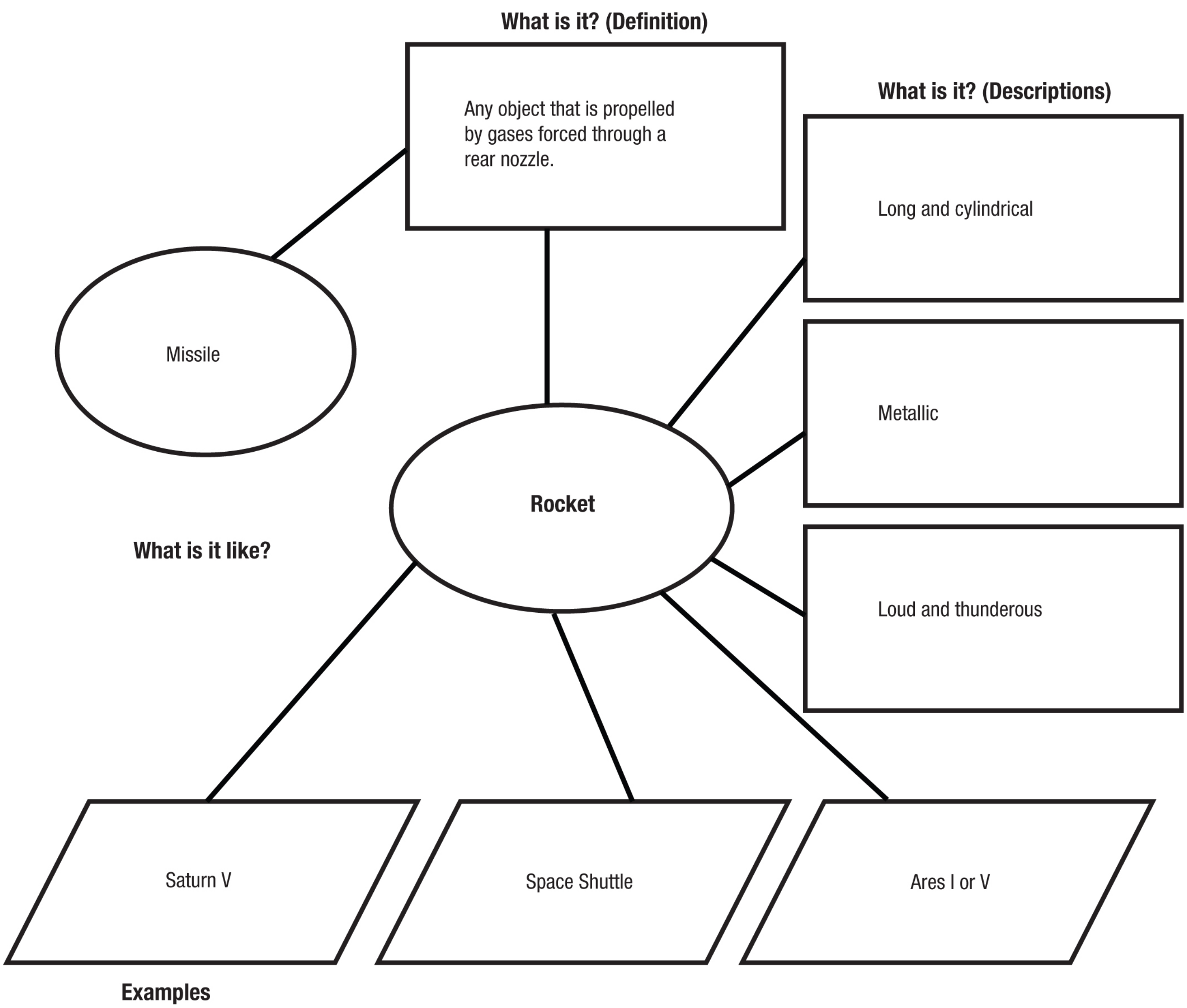
Approved Subcontractor List

Subcontractor	Materials	Price Per Unit
Bottle Neck Engine Corporation	Two-liter Bottle	$20,000 per bottle
Ares Launch Center	Use of Launcher & Pump	$10,000 per launch
H2O Unlimited	Fuel	$30 per milliliter
Stick To It Tape and Glue	Duct Tape	$5,000 per 2 inches (5 cm)
	Strapping Tape	$5,000 per 2 inches (5 cm)
	Masking Tape	$2,500 per 2 inches (5 cm)
	Cellophane Tape	$1,000 per 2 inches (5 cm)
	Dental Floss	$500 per 2 inches (5 cm)
	Glue Stick	$2,000 per container
	Hot Glue Stick	$5,000 per stick
	Low-temp. Glue Gun	$1,000 per rental
Totally Tubular	Toilet Paper Tubes	$50 per tube
	Wrapping Paper Tubes	$100 per tube
	Paper Towel Tubes	$150 per tube
Write-On Paper	Cardboard	$2,500 per sheet
	Construction Paper	$1,500 per sheet
	Egg Containers	$1,000 per 6 count
	Popsicle Sticks	$50 per stick
	Poster Board	$10,000 per sheet
	Sand Paper	$5,000 per sheet
	Typing Paper	$1,000 per sheet
	Tag Board	$3,000 per sheet
Put it Together Construction Materials Limited	Clay	$500 per 100 grams
	Cotton Balls	$50 per ball
	Graduated Cylinders	$10 per cylinder
	Hole Punch	$10 per punch rental
	Yard Sticks	$10 per stick
	Ruler	$5 per ruler
	Safety Goggles	Complimentary
	Scissors	$5 per pair
	Small Washers	$5 per washer
	Spring Scale	$10 per scale
	Tape Measure	$50 per tape rental
	Tennis Ball	$100 per ball
	Long Stick	$10 per stick
Color My World Paints	Decorative Decals	$50 per decal
	Felt-Tipped Pens	$50 per pack
	Magic Markers	$10 per marker
	Paints	$50 per color

Appendix A

Example of a Completed Concept Definition Map

(Adapted from Schwartz, 1988)



Appendix B

Optional Activity: Investigating the History of Rocketry with *October Sky*

1. Play the opening segment (Chapter 1 on the DVD, "The Age of Sputnik") to *October Sky*. This movie is about a boy who lives in a coal-mining town in West Virginia in 1957. Based on the book, *Rocket Boys*, by Homer Hickam, this true story details Homer's struggles as he dreamt of sending rockets to outer space. The first scene shows people listening to the news on the radio that the Union of Soviet Socialist Republic (USSR) had launched the first human-made satellite (Sputnik). Provide additional background information about the Cold War context and the events that took place in 1957 when the Soviet Union became the first country to launch a satellite into orbit. Ask students questions similar to the following:
   - How do you think Americans must have felt after hearing the news that a Cold War foe had just launched a satellite into space for the first time? (This symbolized to them that the Soviets were more advanced than the U.S. Many felt that Americans were falling behind technologically. Sputnik may have caused fear in the minds of some people.)
   - Why might this cause fear? (People thought that if the Soviets could launch a satellite into space, they could also launch a missile at the United States.)
   - According to the radio newscast, what was the response made by Dr. Wernher von Braun? (First, he said that there was no confirmed sighting of the satellite. Second, he said the United States was working on launching a satellite of their own.)
   - What was the long-term response from the United States? (The United States started emphasizing the subjects of mathematics and science in the nation's schools.)
2. Let your students listen to the sound of the beeping radio signal that Sputnik made. An audio clip is available at: http://www.hq.nasa.gov/office/pao/History/sputnik/
3. Sputnik inspired Homer Hickam to experiment with model rockets. His first experiment resulted in him blowing up his mother's fence. Show the segment where Homer and his friends experiment with launching rockets. Start the video at the 34-minute mark of the film where the worker says, "SAE 1020 bar stock…" (Chapter 6 on the DVD, "Rocket Roulette"). Show the next two minutes, and then ask the question below. (You may want to show this segment again after the question.)
   - As Homer Hickam and his friends experimented with model rockets, many of their first attempts failed. This happens with rocket scientists of all ages. They learn from their experiences. What two factors were they going to change during this segment? (Reduce the mass and increase the length.)
4. Show a short segment (one minute) starting at the 46-minute mark of the film (Chapter 9 on the DVD, "Up in Smoke"). Ask questions similar to the following:
   - Describe the launch of the rocket this time. (It was a successful launch.)
   - What did they measure once it was launched? (The time of descent.)
5. Homer and his friends were accused of starting a forest fire with their rocket. Show a one-minute segment starting at 75:30 (partway through Chapter 13, "Search for Auk 13," on the DVD). Homer uses mathematics to demonstrate that his rocket did not cause the fire.
   - What measurement did he use that helped to determine that the rocket was not the cause? (The time it took the rocket to fall.)

