

Lesson 5: Learn to Build a Rocket in 5 Days

Grade Level: 4 (3-5)

Lesson #: 5 of 6

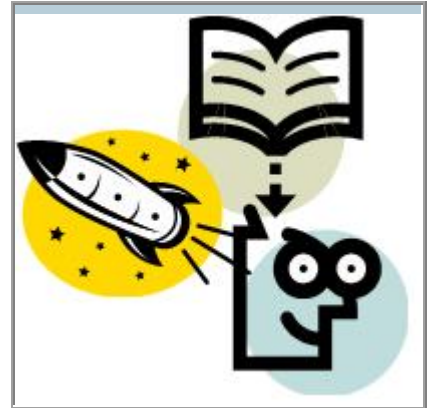
Time Required: 15 minutes

Lesson Dependency:
None

Keywords: Newton, motion, rocket, thrust, weight, control, process, design, re-design, tradeoffs

Summary: In this lesson, students discover the entire process that goes into designing a rocket for any customer. In prior lessons, students learned how rockets work, but now they learn what real-world decisions engineers have to make when designing and building a rocket. They learn about important factors such as supplies, ethics, deadlines and budgets. Also, students learn about the Engineering process, and recognize that the first design is almost never the final design. Re-Engineering is a critical step in creating a rocket.

Engineering Connection: When designing a rocket, engineers must not only consider how far and fast it needs to go, but also how much it will cost, how safe it will be, how heavy it will be, and what impact it will have on the environment. Very often, the strongest design will be too heavy or too expensive. That is why engineers must often find a compromise that satisfies all the requirements of a project. Engineers also often make several design iterations along the way. This means they design and test a rocket, discover what needs to be fixed, and then redesign and test until they come up with a successful final design.



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Learning Objectives

After this lesson, students should be able to:

- Define and give an example of a "tradeoff" in engineering design.
- Explain that engineering design has several steps, that a project is not usually perfect after the first design, and it may take several redesigns before a project is considered done.
- Give an example of a factor to consider when building a rocket, such as: limited money, the needs of the customer, limited time, resources, ethical considerations, environmental considerations, safety considerations, as well as the rocket's performance.

Introduction/Motivation

What are some questions that engineers have to take into consideration when designing a rocket? More specifically, what are Spacewoman Tess and Spaceman Rohan's needs for their rocket? This is perhaps the most important question because as their engineering team, they are your customers, and you are providing a service to them by designing a rocket that fits their

needs. (Write their answers on the board. They might come up with things like: How high does it need to go? How much weight does it have to carry? How much can it cost? How safe does it need to be? Is it going to harm the environment? How long do we have to build it? For younger kids you may have to prompt them to get answers. How will the rocket be used? (Answer: It will be used to carry satellites and a spacecraft for Tess.) How will it be fueled (i.e., what type of propellant?)?) So, let's look at our list. There are a lot of things an engineer must think about when designing a rocket, or anything for that matter.

Let's think about this question, "How much weight does the rocket have to carry? What does it need to carry?" Do you remember that our rocket needs to carry satellites for Maya, a spacecraft for Tess, and all the propellant to get the rocket up into space - a very heavy load! How might you go about designing a rocket to carry a lot of weight? (Possible answers: put in a huge rocket motor, make the rocket very light, or use a very powerful rocket such as a nuclear rocket.) All of these ideas would likely work, but some of them might not be good matches for the other questions on the board. For example, a bigger rocket can lift more, but it will cost more and might take longer to build. Or, a lighter rocket might be made out of very expensive materials or might not be strong enough to endure the stresses of launch. A nuclear rocket might not be safe and could potentially damage the environment if there was a disaster during/after liftoff.

Engineering is a delicate balance between many types of different factors. Engineers call these necessary decisions that affect other actions *tradeoffs*. We might be able to make a super powerful rocket that is inexpensive, but it might be very harmful to the environment. This is the tradeoff. A rocket might have some good qualities and some bad qualities. If the bad qualities outweigh the good qualities, then we should look for a different rocket design. When designing a rocket, an engineer must keep in mind the rocket's uses, performance, cost, deadlines, safety, weight, controllability, environmental impact, and many other factors which must be carefully balanced in order to create a successful rocket.

Do you think engineers always get a rocket design right the first time? The answer is no! It takes many re-designs to get something as complicated as a rocket right. An engineer calls this process re-engineering. It is simply learning from the mistakes of the past and applying those lessons learned to better a product. We do that with homework too, right? We learn from our mistakes and do a better job next time.

Today you will learn about the actual engineering process and how it applies to designing a successful rocket for Tess, Rohan and Maya.