Appendix C

Possible Options for the Ground Challenge

Choose the most efficient method of transporting personnel and equipment to the construction site so that the complex will be completed as scheduled. The maximum number of trips you can make is four. Efficiency is defined as hauling as much as possible during each trip with the smallest vehicles possible. For each trip, determine two possible options to complete the stage. At each trip, four people arrive at the construction site and must leave at the end of the stage. Choose the best option and provide a rationale.

Note to Teachers: Payload masses and estimated masses of supplies and equipment are given in both metric and traditional U.S. units. When making the conversions, masses were rounded to the nearest fives and tens to make calculations easier for students.

The following tables represent two possible options for completing each stage of the construction. Student transportation choices may vary, but should be similar due to the limitations of the transportation vehicles.

Option 1	
Stage/Trip	**Transportation Choices**
Trip 1 Option 1	To the site: • Tractor flat-bed trailer to haul all equipment = 30,925 lb (14,027 kg) with two people. • Full-size pickup for food, water, personal belongings, and two people. Return home: • Leave the trailer; two people bring back the tractor, and two people bring back the pickup.
Trip 2 Option 1	To the site: • SUV or club cab to transport four people and food, water, and personal belongings. Return home: • SUV or club cab to transport four people and personal belongings.
Trip 3 Option 1	To the site: • SUV or club cab to transport four people and food, water, and personal belongings. Return home: • SUV or club cab to transport four people and personal belongings.
Trip 4 Option 1	To the site: • Two people bring the tractor back to the site. Two people bring the pickup with food, water, and personal belongings. Return home: • Tractor flat-bed trailer is brought back with two people. • Pickup with two people.
Rationale for Option 1	Everything is now on site with one trip in order to build the base.

Option 2	
Stage/Trip	**Transportation Choices**
Trip 1 Option 2	To the site: • One club-cab trailer with 6,000 lb (2,722 kg) building panels and two people. • One pickup trailer with foundation materials and flooring sections (3,000 lb) 1,361 kg with two people. • The remaining 1,850 lb (839 kg) can go in either bed along with the food, water, and personal belongings. Returning home: • Two people drive back each vehicle.
Trip 2 Option 2	To the site: • One club cab with 6,000 lb (2,722 kg) trailer for the total materials and four people with food, water, and personal belongings. Returning home: • Four people drive back club cab.
Trip 3 Option 2	To the site: • One club cab with 3,000 lb (1,361 kg) trailer for hauling solar-powered car, food, and supplies for six months. Returning home: • Four people drive club cab back.
Trip 4 Option 2	To the site: TBD by student:
Rationale for Option 2	It is more efficient not to use an under-utilized tractor-trailer and leave it behind after the first trip.

Appendix D

Label Templates for Available Vehicles

Pickup Truck – three-person cab
Maximum Payload Capacity: 1,750 pounds (794 kilograms)
Towing Capacity: 5,000 pounds (2,268 kilograms)
Size of Cargo Bed: 4 feet (1.2 meters) by 8 feet (2.4 meters)

Club Cab Pickup Truck – four-person cab
Maximum Payload Capacity: 2,000 pounds (907 kilograms)
Towing Capacity: 6,000 pounds (2,722 kg)
Size of Cargo Bed: 4 feet (1.2 meters) by 6.5 feet (2 meters)

Trailer
Maximum Payload Capacity: 6,000 pounds (2,722 kilograms)
Size: 8 feet (2.4 m) wide by 12 feet (3.7 meters) long

Trailer
Maximum Payload Capacity: 3,000 pounds (1,361 kilograms)
Size: 8 feet (2.4 meters) wide by 12 feet (3.7 meters) long

SUV
Capacity: Seven Passengers,
Luggage/food/water Supply for a Seven-day Stay
or
Four Passengers (and luggage) and
750 pounds (340 kilograms) of Construction Equipment or Tools

Tractor-flat-bed-trailer Rig
Maximum Payload: 40,000 pounds (18,144 kilograms)
Flat-bed Trailer Size:
48 feet (14.6 meters) long by 8.5 feet (2.6 meters) wide

Appendix E

Templates for Representing Equipment and Supplies

Trip 1

Building Materials: 6,000 pounds (2,722 kilograms)
Panels: 16 feet (5 meters) long by
4 feet (1.2 meters) wide

Trip 1

Insulation:
200 pounds (91 kilograms)
Rolls: 4 feet (1.2 meters) in diameter

Trip 1

Flooring Sections:
1,000 pounds (454 kilograms)
8 feet (2.4 meters) long by 2 feet
(0.6 meters) wide

Trip 1

Foundation Materials:
2,000 pounds (907 kg)
Concrete/steel Sections:
4 feet (1.2 meters) long
by 4 feet (1.2 meters) wide

Trip 1

Interior Wall Finish:
500 pounds (227 kg)
4 feet (1.2 meters) by 8 feet
(2.4 meters) panels

Trip 1

Food/Water for One Week:
250 pounds (113 kilograms)

Trip 1

Construction Equipment:
500 pounds (227 kilograms)

Trip 1

Lumber: 400 pounds (181 kilograms)
Includes 12 foot (3.7 meter) lengths

Trip 2

Cabinetry Materials:
1,000 pounds (454 kilograms)

Trip 2

Plumbing Supplies (include water supply):
1,750 pounds (794 kilograms)

Trip 2

Tools and Construction Equipment:
500 pounds (227 kilograms)

Trip 2

Electrical Supplies
(include air-conditioning):
1,000 pounds (454 kilograms)

Trip 2

Power Supply:
1,000 pounds (454 kilograms)

Trip 2

Food/water for One Week:
250 pounds (113 kilograms)

Trip 3

Solar-powered Vehicle:
2,000 pounds (907 kilograms)
6 feet (1.8 meters) by 15 feet (4.6 meters)

Trip 3

Food Supply/Staples for Six Months:
5,000 pounds (2,268 kilograms)

Trip 4

Experimental Equipment:
7,500 pounds (3,402 kilograms)

Appendix F

Building A Bottle Rocket

1. Wrap and glue or tape a tube of poster board around the bottle.

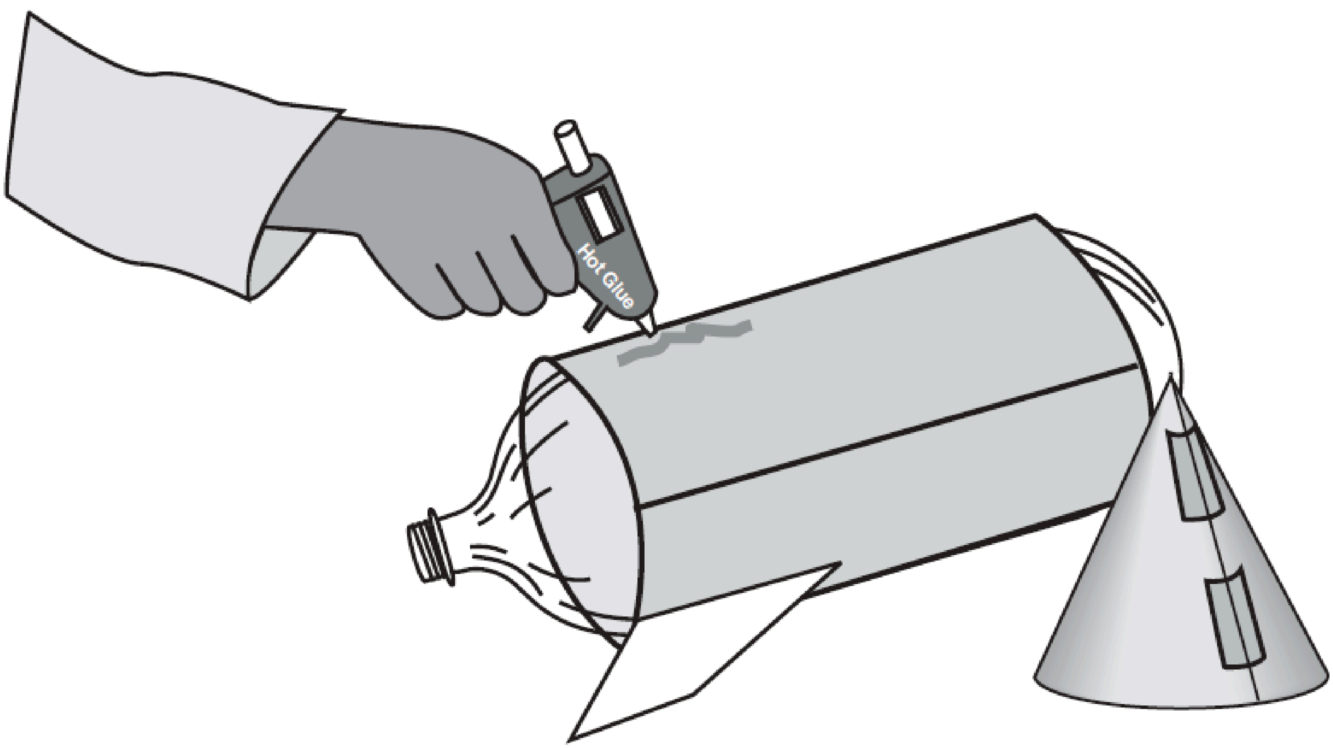
2. Cut out several fins of any shape and glue them to the tube.