Lesson Background & Concepts for Teachers

Basic Design Life Cycle

Problem Identification: The first step in the Design Life Cycle is determining what the problem is — or what the customer needs. Engineers are problem solvers at heart. Their job is to design and build something better than before. Sometimes this involves modifying an old idea and sometimes it means starting from scratch with a whole new idea. At the beginning of a project, an engineer starts out with a list of requirements, or things that a product must do. For a rocket, requirements might include how fast it must be, how safe it has to be, how much it can cost, how much it can weigh, or when does it have to be completed. The requirements define what needs to be done to accomplish the project, or job. It is the engineer's job to come up with a solution to the problem that meets all the requirements.

Forming Ideas: The next step in the engineering design process is an idea: "I wonder if..." The idea phase is where a group of engineers will brainstorm a bunch of ideas that might work as a solution to a problem. When these ideas are combined, a rough idea for a solution is complete.

Feasibility: Engineers must then decide if the solution they came up with is feasible. Feasibility is not a question of "is it possible" (since little is impossible in today's high-tech, fast-changing world), but the questions are: can we afford it, is it safe, and is it the right thing to do? Projects are judged for feasibility by a panel of reviewers with strengths and expertise in science, engineering and project management.

Conceptual Design: Once a project is deemed to be feasible, the next step is the conceptual design. The primary questions that are answered during the conceptual design are:

- What is the general configuration of the structure to be built?
- What major trade studies should be made (i.e., hardware, software, materials)?
- What is it going to cost (calculated estimation)?
- How long will it take (calculated estimation)?

The design that comes out of the conceptual design phase is not the final design, but during this phase many of the important questions about what the final design will look like are answered.

Preliminary Design: If the conceptual design is acceptable, the team can move on to the preliminary design. Actions for the preliminary design are:

- Perform trade studies (decide on best components, materials, etc.).
- Create initial detailed designs.
- Create a detailed schedule and cost plan.
- Further develop concepts with the goal of reducing risk.
- Establish sufficient margins of safety.

Detailed Design: The detailed design phase is where the detailed design is agreed upon and finalized. The customer must be happy and agree with the design, budget and schedule before anything can be built.

Build and Test: This is the point where the manufacturing of hardware begins. (Presumably) all design details are complete and every part of the design is ready to proceed into reality. As part of this work, engineering models are often constructed for performance checks and tests. These tests are done with significant margins added to each of the tests - making them more extreme than anticipated during the mission. Any failures or weaknesses in the design must be corrected (back to conceptual or preliminary design) and retested to prove the product will fulfill its requirements.

Delivery of Product: Finally, after much hard — yet very satisfying — work, the product is then delivered or sold to the customer along with documentation of all tests and operations to prove that the design works.

Re-Engineering

Design, testing and re-design are integral parts of engineering that improves the final product. Nothing is ever just right the first time. Mistakes are inevitably made, but engineers learn from their mistakes, which are used to improve the product during redesigns. Even a design that works can be improved — maybe it can be produced even more inexpensively, maybe it can last longer, maybe it can be faster, etc.

Attached are some examples of rockets and their builders. Note that some of the rockets have numbers after their name: a number that is increased each time they re-design and improve the rocket!

Vocabulary/Definitions

Budget: A detailed plan for the resources and money available for a project.

Feasibility: Making sure that the basic engineering design is not only possible physically, but also to make sure that it can be built and satisfy all the requirements (i.e., cost, timeline, safety, ethically, etc.).

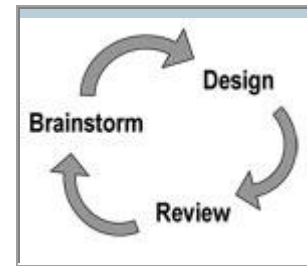


Figure 1. The engineering design process.
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Re-Engineering: To learn from mistakes of the first design to improve the next design.

Trade-off: Giving up one thing in return for another.

Associated Activities

- **Rockets on a Shoestring Budget** - In this activity, students must re-engineer their pop rockets while they are limited by supplies, budgets and deadlines – just like in the real world!

Lesson Closure

How often do we come across limited resources? Are there enough swings on the playground for every student to have one? (Answer: no, of course not) What do you do if there is not enough of something? (Answer: share) If three kids are sharing a swing for 10 minutes, is it fair for one to stay on for 30 minutes? (Answer: no) If your parents gave you a dollar to buy candy, can you buy all the candy in the store? (Answer: No, you must pick from everything available.) How do you decide which candy you will buy? Why is one candy better than another? Would you choose a candy that tastes the best but only lasts 30 seconds or a candy that does not taste as good but you can enjoy it for 5 minutes? (Answer: Depends on what is valued more: taste or duration of enjoyment.) Sometimes we have to make "tradeoffs" to get the most out of an object or activity. You may have to tradeoff length of time on the swing to let everyone use it. You may have to tradeoff duration for a candy that tastes best. Engineering projects also have tradeoffs. Sometimes the tradeoff is weight, control or thrust for cost or money. Sometimes it is the materials available with which they can build. The engineering process takes many steps to ensure that all the requirements are met, and that is when tradeoffs happen. Also, an engineering project is never perfect the first time, and it often takes several redesigns to get it right.

Even with the proper engineering tools and knowledge of rocket design, an engineering team still needs familiarity with the engineering process to be in tune with the customer's needs. Hopefully, now as Tess and Rohan's engineering team you have all the tools necessary to meet their need to get Maya's satellites to space and turn Tess' explorations into reality.

Assessment

Pre-Lesson Assessment

Prediction: Have the students make a prediction on the following question:

- How many people think they can build a perfect rocket on the first try? (Tally student answers on the board. Tell the students that they will learn whether or not most engineers can design something right on the first try today.)

Discussion Question: Solicit, integrate and summarize student responses.

- When a company wants to build a rocket, does someone just give them the materials for free? (Answer: No, cost is a very important consideration in an engineering project. Before a group of engineers receives money to build a rocket, they must have a detailed design that outlines how the rocket will perform, how much it will cost and how long it will take to build.)

Post-Introduction Assessment

Reasonable Question or NOT? Spacewoman Tess, Spaceman Rohan and their daughter Maya are incredibly busy planning their trips. They have given you, as their engineering team, 5 minutes to ask them a few questions regarding their rocket design. Have the students as a class vote on whether or not the following questions are reasonable questions to ask regarding designing Spacewoman Tess' rocket:

- What is the purpose of the rocket?
- How much money do we have to build the rocket?

- Should the rocket be pretty or ugly?
- How much time do we have to design and build the rocket?
- When do you need the rocket?
- How long will you need to be in space?
- What are the satellites for?
- When will the satellites need to be in orbit?
- What color should the rocket be?

Brainstorming: In small groups, have the students engage in open discussion. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Encourage wild ideas and discourage criticism of ideas. Ask the students:

- What are some steps you think engineers have to take to design a rocket? (Prompts: Do they have to think of ideas? Gather materials? Build a model? What else?)
- What are some trade-offs an engineer might have to consider when designing a rocket? (Possible answers include: safety, cost, materials, height of launch, weight, etc.)

Post-Lesson Assessment

Design Flowchart: Have the students create a list and description of the steps in an official engineering project. Also, have them produce these steps in a flowchart (see Figure 2). Ask them what happens when there is some weakness or problems during the build and test phase? What would you do and back to which step does that take you?

- Problem Identification
- Forming Ideas
- Feasibility Study
- Conceptual Design
- Preliminary Design
- Final Design
- Build and Test
- Re-Engineering
- Delivery of Product

Lesson Extension Activities

Break students into teams. Have each team draw a picture to illustrate each step of the engineering design process. Hang these drawings around the room to remind students of the engineering design process.

Have the students research a rocket and write a one-page paper about the engineering history of that rocket. They should answer questions such as how long did it take to design? How much did it cost? What were the requirements for the rocket? And were there any tradeoffs made during the design?

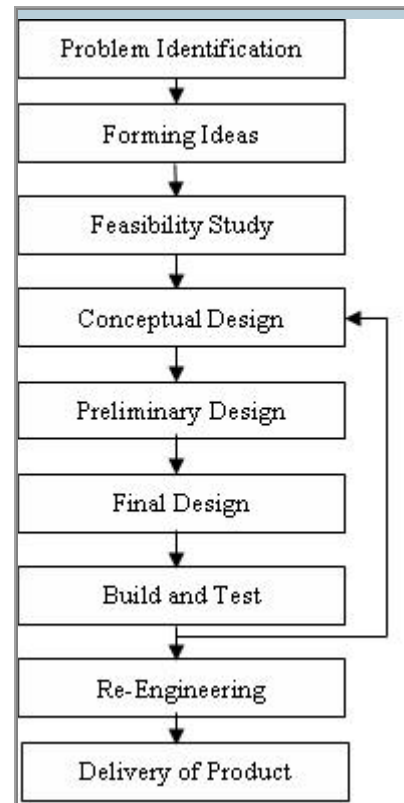


Figure 2. Sample design flowchart
Copyright © Flowchart created by Malinda Schaefer Zarske, University of Colorado at Boulder, 2005.

Activity 5: Rockets on a Shoestring Budget

Grade Level: 3 (K-5)

Group Size: 2

Time Required: 50 minutes **Activity Dependency:** None

Expendable Cost Per Group: US \$.20

Keywords: rockets, pop rockets, strawkets, re-engineer, Newton, motion, budget

Summary: In this activity, students revisit the Pop Rockets activity from Lesson 3. This time, however, the design of their pop-rockets will be limited by budgets and supplies. They will get a feel for the limitations of a real engineering project as well as an opportunity to redesign and retest their rockets.