3. Form a nose cone and hold it together with tape or glue.

4. Press a ball or modeling clay into the top of the nose cone.

5. Glue or tape nose cone to upper end of bottle.

6. Decorate your rocket.



Appendix G

Water Bottle Rocket Launcher

Management

Consult the materials and tools list to determine what you will need to construct a single bottle rocket launcher. The launcher is simple and inexpensive to construct. Air pressure is provided by means of a hand-operated bicycle pump. The pump should have a pressure gauge for accurate comparisons between launches.

Most needed parts are available from hardware stores. In addition, you will need a tire valve from an auto parts store and a rubber bottle stopper from a school science experiment. The most difficult task is to drill a 0.375 inch hole in the mending plate called for in the materials list. An electric drill is a common household tool. If you do not have access to one, or do not wish to drill the holes in the metal mending plate, find someone who can do the job for you. Ask a teacher or student in your school's industrial arts shop, a fellow teacher or the parent of one of your students to help.

If you have each student construct a bottle rocket, having more than one launcher may be advisable. Because the rockets are projectiles, safely using more than one launcher will require careful planning and possibly additional supervision. Please refer to the launch safety instructions.

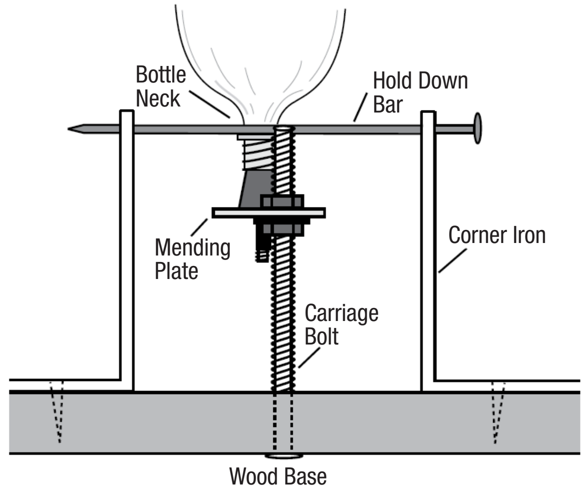
Materials and Tools

- Four 5 inch corner irons with 12.75 inch wood screws to fit.
- One 5 inch mounting plate.
- Two 6 inch spikes.
- Two 10 inch spikes or metal tent stakes.
- Two 5 inch by 0.25 inch carriage bolts with six 0.25 inch nuts.
- One 3 inch eyebolt with two nuts and washers.
- 0.75 inch diameter washers to fit bolts.
- One number 3 rubber stopper with a single hole.
- One Snap-in Tubeless Tire Valve (small 0.453 inch hole, 2 inches long).
- Wood board 12 by 18 by 0.75 inch (30.5 by 45.7 by 1.9 centimeter).
- One two-liter plastic bottle.
- Electric drill and bits including a 0.375 inch bit.
- Screwdriver.
- Pliers or open-end wrench to fit nuts.
- Vice.
- 12 feet (3.66 meters) of 0.25 inch cord.
- Bicycle pump with pressure gauge.

Background Information

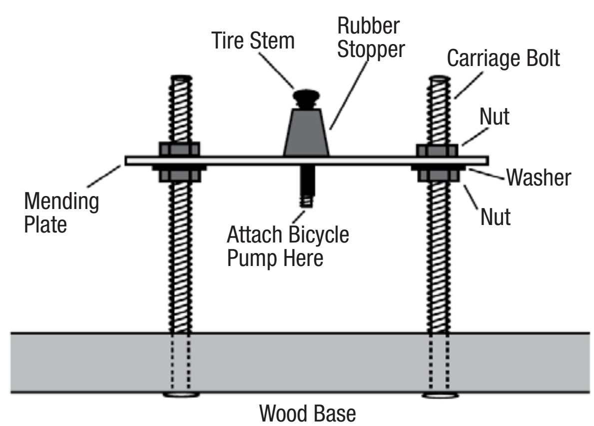
Like a balloon, air pressurizes the bottle rocket. When released from the launch platform, air escapes the bottle, providing an action force accompanied by an equal and opposite reaction force (Newton's Third Law of Motion). Increasing the pressure inside the bottle rocket produces greater thrust since a large quantity of air inside the bottle escapes with a higher acceleration (Newton's Second Law of Motion). Adding a small amount of water to the bottle increases the action force. The water expels from the bottle before the air does, turning the bottle rocket into a bigger version of a water rocket toy available in toy stores.

Construction Instructions



Positioning Corner Irons

1. Prepare the rubber stopper by enlarging the hole with a drill. Grip the stopper lightly with a vice and gently enlarge the hole with a 0.375 inch bit and electric drill. The rubber will stretch during cutting, making the finished hole somewhat less than 0.375 inch.
2. Remove the stopper from the vice and push the needle valve end of the tire stem through the stopper from the narrow end to the wide end.
3. Prepare the mounting plate by drilling a 0.375 inch hole through the center of the plate. Hold the plate with a vice during drilling and put on eye protection. Enlarge the holes at the opposite ends of the plates, using a drill bit slightly larger than the holes to do this. The holes must be large enough to pass the carriage bolts through them.
4. Lay the mending plate in the center of the wood base and mark the centers of the two outside holes that you enlarged. Drill holes through the wood big enough to pass the carriage bolts through.
5. Push and twist the tire stem into the hole you drilled in the center of the mounting plate. The fat end of the stopper should rest on the plate.
6. Insert the carriage bolts through the wood base from the bottom up. Place a hex nut over each bolt and tighten the nut so that the bolt head pulls into the wood.
7. Screw a second nut over each bolt and spin it about half way down the bolt. Place a washer over each nut, and then slip the mounting plate over the two bolts.
8. Press the neck of a two-liter plastic bottle over the stopper. You will be using the bottle's wide neck lip for measuring in the next step.
9. Set up two corner irons so they look like book ends. Insert a spike through the top hole of each iron. Slide the irons near the bottle's neck so that the spike rests immediately above the wide neck lip. The spike will hold the bottle in place while you pump up the rocket. If the bottle is too low, adjust the nuts beneath the mounting plate on both sides to raise it.
10. Set up the other two corner irons as you did in the previous step. Place them on the opposite side of the bottle. When you have the irons aligned so that the spikes rest above and hold the bottle lip, mark the centers of the holes on the wood base. For more precise screwing, drill small pilot holes for each screw, and then screw the corner irons tightly to the base.
11. Install an eyebolt to the edge of the opposite holes for the hold down spikes. Drill a hole, and hold the bolt in place with washers and nuts on top and bottom.
12. Attach the launch pull cord to the head end of each spike. Run the cord through the eyebolt.
13. Make final adjustments to the launcher by attaching the pump to the tire stem and pumping up the bottle. Refer to the launching instructions for safety notes. If the air seeps out around the stopper, the stopper is too loose. Use a pair of pliers or a wrench to raise each side of the mounting plate in turn to press the stopper with slightly more force to the bottle's neck. When satisfied with the position, thread the remaining hex nuts over the mounting plate and tighten them to hold the plate in position.