Engineering Connection: Engineers must consider all aspects of a project during design. Considerations in rocket design include: how far and fast it needs to go, but also how much it will cost, how safe it will be, how heavy it will be, and what impact it will have on the environment. To reach a goal with limited resources, choices must be made balancing cost, value, and performance, called tradeoffs. Engineers often must be very creative to balance resources and performance.



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Learning Objectives

After this activity, students should be able to:

- Give an example of a real-world constraint on engineering projects, such as budgets, deadlines, supplies or safety.
- Explain that engineering design has several steps, that a project is not usually perfect after the first design, and that it may take several redesigns to get a project right.
- Use and fill out a budget sheet to create a specific design using imitation money.

Materials List

Each group needs:

- 1 35-mm film canister (with internal snapping lid - see Figure 1)

Note: For this activity, students must use a film canister with an internal-sealing lid instead of one that snaps over the outside of the rim. These are usually clear, white canisters — not the solid black or grey ones. Film canisters are available free of charge from camera shops and stores where film is processed, such as grocery stores, Target, Costco, etc. These businesses recycle the canisters and are often willing to donate them for educational use. The majority of the canisters you will obtain at one time will be the solid black ones, which will not work; you may have to make many trips to one the above locations to receive enough of the white translucent canisters with the internal-sealing lids!

- 1 penny
- Scissors
- ½ antacid tablet
- For the entire class to share:
 - Clear cellophane and masking tape
 - Unlined white paper
 - Heavy construction paper
 - Safety glasses/goggles (at least enough for the instructor and group launching)
 - Paper towels
 - Access to cold and hot water faucet
 - An empty pitcher (if launching rockets inside)

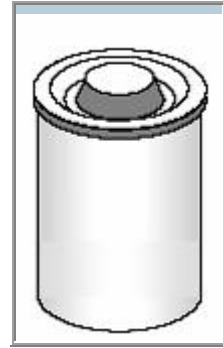


Figure 1. A drawing of a film canister.
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Introduction/Motivation

Dreaming about how to build something is completely free. Engineers, however, are actually paid to think about how to build something. Doesn't that sound like fun? Being imaginative, therefore, is an important skill for an engineer. Building something also takes materials, building skills and space in which to build. Materials cost money, gaining skills costs money (either education or trial and error with materials), and enough available space in which to build a project usually costs money. This is why engineers strive to build things that are useful and can be sold at a profit or used to save people money in the long run.

Building a rocket and using whatever it takes for a successful launch is fun, but the real challenge comes when the resources are limited. (Note: NASA essentially had unlimited freedom during the race to the moon, as the government gave them whatever resources they needed!) This is when an engineer's creative thinking skills are very important! To reach a goal with limited resources, choices must be made balancing cost, value and performance. We call these decisions which affect our actions *tradeoffs*. Tradeoffs are when we give up one thing in return for another. Buying the best engine for a rocket may mean there is not enough money for proper structural materials, and subsequently, the rocket may fail. Using the strongest materials may mean the rocket is too heavy and cannot lift off. Using Fuel A may improve thrust over Fuel B, but Fuel A costs twice as much as Fuel B (not a good value). It is only worth using the more expensive fuel if the extra money means the difference between success and failure. Part of being an engineer is about deciding how best to compromise on these issues *before* actually building something.

When designing a real rocket, engineers have budgets, deadlines and requirements that limit what they can build and how they can build it. An engineer must work within these limits. Spacewoman Tess and Spaceman Rohan have needs, such as getting their satellites and spacecraft into space. They have a required timeline: they need to get up to space quickly in order for the satellites to be orbiting before Maya starts her journey. Also, they do not have much money with which to work. A good rocket design is a careful compromise between speed, strength, weight, cost and safety. While we may have the technology to build better rockets, we may not have enough money or time to actually build one. We also may change the way we build a rocket because of safety or environmental concerns. It may take many designs and tests before an engineer has a design that satisfies all the requirements. Today, we are going to work within a

budget. We are going to be given a certain amount of money to buy materials to build our best pop-rocket. Do you think you can do it? Let's try!

Background Information

Pop Action (Review from Lesson 3)

Rockets move by expelling fuel in one direction to move in the opposite direction (Newton's third law of motion). For our pop-rockets, we will be getting the thrust force from a pressure build-up caused by a chemical reaction. When the antacid tablet is placed in water, many little bubbles of gas are created. What exactly is going on?

Antacid tablets contain aspirin, sodium bicarbonate (NaHCO_3) and citric acid (H^+). Bicarbonate compounds react with acids to form carbon dioxide and water.

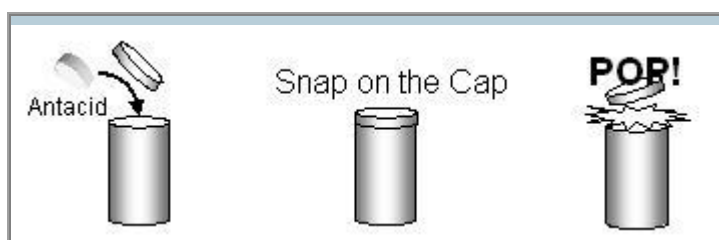
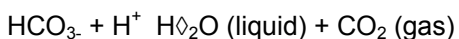


Figure 2. The basics of a pop-rocket
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2003.

In an antacid tablet, the bicarbonate and citric acid are solids and so the H^+ and CO_3^{2-} ions are not free to move, collide and react. When plopped into water, the citric acid and sodium bicarbonate dissolve, freeing the ions to react. This results in the formation of carbon dioxide gas.

The bubbles go up, instead of down, because they weigh less than water. When the bubbles get to the surface of the water, they break open. All that gas that has escaped from the bubbles pushes on the sides of the canister. Eventually, something has to give — the canister literally pops its top (which is really its bottom, since it is upside down in this activity). All the water and gas rush down and out, pushing the canister up and away, along with the rocket attached to it.

The rocket travels upward with a force that is equal and opposite to the downward force propelling the water, gas, and lid (Newton's third law of motion). The amount of force is directly proportional to the mass of water and gas expelled from the canister and how fast it is expelled (Newton's second law of motion).

Procedure

Before the Lesson

1. Gather materials.
2. Print and cut enough Blast-Off Bucks and Budget and Sketch Worksheets (attached).
3. Choose a wall inside or outside that you can launch next to, and mark off 10 feet at 1-foot intervals with tape or chalk.
4. Prepare crushed tablets (see Troubleshooting Tips for help with this step). Note: Half tablets of antacid are more than enough to pop off the canister lids; more than $\frac{1}{2}$ tablet is unnecessary and will make the lid pop off sooner, which is not desirable for this activity.
5. Clean up any white powder that has been spilled, as it may be mistaken for many other illegal or dangerous substances.

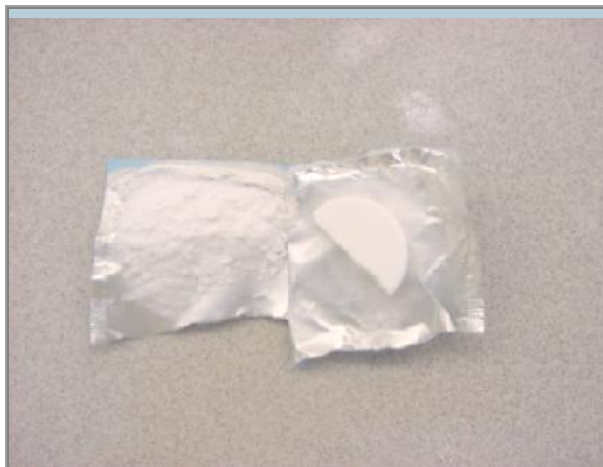


Figure 1. Antacid tablet.
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With the Students

1. Tell the students that their challenge today is to build a pop-rocket that is at least 6 inches tall and can lift a penny at least 4-feet high. Since engineers often build small-scale models of their designs and test them, these pop-rockets act as a step in the rocket design cycle. The penny must be protected inside a paper tube. Unlike the last time they built rockets (in Lesson 4, Blast Off: Pop Rockets Activity), the materials for building these rockets will be limited. (Note: Antacid tablets should be given out only as needed so that the instructor knows that all tablets are accounted for and used appropriately in the experiment.)
2. Give each group a Trial Budget Worksheet (attached), and have them put their names on it.
3. Give each group 8 Blast-Off Bucks (attached).
4. Student groups should be given 5 minutes to fill out their budget, draw a concept sketch and present their budget and sketch to the teacher for an approval signature.
5. The instructor should check the budget/sketch to make sure the students are on the right track: verify that the budget math is done correctly and is not less than zero. Make sure everyone puts the lid of the canister at the bottom of the rocket in his or her sketch. Make sure they indicate the rocket will be at least 6 inches tall.
6. Have students pay the amount required for their materials (if they have extra bucks, they should save them), and give them the materials they chose on their budget sheet.
7. Give the groups 10 minutes to build their rocket using scissors and their materials. (Each group can follow the Rocket Build Instruction Sheet to build their rocket but are free to try any design they think will work – as long as it is at least 6 inches tall.)
8. Students should place their penny inside the paper tube of their rocket; they should NOT place the penny inside the film canister itself.
9. Have students put their name and any designs they want on their rocket.
10. One group at a time will come up to the launch area and put on safety glasses. All others should be a safe distance away.
11. Ask one group representative to hold their rocket upside down and (teacher) fill the canister $\frac{1}{3}$ full of either hot or cold water - according to their budget sheet.