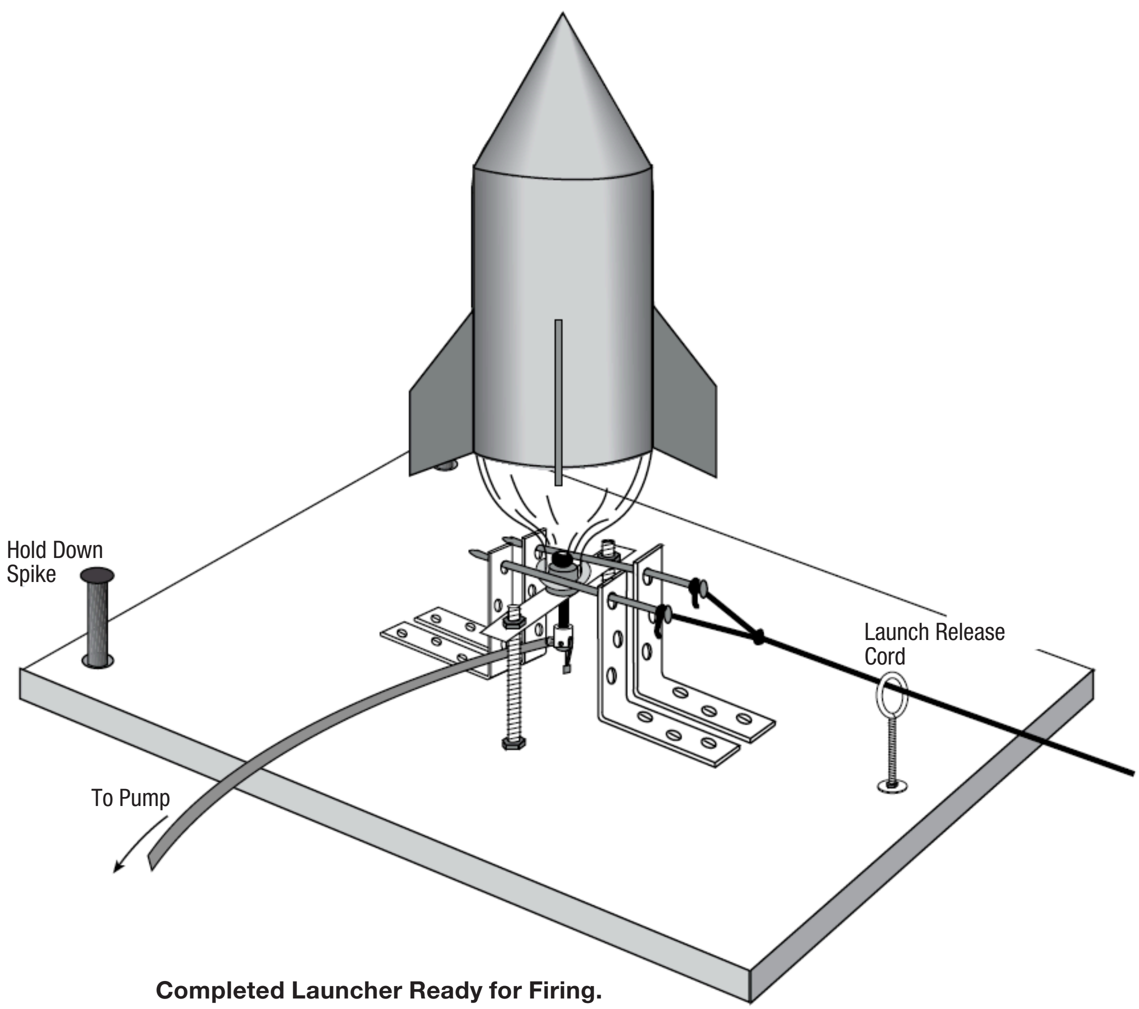


Attachment of Mending Plate and Stopper

14. Drill two holes through the wood base along one side. The holes should be large enough to pass large spikes or metal tent stakes. When the launch pad is set up on a grassy field, the stakes will hold the launcher in place when you yank the pull cord. The launcher is now complete.

Launch Instructions

1. Select a grassy field that measures approximately 100 feet (30.48 meters) across. Place the launcher in the center of the field, and anchor it in place with the spikes or tent stakes. Note: If it is a windy day, place the launcher closer to the side of the field from which the wind is coming so that the rocket will drift onto the field as it comes down.
2. Have each student or student group set up their rocket on the launch pad. Other students should stand back several feet (meters). It will be easier to keep observers away by roping off the launch site.
3. After the rocket is attached to the launcher, the student pumping the rocket should put on eye protection. The rocket should be pumped no higher than about 50 lb/in^2 (8.93 kg/cm^2) of pressure.
4. When pressurization is complete, all students should stand in back of the rope for the countdown.
5. Before conducting the countdown, be sure the place where the rocket is expected to come down is clear of people. Launch the rocket when the recovery range is clear.
6. Only permit the students launching the rocket to retrieve it.



Completed Launcher Ready for Firing.

Appendix H

Transcripts

The multimedia files were developed especially for this module and are to be used as background information for the teacher and in conjunction with the classroom lessons. They are available online at:
http://www.nasa.gov/mission_pages/constellation/ares/ares_education.html

Ares I — Narrated by Bob Armstrong

(Runtime — 4:46 minutes)

I'm Bob Armstrong. I work at NASA's Marshall Space Flight Center in Huntsville, Alabama. Our office is tasked with designing, building, and testing this Nation's next generation of space launch vehicles. This vehicle here is the crew launch vehicle, or Ares I. It's the first in the stable of new launch vehicles for this country. It's an inline two-stage vehicle. It stands over 328 feet, which is a little taller than a 32-story building. It weighs, at liftoff, about 2 million pounds, which is about twice the mass of a 747 fully fueled aircraft. Its thrust at takeoff, 3.5 million pounds — which is 13 million times the propulsion capability of a 747 aircraft. This vehicle can place 48,000 pounds of payload into orbit, which is about 24, one-ton pickup-truck loads of cargo.

The first stage of this vehicle, shown here, is a solid rocket booster — similar to those that fly on the shuttle today. Although, this has got a fifth segment, where the Shuttle flies with four segments. We've upgraded it to give it a little more flight performance. The first stage burns for about two minutes. At that point, it is jettisoned. It is recovered under parachutes. Studies are under way to see if we might reuse that piece of hardware. Once the first stage is jettisoned, the second stage fires. Now, the second stage is made up of three components. The first component is where the fuel is housed — the tankage, if you will. It houses the fuel, the liquid hydrogen, in this case, and the oxidizer, the liquid oxygen. The second component is the engine — in this case, it's the J-2X. Now, the J-2X is housed under the inner stage adaptor here, so you can't see it. The J-2X is a modified, upgraded version of the J-2 that flew on the second and third stages of the Saturn V launch vehicle. Now, the third component of this upper stage is the instrument unit housed up here — that's where the avionics or the brains of this launch vehicle reside. This upper stage is a new design, being designed by an in-house NASA team.

Now, the payload is the crew exploration vehicle, and it sits on top of the launch vehicle. After the upper stage burns out, which is about at 450 seconds that it burns, it will be expended. Depending on the mission that it's flying, it can dock with the International Space Station — in that case, it will carry six crew. However, if it's one of two vehicles, setting up for a Moon mission, it would dock with the lander and the Earth departure stage that had been delivered there earlier by the Ares V, which is this vehicle's sister vehicle. A real important milestone is coming up in the April 2009 timeframe, and it's going to be a flight demonstrator test of this vehicle here. The vehicle will be made up with some flight hardware and some simulated hardware, but it's going to give us a good idea of how this vehicle will fly under real conditions. It's also going to help us understand how do we process this vehicle — on the ground, as well as launch this vehicle. April of 2009 is not far off, and we look forward to this big milestone.

Ares V — Narrated by Bob Armstrong

(Runtime — 4:47 minutes)

I'm Bob Armstrong. I work at NASA's Marshall Space Flight Center in Huntsville, Alabama. Our office is tasked with designing, building, and testing this nation's next generation of space launch vehicles that are going to take us back to the Moon. This vehicle next to me is the Ares V Cargo Launch Vehicle. It is the sister vehicle of the crew launch vehicle, the Ares I. This vehicle stands about 365 feet tall. It weighs, at liftoff, about seven million pounds, which is about seven times the weight of a 747 fully fueled aircraft. At liftoff, it generates over 10 million pounds of thrust. And when this vehicle lifts off, the solid rocket boosters, similar to the one that flies on the Ares I, the sister vehicle — there are five segments — they will be firing at liftoff. Also, the center core, which is a liquid oxygen and liquid hydrogen — the fuel is hydrogen core, will be firing.

On the bottom of that core are five RS-68 engines. The RS-68 engines are flying today on the Delta IV launch vehicle. At liftoff, these solids will fly for about two minutes. They will burn out, and they will be jettisoned, recovered under parachutes — studies are under way to see whether they will be reused or not. The liquid core will continue to burn, and at about 400,000 feet, it will be expended and burn up on re-entry. At that point, the upper stage engine, which is under this shroud — you can't see it — but it's the same engine that flies on the Ares I, the J-2X, will fire suborbitally. It will place the Earth departure stage and the lander in low-Earth orbit.

Once that is in orbit, we'll check it out — make sure everything is OK — and at that point, we'll launch the Ares I Crew Launch Vehicle. As its name implies, it's going to launch the crew. They will rendezvous with the lander and the Earth departure stage, which still contains fuel. Once they rendezvous and check everything out, the Earth departure stage will fire the J-2X Engine a second time and send the payload and the crew on a trajectory to the Moon. Then, the Earth departure stage is no longer needed. It is expended.

Now, when they get near the Moon, the crew will transfer from the crew exploration vehicle, or Orion, into the lander. We have four crew members on board. All four will take the lander and go down to the surface. That's a little different than Apollo — Apollo only allowed two to go down to the surface — one had to stay on orbit. This doubles our capability, and it's because of the size of the vehicles, as well as the autonomous capability of the crew exploration vehicle. So, while the crew goes to the surface, the crew exploration vehicle remains in lunar orbit. Now, one thing about the lander that is also different — we have the capability to land anywhere on the Moon, which is, in the Apollo days, we could only land in the equatorial areas. We also have twice the volume in the crew exploration vehicle than we did in the Apollo days, so there are some important differences.

Now, once the crew is done with its work on the Moon — initial stays will be about 10 days — they'll get back in the lander. The upper stage of the lander, the top part shown here, will fire, take the crew off the surface of the Moon, up to rendezvous with the Orion. At that point, the crew will transfer from the lander into the Orion. The lander will be expended. Some day down the road, we might want to reuse those landers if we can find water, ice on the Moon to use as potential fuel. After the crew transfers to the Orion, the Orion service module engine will fire sending them on a direct trajectory back to the Earth. When they get near the Earth, the service module, which is no longer needed, will be jettisoned and it will allow the capsule heat shield, which is under the service module to be used in a pristine state. The crew will re-enter through the atmosphere. The heat shield will protect them and the capsule from the extreme temperatures of re-entry. Parachutes will deploy much like on Apollo, but unlike Apollo, we're going to land on the land, as opposed to in the water. Landing on the land allows us to potentially reuse the capsule and it's much easier to recover the crew. We do not have to have a Navy to go out and get the crew. The Ares I Crew Launch Vehicle will be flying in the 2015 time frame. This vehicle, we plan on having flying in the 2018 time frame for a return to the Moon in the 2020 time frame.

Why Two Rockets?— Narrated by Bob Armstrong

(Runtime — 2:31 minutes)

I'm Bob Armstrong, and I work at NASA's Marshall Space Flight Center in Huntsville, Alabama. We're tasked with designing, building, and testing this nation's next generation of space transportation vehicles that are going to return us to the Moon.

Next to me are those two vehicles. The first one is the crew launch vehicle. It takes the crew into low-Earth orbit. It can supply the space station when it first comes on-line. Ultimately, it will be used in concert with its sister vehicle, the Ares V, or cargo launch vehicle to return us to the Moon.

Now, people ask, 'Why are you flying two vehicles instead of one, like they did in the Saturn V days?' There are numerous reasons for that — one of the most important, though, is safety reasons. Numerous panels that were convened following the *Challenger* and *Columbia* accidents pointed out the need to separate crew from cargo. On the Shuttle, we fly crew and cargo together.

For these vehicles, we've taken a different tact, and we've separated them. In a mission to the Moon, the cargo goes up on the 'cargo vehicle truck,' if you will, into low-Earth orbit, and it waits for the crew. So, once we get the cargo up there, we know it's working, we can send the crew up. This vehicle, the crew vehicle, as you can see, is a less complex vehicle, so it's likely to be more reliable. Additionally, we have a launch escape system called the launch abort system on this. If we do have a problem during launch, we can get the crew off safely to fly another day.

Another advantage of having separate crew and cargo: we've got this true 'work truck' here, if you will, that ahead of the crew or at anytime in between missions, we can deliver cargo — cargo such as habitats, rovers, in-situ resource utilization equipment — all kinds of equipment that we can deliver to the surface of the Moon without having the astronauts present, so we do not put them in any kind of danger.

Getting Ready For Launch — Narrated by Joel Best

(Runtime — 5:37 minutes)

Hi, I'm Joel Best. I work at the NASA Marshall Space Flight Center supporting the Ares I launch vehicle project. I work in the operations and supportability area, and what we do is we develop the operational concepts as well as the operations requirements for supporting the Ares I launch vehicle. We not only do ground operations, but we also do flight operations — the requirements for both of those areas.

The Ares I launch vehicle is comprised of three different elements: there's the upper stage, the first stage, and then the J-2X Engine. The J-2X Engine, the components are made out at the Pratt & Whitney Rocketdyne facility in Canoga Park, California. Those components are shipped to the Stennis Space Center, and they're put together there into what we know as the J-2X Engine. It is green run, test-fired, there at the Stennis Space Center, and then the engine is shipped to the Michoud Assembly Facility where the upper stage element is fabricated and manufactured.

Once the engine is integrated into the upper stage, that whole unit is shipped down to the Kennedy Space Center on a covered barge. Now the first stage, those are actual canisters that are reused over and over again, and they're filled out at the Utah facility by ATK Thiokol. Then they're shipped by rail in rail cars down to the Kennedy Space Center, and then they're put together down at Kennedy in the Vehicle Assembly Building. Once all the launch vehicle elements arrive at the Kennedy Space Center, the first stage elements are processed in an off-line hazardous facility and then they are sent over to the Vehicle Assembly Building. The upper stage with the J-2X Engine and inner stage already installed come in and they go straight to the Vehicle Assembly Building and wait for the first stage to get stacked.

Well, before any stacking can begin, a big thing called the mobile launcher — it's like a big barge — comes into the stacking cell; and then the first stage, piece by piece, is stacked on this mobile launcher; and then the upper stage is stacked on top of the first stage. Once, all of that is stacked, the Orion spacecraft with the LAS on top is put on top of the upper stage and then it's considered an integrated Orion-Ares launch vehicle stack. That, then, rolls out to the pad on this mobile launcher. The mobile launcher doesn't roll out on its own. There's a crawler transporter that comes in — it's like a big caterpillar. It's got treads like a bulldozer does. It comes in and it goes under the mobile launcher, picks it up, rolls it out of the VAB, and then goes down the crawlerway out to the launch pad — takes this whole integrated stack. And there's a launch umbilical tower that is part of the mobile launcher that holds everything in place. It not only allows you to get access to the whole integrated stack, but there's also a damping arm and a stiffening arm on there to hold it in place until it gets to the launch pad. Well, all this rolls out there, and it gets integrated into the launch pad — it gets hooked up and connected — and then the launch countdown activities begin.

On the day of launch, there are people supporting in control centers all over the country and at different NASA centers monitoring the launch vehicle and the Orion spacecraft to make sure everything is a 'go' for launch. Now, keep in mind that launch countdown begins about 24 hours before the launch vehicle actually launches. So, there are mission controllers at the mission control center at Johnson Space Center. There are engineering support personnel at the Marshall Space Flight center monitoring the propulsion elements. And then, of course, there is the launch control team in the launch control center at Kennedy Space Center. There's also the range safety personnel at the 45th Space Wing down at the Kennedy Space Center, and then there are people in the firing room, too, to make sure that everything is OK for actually launching the vehicle. All these people all over the country at the different control centers are monitoring all the vehicle systems to make sure everything is ready to launch.

And then, about 12 hours before launch, they put up balloons to make sure that the wind conditions are favorable for the launch at that point in time. Then, they upload what they call "initialization loads" that tell the vehicle, 'OK, you need to go according to this trajectory, based on what the winds are for today. And, once all of that is in place, they begin the launch countdown. They load the crew in the Orion vehicle and they make sure everything — all systems are go, all systems are operating as they should. And then, as it gets really close to launch, they poll all the different people in the control centers and make sure every single one gives a 'thumbs up' or a 'go for launch.' And then at T minus 0, they press the button and the launch vehicle is on its way and it begins its ascent into space. What they tell me about the Ares I launch vehicle is because the first stage is the solid, with a lot of thrust, it's going to just zoom off the pad and just take off like a bolt of lightening. So, I'm looking forward to seeing one of those. Now, the Ares V launch, it's going to have two solid rocket boosters as well as a core stage with five engines on the bottom, so I imagine the rumble from that is just going to vibrate all over the place and you can just feel it in your chest.

Why Go to the Moon?—Narrated by Joel Best

(Runtime — 1:43 minutes)

Since the Moon is so much closer to the Earth than Mars, it is important for us to go to the Moon to learn how people work and live in space and learn any lessons that we need for going to these other planets; because with the Moon being relatively close-by, we can get the astronauts home if we need to. And that's why it's important for us to go to the Moon first, before we go to any of the other planets. And it's also cool to go to the Moon, not only because we did it once before, but this time we're going to set up lunar outposts, and we're going to learn about the lunar soil, the regolith as it's called, and what attributes of it might be useful for us here on Earth. And, we're also going to learn how to grow things in space, and have astronauts be able to survive and take care of themselves long-term in space. And that is going to benefit us tremendously for all of our long-term Constellation goals.