The next steps must be done quickly:

1. Have the group representative very quickly drop in the solid or crushed $\frac{1}{2}$ antacid tablet (again according to budget sheet).
2. Snap the lid on very tightly, as quickly as possible.
3. Turn the rocket upright (film canister lid aimed down), and place it into the empty pitcher or onto the flat launch site and stand back!

The rocket should pop within 1-5 seconds

1. Note the maximum height reached by the rocket. Have the group record it on their Trial Data Worksheet, and answer questions 1 and 2.
2. Once a team has launched their rocket, they should redesign and rebuild their rocket.
3. Allow the students to re-launch their rockets once they have completed a redesign.
4. Have them record the height of their final launch and answer the rest of the questions on the Trial Data Worksheet.

Attachments

- Rocket Build Instructions
- Blast-Off Bucks
- Trial Data Worksheet
- Budget and Sketch Worksheet

Safety Issues

Remind students not to put the antacid tablets (crushed or solid) in their mouths; if a student eats a solid tablet they could become very sick.

Hand out antacid only as necessary; do not give each group a "supply" in advance.

Make sure the students wear safety glasses while they are launching their rockets; students who are not launching rockets should be a safe distance away.

Troubleshooting Tips

In order to effectively use half tablets of antacid in powder form, the following method of preparation can be used:

- Use scissors to cut a two-tablet packet down the middle (between the two whole tablets).
- Carefully, tear open each of the foil antacid packets and remove both tablets. Break them in half as evenly as possible.
- Place $\frac{1}{2}$ of each tablet back into its foil packet.
- Fold over the open end of one of the packets, hold it shut and use a blunt object to crush the half tablet in the packet (this takes some practice but works well). Repeat for the other tablet.
- Now you should have two crushed half tablets nicely contained in their packets and two solid half tablets set aside.
- Common student problems when building rockets:
 - Forgetting to tape the rocket body to the film canister.
 - Failing to mount the canister with the lid down.
 - Not extending the canister far enough from the paper tube to ensure the lid can be snapped on easily.

It may be easier for the students to build the rockets and then allow the teacher to launch them. The chemical reaction of the Alka Seltzer® and water sometimes happens too fast for small hands.

Remember to have the students stand back when the rockets are launching so that they do not get hit with flying rocket parts.

Assessment

Pre-Activity Assessment

Brainstorming: As a class, have the students engage in open discussion. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas. Have them raise their hands to respond. Write their ideas on the board. Ask the students:

- How do companies get money to build rockets? (Answer: They take out a bank loan and then sell the rocket for a profit (assuming it works), they get money from the government (i.e., taxes), the owner of the company has money from some other source, a company that wants to launch something gives them the money to build a rocket, etc.)

Activity Embedded Assessment

Worksheet: Have the students record measurements and follow along with the activity on their Trial Data Worksheet. After students have finished their worksheet, have them compare answers with their peers.

Group Question: During the activity, ask the groups:

- What made your rocket fail or succeed? What are the most important factors in building a successful rocket? Is it weight? Aerodynamics? Stability? Fuel? A good film canister?

Post-Activity Assessment

Re-Engineering: Ask the students how they could improve their pop rocket, and have them sketch or test their new ideas. Have the students use the data from their own design results as well as the results they observed from other groups to come up with design improvements.

Journal Reflection: Ask the students to write a paragraph, in their science journal or on a sheet of paper, to explain the design process they went through in order to build a better rocket. Have them answer the following question:

- Describe how you designed your rocket in three steps.

Activity Extensions

To extend the activity, give the students more time the first day to complete and launch their first rocket. Talk to them about redesign and why it is important for engineers to learn from their mistakes. On the second day reissue Blast-Off Bucks, and have them design and build a new rocket with the lessons they learned from day one.

Have students create a bar graph (X axis: group names and trial numbers, Y axis: height that the rocket reached) representing all of the group's rocket data.