The thing I like most about working on the Ares I launch vehicle is that we are working at the very beginning development phase of the rocket that will replace the Space Shuttle. And we have this amazing opportunity to plan, develop, and carry out the ground operations and flight operations that are going to enable this Ares I launch vehicle to successfully carry the astronauts into orbit — so they can go on to the International Space Station, and then later go on to the Moon.

Launch Period vs. Launch Window — Kris Walsh

(Runtime — 1:41 minutes audio)

One is the launch period, which is how many days we can launch a mission to the proper orbit. For low-Earth orbit, basically there's no concern. That launch period is 365 days a year. To go to Mars, or to an asteroid, you're severely limited because you need a certain energy to be imparted to that satellite. They might use another planet, or the Moon to get into the proper orbit. So, we work with the satellite provider. We work with the NASA (National Aeronautics and Space Administration) organization that give(s) us targets -- we get the satellite to that target with a certain energy and then the mission designers take over from there. We also have a launch window on a day-to-day basis. And that can range from one second to over an hour. All our Mars missions were one-second windows and we got those all off in the first or second day. When we do have 12 minutes or more, if we have a problem with the launch countdown, we can safe the vehicle, recycle, and attempt again on the same day. If we have a one-second window, if we have any problems in the last four minutes of the countdown, we are down for 24 hours.

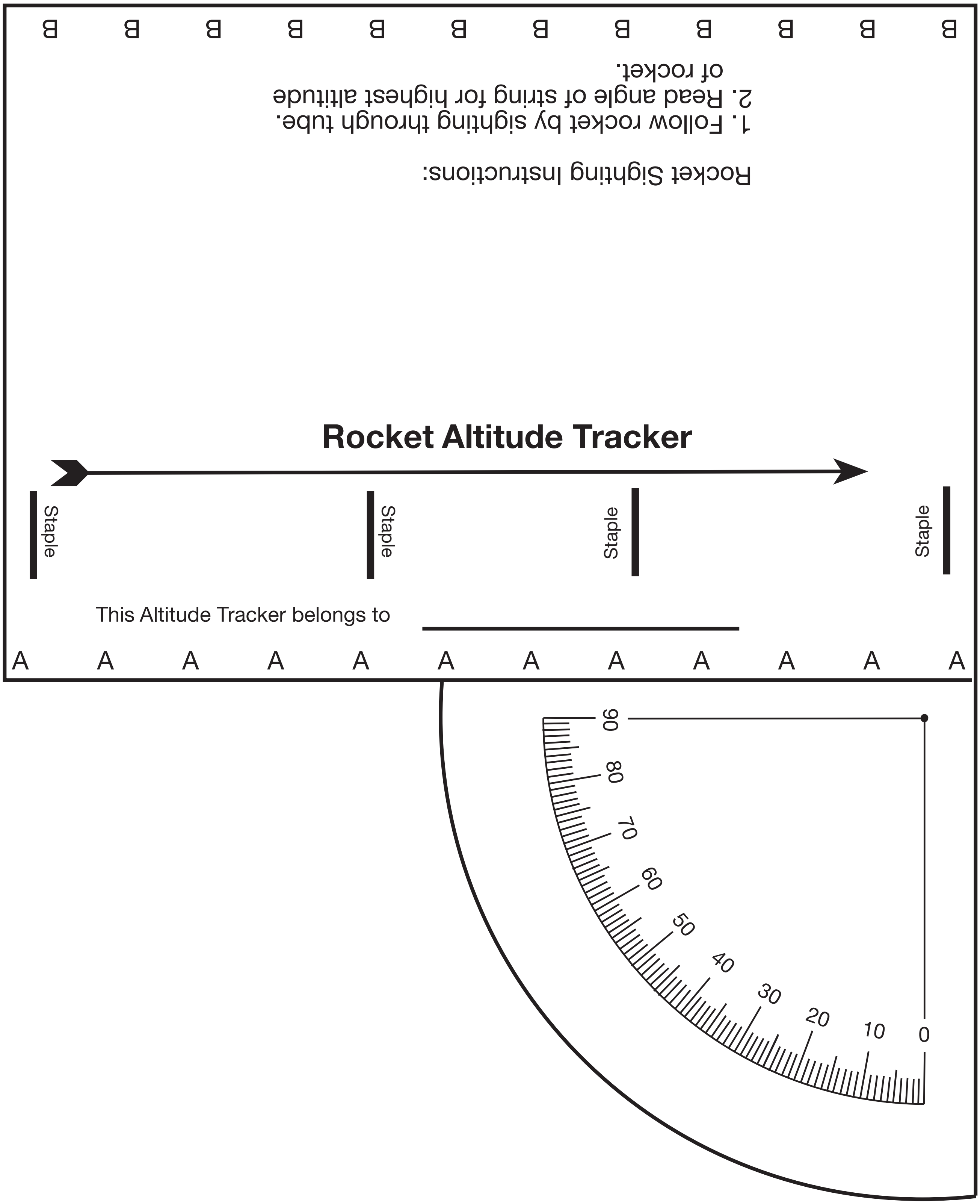
Mission Integration Manager — Kris Walsh

(Runtime — :42 seconds audio)

Every mission has a mission integration manager, or sometimes called 'missile mother.' They work all the specifications to make sure that this rocket is what's required to do the mission. They work with engineering. They work with integrative product teams. They work with suppliers. They work with quality. And they work very closely with the launch sites. And they are our primary interface with NASA (National Aeronautics and Space Administration), KSC (Kennedy Space Center), and the spacecraft manufacturer, Lockheed Martin. It's a lot of work, but it's a lot of fun, and there's not much you can do in this world that is as exciting as a launch countdown.

Appendix I

NASA Altitude Tracker



Appendix J

Safety Rules

Safety begins now. As in any project requiring a group of students to work together to use tools to construct, test, and redesign products, there are certain safety precautions. It is necessary for both the teacher and students to understand these rules and follow them exactly.

General Lab Safety

1. During the use of tools for any construction or launches, students and adults should wear safety goggles.
2. Before any tool is used, discuss the safety issues surrounding the proper use of the equipment.

Building the Rocket

1. Use only plastic drink bottles. New bottles should be used whenever possible. Bottles that have been exposed to sunlight for long periods of time should not be used. Bottles should be retired from use after 10–15 launches.
2. Use only the materials approved by the classroom teacher to construct the rocket.
3. No metal pieces or sharp objects may be used in the construction.
4. Take precautions when cutting bottles. The first incision can be made with a sharp carpet knife and the other cuts can be completed with scissors.
5. Do not use hot glue when attaching fins to the rocket body. The heat from the glue can weaken the plastic to the extent that the rocket may not be able to withstand the launch pressures. The use of cold-melt hot glues is acceptable. No cyanoacrylates (e.g., Super Glue™) should be used.
6. The supervisor must approve each design before the launch.

The Launch Area

1. Check your launch area for any potential concerns. Choose a large clearing such as an athletic practice field or vacant lot. When launching in smaller areas, use reduced pressures and adjust the launch angle to compensate for the wind.
2. The launch area and range should be large enough for the rocket pressure and should be clear before launching any rocket.
3. Do not attempt to catch a spent (falling) rocket or payload. Vertically, a rocket will typically reach nearly 500 feet (152 meters). A very aerodynamic rocket will impact the ground with speeds approaching 120 miles per hour (54 meters/second). When adding weight to the rocket with nose cones and payload, additional safety margins must be established.

The Launch

1. Launch your water rocket only under the guidance of a trained, professional adult.
2. Assign a student supervisor to be responsible for completing the "Safety Checklist" before launching (see Appendix B).
3. Always anchor the launch pad. When working on a solid concrete area, you may be able to weigh the pad down, tie it down to something solid, or attach the cord to a tree or a building in the opposite direction to counter the pull.
4. Safety goggles must be worn when within 33 feet (10 meters) of a pressurized rocket.
5. All persons not directly involved in the launch should be at least 16 feet (approximately 5 meters) away from the rocket when it is being pressurized and during the launch process.