Activity Scaling

For K and 1st grade students, build rockets without a budget. Ask students if they think it is more expensive to build a rocket with more supplies. Ask them if they could build a rocket without paper. What if they could have all the paper they wanted? What would it look like then? Have students count out loud to see how long it takes each rocket to "pop." Then, ask for a choral response to these basic questions:

- Why does the rocket come back down when shot up? (Answer: gravity)
- Where is the energy coming from to power the rocket? (Answer: the reaction between the antacid table and water)
- If you could re-do your rocket, what would you change? Explain that engineers do not always get a project right the first time and often have to re-design their project several times before getting it right. Sometimes, it may take all of their money (budget). It is okay

when this happens, as it is part of the learning process; subsequently, after several tries, engineers can develop the best rocket for the money.

For 2nd and 3rd grade students, make all rockets the same size (height) so the comparison between materials is more obvious. Students should be able to build the rockets but may need help with the launching procedure.

For 4th and 5th grade students, introduce the idea of launch insurance; that is, if a group pays one Blast-Off Buck, they can re-launch their rocket if the first launch fails. Have students graph the class results of rocket versus height.

Assessment

Pre-Activity Assessment

Brainstorming: As a class, have the students engage in open discussion. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas. Have them raise their hands to respond. Write their ideas on the board. Ask the students:

- How do companies get money to build rockets? (Answer: They take out a bank loan and then sell the rocket for a profit (assuming it works), they get money from the government (i.e., taxes), the owner of the company has money from some other source, a company that wants to launch something gives them the money to build a rocket, etc.)

Activity Embedded Assessment

Worksheet: Have the students record measurements and follow along with the activity on their Trial Data Worksheet. After students have finished their worksheet, have them compare answers with their peers.

Group Question: During the activity, ask the groups:

- What made your rocket fail or succeed? What are the most important factors in building a successful rocket? Is it weight? Aerodynamics? Stability? Fuel? A good film canister?

Post-Activity Assessment

Re-Engineering: Ask the students how they could improve their pop rocket, and have them sketch or test their new ideas. Have the students use the data from their own design results as well as the results they observed from other groups to come up with design improvements.

Journal Reflection: Ask the students to write a paragraph, in their science journal or on a sheet of paper, to explain the design process they went through in order to build a better rocket. Have them answer the following question:

- Describe how you designed your rocket in three steps.

Activity Extensions

To extend the activity, give the students more time the first day to complete and launch their first rocket. Talk to them about redesign and why it is important for engineers to learn from their mistakes. On the second day reissue Blast-Off Bucks, and have them design and build a new rocket with the lessons they learned from day one.

Have students create a bar graph (X axis: group names and trial numbers, Y axis: height that the rocket reached) representing all of the group's rocket data.

Activity Scaling

For K and 1st grade students, build rockets without a budget. Ask students if they think it is more expensive to build a rocket with more supplies. Ask them if they could build a rocket without paper. What if they could have all the paper they wanted? What would it look like then? Have students count out loud to see how long it takes each rocket to "pop." Then, ask for a choral response to these basic questions:

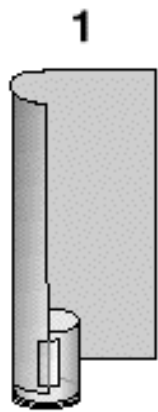
- Why does the rocket come back down when shot up? (Answer: gravity)
- Where is the energy coming from to power the rocket? (Answer: the reaction between the antacid table and water)
- If you could re-do your rocket, what would you change? Explain that engineers do not always get a project right the first time and often have to re-design their project several times before getting it right. Sometimes, it may take all of their money (budget). It is okay when this happens, as it is part of the learning process; subsequently, after several tries, engineers can develop the best rocket for the money.

For 2nd and 3rd grade students, make all rockets the same size (height) so the comparison between materials is more obvious. Students should be able to build the rockets but may need help with the launching procedure.

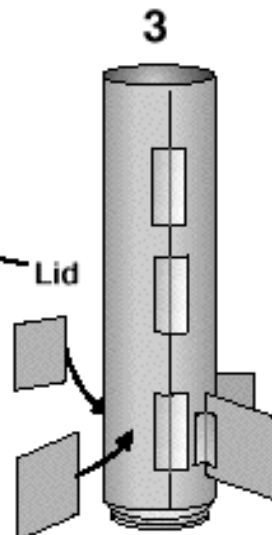
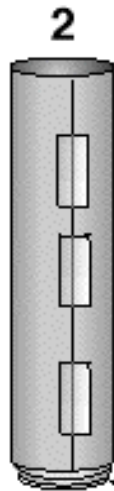
For 4th and 5th grade students, introduce the idea of launch insurance; that is, if a group pays one Blast-Off Buck, they can re-launch their rocket if the first launch fails. Have students graph the class results of rocket versus height.