6. If you are filling rockets with a garden hose, make sure the hose has a shutoff valve and that water is kept some distance from the launch area. Keep the water turned off when not in use.
7. To pressurize the rocket, use only bicycle pumps, air compressors, or scuba tanks with air pressure gauges. Never charge a rocket without air pressure measurements.
8. Rockets can be pressurized with various air pressures, but never above 50 psi under any circumstances. Bottle designs vary and bottles can burst at lower pressures due to bottle type, fatigue from overuse, poor construction techniques, or exposure to sunlight. Never attempt to perform a bottle burst test.
9. Keep electrical cords away from all water sources. If using a compressor, use long air hoses rather than long electrical cords.
10. Assign the following personnel to be responsible for the launch:
    - Safety Officer: Checks for safe practices and can stop a launch whenever unsafe practices are observed.
    - Loading Officer: Responsible for securing the rocket to the pad and charging the rocket with the appropriate air pressure.
    - Principal Investigator/Launch Officer: Makes final decisions about rocket design. Commences the countdown and launches the vehicle.
    - Downrange Officer: Spots the rocket and assures the safe landing of the rocket and payload. Observes the launch and records data.
11. As the bottle is being pressurized, all except the loading officer should stay away from the area. Never lean over a pressurized bottle.
12. All persons should face the rocket during launch. Kneel down and participate in the countdown. Keep the sun at your back or over your shoulder. Do not face the sun.
13. If a leak is observed during pressurization, stop adding air and release the rocket using the standard launch techniques based on the launcher you are using. Then, repair the leak or replace the bottle.
14. Bottles that are modified with fins, nose cones, and extra mass should be carefully tracked by all personnel and avoided as the rocket returns to Earth. Never attempt to catch a spent (falling) rocket or any payload that the rocket has launched.
15. If the rocket fails to release after the pin is pulled, immediately clear the area and inform the adult supervisor. The supervisor will jiggle the rocket with a long stick and cause it to release.

Signatures

I have read the Safety Rules and will observe them during the construction and launch of water bottle rockets.

Signature of student/supervisor ____

National Association of Rocketry

http://www.nar.org

Appendix K

Safety Checklist

In the lab or on the construction site: Signature of Group Safety Officer ________________________________

	All participants are wearing safety goggles.
	All participants know the proper use of equipment and the safety issues involved with using that equipment.

While building the rocket: Signature of Group Safety Officer ____

	Bottles are new or have been used for fewer than 10 launches.
	Only classroom materials are being used in the rocket construction.
	No metal or sharp objects are being used on the rocket.
	Cuts are being made with safe cutting tools.
	No hot-glue guns or cyanoacrylate (e.g., Super Glue™) were used to attach parts to the rocket.
Supervisor approval of final rocket. Signature ____	

The launch site: Signature of Launch Safety Officer ____

	The pad is inspected and appears to be functional.
	The pad is firmly anchored.
	The size of the launch area is adequate for the experiment undertaken.
	Water is not freely running near the launch pad.
	All electrical cords are well away from the launch area and the water source.
	The launch pin is properly placed over the lip of the bottle.
	All personnel in the area are wearing safety goggles before the bottle is pressurized.
	When pressurizing, air line is extended as far from pad as possible. Established pressures are not exceeded.
	All personnel are paying attention to the launch, have their backs to the sun, and are looking at the rocket.

The launch: Signature of Launch Safety Officer ____

	A trained adult is present.
	The safety officer, loading officer, launch officer, and downrange officer are present and have been trained.
	The launch area is clear, both in range and downrange.
	All participants participate in the launch countdown led by the launch officer.
	The safety officer can abort the launch at any time for any reason.

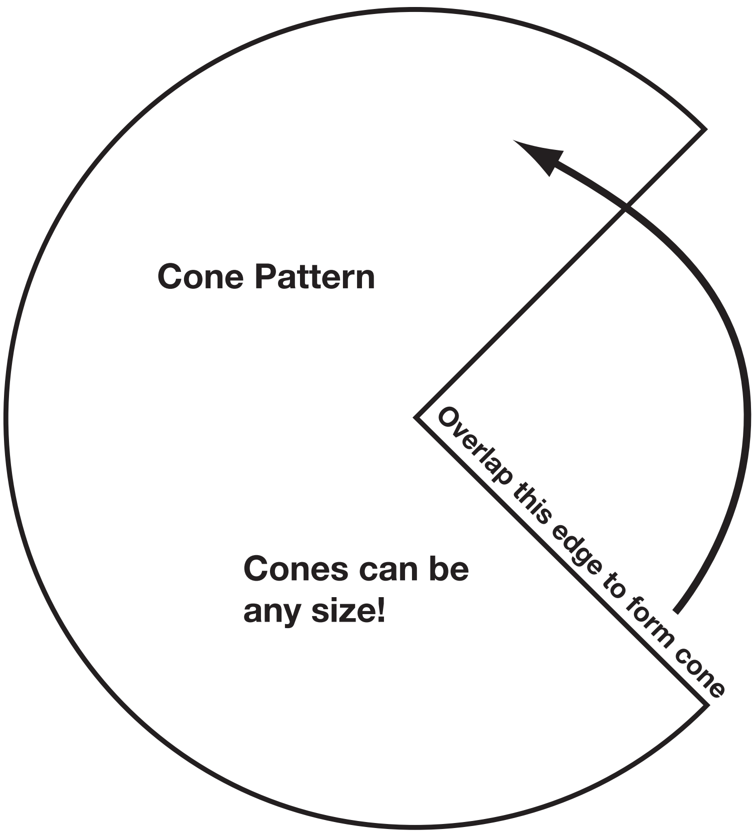
Following the launch: Signature of Launch Safety Officer ____

	All electricity is turned off.
	All water is turned off at the source.
	Launch area is cleared of all materials and related debris.

Appendix L

Nose Cone Pattern

1. Cut out cone pattern.
2. Overlap edge to form a cone and tape down.
3. Attach nose cone to paper towel tube with tape.



Appendix M

Materials List

Pop Rocket Variables

For each group of three to four students:

Student activity, "Pop Rocket Variables," page 6.

- Student text, "Variables and Operational Definitions," page 12.
- Plastic 35 mm film canister with an internal-sealing lid.
- Effervescing antacid tablet.
- Paper towels.
- Water.
- Eye protection.
- Computer with Internet access connected to a video projector.
- (Optional) *October Sky* VHS or DVD with television or video projection.

Pop Goes Newton

For each group of three to four students:

- Student activity, "Pop Goes Newton," page 17.
- Student text, "Newton's Laws of Motion," page 21.
- Completed student activity, "Pop Rocket Variables" from previous lesson (Briefing).
- (Optional) Video, *Newton in Space*.

The History of Rocketry

- Student text, "From Earth to the Moon and Beyond," page 34.
- Printed copies or online access to "Brief History of Rockets:" http://exploration.grc.nasa.gov/education/rocket/TRCRocket/history_of_rockets.html
- Construction paper, yardsticks, and markers (Optional).

Launching Ares

- Return to the Moon: The Journey Begins Now, available in the video archives at the following URL: http://www.nasa.gov/mission_pages/constellation/main/index.html
- Mission Integration Managers: Audio with Kris Walsh.
- Getting Ready for Launch: Video with Joel Best.

Copies of the following for each student or group of students:

- Student activity, "Ground Challenge," page 43.
- Student text, "From Earth to the Moon and Beyond," page 34.
- Student activity, "Moon Challenge," page 47.
- Pieces of colored construction paper labeled with the names of different types of equipment and supplies to be transported. The labels include their masses and dimensions and the stage numbers in which they are needed. (See Appendix D and E for label templates.)

Optional materials: Especially helpful for kinesthetic learners, construct manipulative representations of the various transportation vehicles using different sized boxes, labeled with their maximum payload capacities (see label templates in Appendix D):

- Pickup truck: Personal checkbook boxes approximately 3 1/2 by 6 inches (9 by 15 centimeters).
- Club cab pickup: Business checkbook boxes approximately 3 1/2 by 8 inches (9 by 20 centimeters).
- SUV: Select a box that has dimensions similar to those representing the pickup truck but with more depth.
- Trailers: Flat box similar to audiotape box approximately 3 by 4 inches (8 by 10 centimeters).

- Tractor-trailer: Shoebox.
- Tape or twist-ties to hook the trailers to the pickup trucks.
- Template labels can be placed on top of the boxes to represent the materials to be carried by a specific vehicle in a specific stage.
- Masking tape to mark off a 12-foot (approximately 3.7-meter) diameter circle on the classroom floor.

Investigating Water Rockets: Abbreviated Approach

Activity 1: What Do I Need to Know Before Launch?

- "Appendix J: Safety Rules," page 124.
- "Appendix K: Safety Checklist," page 126.
- Student activity, "Measuring Altitude," page 62.
- "NASA Altitude Tracker," page 123. (This pattern can be copied or glued onto tag board.)
- Thread, lightweight string, or fishing line.
- Cellophane tape.
- Small washer or 1–2 ounce (28–57 gram) fishing sinker.
- Scissors.
- Rope or string to measure out range (33 feet or 10 meters).
- Angle-to-height Conversion chart, page 64.
- Tennis ball per pair of students.

Activity 2: Propulsion for Entire Class

- Student activity, "Altitude vs. Water Volume," page 84.
- Several two-liter plastic soft drink bottles.
- Water.
- Graduated cylinders (one-liter).
- Tire pump or air compressor.
- Safety glasses.
- Altitude trackers.
- Conversion charts, page 64.
- Rope to measure out range (33 feet or 10 meters).
- Compass to determine north, south, east, or west.
- Launcher (see Appendix G) or search the Internet to purchase a launcher.

Activity 3: Fin Shape

- Student activity, "Investigating Fin Shape or Size," page 72.
- Paper towel tubes.
- Tag board (for fins).
- Ruler.
- Cellophane tape and/or glue.
- Scissors.
- Safety glasses.
- Launching mechanism (vacuum with blower or leaf blower).
- Yard (or meter) stick for measuring distances.
- Arrows: some with and some without feathers.

Investigating Water Rockets: Comprehensive Approach

Activity 1: What Do I Need to Know Before Launch?

- "Appendix J: Safety Rules," page 124.
- "Appendix K: Safety Checklist," page 126.
- Student activity, "Measuring Altitude," page 62.
- "NASA Altitude Tracker," page 123. (This pattern can be copied or glued onto tag board.)
- Thread, lightweight string, or fishing line.
- Cellophane tape.

- Small washer or 1–2 ounce (28–57 gram) fishing sinker.
- Scissors.
- Rope or string to measure out range (33 feet or 10 meters).
- Angle-to-height conversion chart, page 64.
- Tennis ball per pair of students.

Activity 2: Nose Cone Experts

- Student activity, "What a Drag" page 65.
- Paper towel tube.
- "Appendix Nose Cone Patterns," page 127.
- Yard (or meter) stick.
- Several two-liter plastic soft drink bottles.
- Modeling clay.
- Card stock.
- Leaf blower or vacuum set to blow.
- Books to make a path.
- Long hall or open area.

Activity 3: Fin Experts (two groups)

- Student activity, "Flying Straight," page 68, for students in both groups.
- Student activity, "Investigating Fin Shape or Size," page 72, for one group. (Optional for students needing more structure.) Student activity, "Investigating Fin Number and Placement," page 78 for the second group. (Optional for students needing more structure.)
- Paper towel tubes.
- Tag board (for fins).
- Ruler.
- Cellophane tape and/or glue.
- Scissors.
- Safety glasses.
- Launching mechanism (vacuum with blower or leaf blower).
- Yard (or meter) stick for measuring distances.
- Arrows: both with and without feathers.

Activity 4: Propulsion Experts

- Student activity, "Fly Like an Eagle," page 81.
- Student activity, "Altitude vs. Water Volume," page 84. (Optional for students needing more structure.)
- Student activity, "Altitude vs. Water Pressure," page 87. (Optional for students needing more structure.)
- Several two-liter plastic soft drink bottles.
- Water.
- Graduated cylinders (one-liter).
- Tire pump or air compressor.
- Safety glasses.
- "NASA Altitude Tracker," page 123.
- Conversion charts, page 64.
- Rope to measure out range (33 feet or 10 meters).
- Compass to determine north, south, east, or west.
- Launcher (see Appendix G) or search Internet to purchase a launcher.

Activity 5: Weather or Not

- Copy of the student activity, "Weather or Not," page 90.
- Access to a computer with the Internet.
- Weather instruments for measuring wind speed, direction, visibility, and temperature.

Measuring Altitude

- "NASA Altitude Tracker Pattern," page 123.
- Scissors.
- Pin or small nail.
- Thread, lightweight string, or fishing line.
- Cellophane tape.
- Small washer or 1–2 ounce (28–57 gram) fishing sinker.

Fly Me High

- One or more two-liter plastic soft drink bottles.
- String.
- Safety goggles.
- Glue or tape.
- Cardboard or thick paper.
- Modeling clay.
- Scissors.
- Pens and decorating supplies.
- Scale.
- Measuring devices: rulers, yard or meter sticks, and measuring tape.
- Balance.
- Launch pad with secure pin and washers.
- Water.
- Safety goggles.
- Air pump or tank.
- Altitude tracker.
- Decorative decals.
- "Appendix J: Safety Rules," page 124.
- "Appendix K: Safety Checklist," page 126.
- Student activity, "Fly Me High," page 97.

You Get What You Pay For

- Spreadsheet or balance sheet.
- Calculator.
- Student activity, "You Get What You Pay For," page 105.

Bibliography

Publications

Hickam, H., *Rocket Boys*, Delacorte Press, New York, NY, 1998.

McREL *Compendium of Standards and Benchmarks for K-12 Education*.

The *National Science Education Standards*, National Academy Press, Washington, DC, 1996.

Newton, Sir Isaac, *Philosophiae Naturalis Principia Mathematica*, *The Principia: Mathematical Principles of Natural Philosophy.*

Olson, S. and Loucks-Horsley, S. (eds.), *Inquiry and the National Science Education Standards,* National Academy Press, Washington, DC, 2000.

Ramig, J. E., Bailer, J., and Ramsey, J. M., *Teaching Science Process Skills*, Good Apple, Torrance, California, 1995.

Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology, NASA EG-2003-01-108-HQ, Office of Human Resources and Education, Washington, D.C., 2003. Available online at:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Schwartz, R., "Learning to Learn Vocabulary in Content Area Textbooks," *Journal of Reading*, Vol. 32, pp. 108–117, 1988.

Film

October Sky, Gordon, C., and Franco, L. (Producers), and Johnston, J. (Director), Universal City, CA: Universal Pictures, 1999.

Newton In Space, NASA video:
http://quest.nasa.gov/space/teachers/liftoff/newton.html

A higher resolution version of *Newton in Space* is available for a nominal fee at:
http://quest.nasa.gov/space/teachers/liftoff/

Return to the Moon: The Journey Begins Now, NASA video:
http://www.nasa.gov/mission_pages/constellation/main/index.html

Online Resources

Brief History of Rockets:
http://exploration.grc.nasa.gov/education/rocket/TRCRocket/history_of_rockets.html

Camping on the Moon:
http://www.nasa.gov/mission_pages/exploration/mmb/inflatable-lunar-hab.html

Fiftieth Anniversary of Sputnik:
http://www.hq.nasa.gov/office/pao/History/sputnik/

Living in Space, NASA video:
http://spaceflight.nasa.gov/living/

NASA: Ares Overview.
http://www.nasa.gov/mission_pages/constellation/ares/index.html

NASA's Constellation Program: Information and online videos:
http://www.nasa.gov/mission_pages/constellation/main/index.html

NASA Facts: The Ares I Crew Launch Vehicle:
http://www.nasa.gov/pdf/151419main_aresI_factsheet.pdf

NASA Facts: Fact Sheet:
http://www.nasa.gov/pdf/183996main_FS-Transition.pdf

NASA Johnson Space Center Fact Sheets:
http://www.nasa.gov/centers/johnson/about/factsheets/index.html

National Association of Rocketry:
http://www.nar.org/NARmrsc.html

Newton in Space: NASA video and instructional resources:
http://quest.nasa.gov/space/teachers/liftoff/newton.html

Orders of Magnitude: A History of the NACA and NASA, 1915-1990:
http://www.hq.nasa.gov/office/pao/History/SP-4406/contents.html

Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Rockets Teacher's Guide with Activities:
http://exploration.grc.nasa.gov/education/rocket/TRCRocket/Intro.html

Shuttle History and Missions:
http://www.nasa.gov/mission_pages/shuttle/main/index.html

Sputnik and the Dawn of the Space Age:
http://www.hq.nasa.gov/office/pao/History/sputnik/

Timeline of Rocket History. Marshall Space Flight Center:
http://history.msfc.nasa.gov/rocketry/index.html

Weight Estimator. Joint Personal Property Shipping Office.
http://jppso-sat.randolph.af.mil/weight-estimator.asp

Multimedia Resources Available with this Module

The video files are available online at:
http://www.nasa.gov/mission_pages/constellation/ares/ares_education.html

NASA Ares I Crew Launch Vehicle: Video with Bob Armstrong.

NASA Ares V Cargo Launch Vehicle: Video with Bob Armstrong.

Why Two Rockets? Video with Bob Armstrong.

Getting Ready for Launch: Video with Joel Best.

Why Go to the Moon? Video with Joel Best.

Launch Period vs. Launch Window: Audio with Kris Walsh.

Mission Integration Managers: Audio with Kris Walsh

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