Rockets on a Shoestring Budget Activity – Rocket Build Instructions

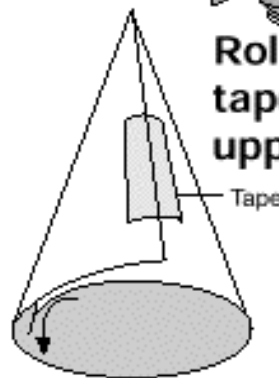
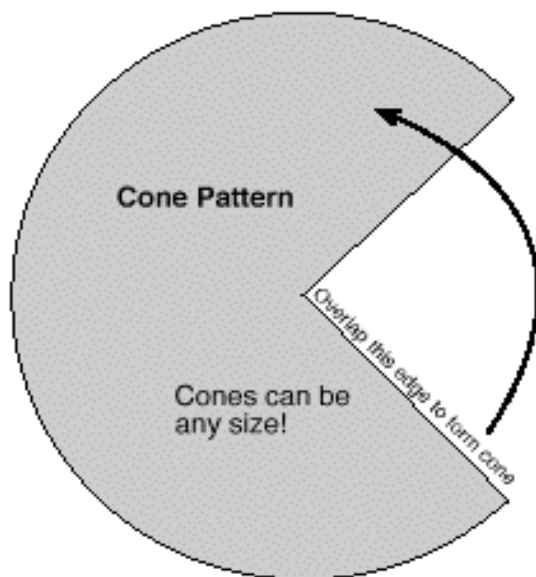
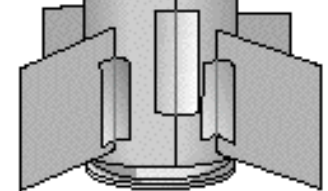
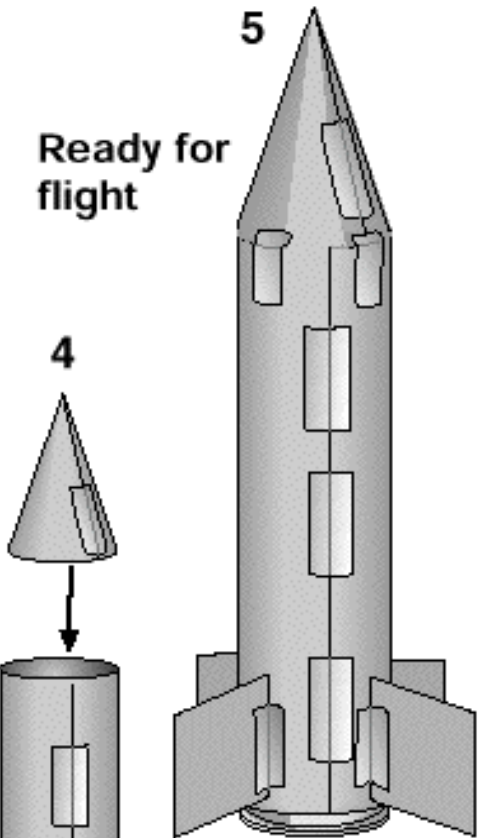
Instructions



Wrap and tape a tube of paper around the film canister. The lid end of the canister goes down!



Tape fins to your rocket.



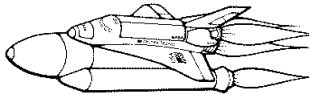
Roll a cone of paper and tape it to the rocket's upper end.

Source: www.spacesociety.org/spaceexpress/Curriculum/film_canisters.html

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One Blast-Off Buck



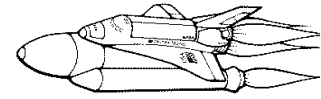
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One Blast-Off Buck



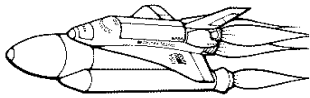
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One Blast-Off Buck



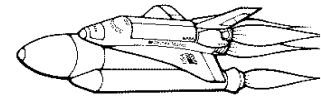
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One Blast-Off Buck



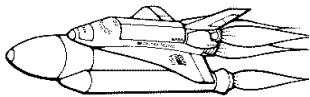
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One Blast-Off Buck



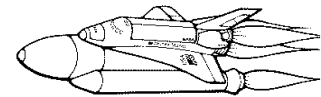
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One Blast-Off Buck



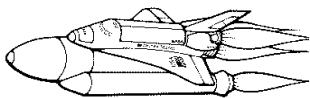
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One Blast-Off Buck



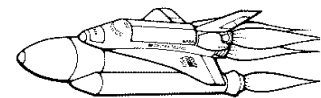
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One Blast-Off Buck



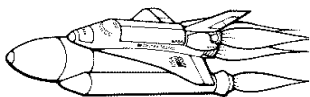
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One Blast-Off Buck



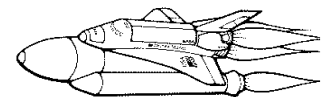
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One Blast-Off Buck



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Name: _____ Date: _____

Company Name: _____

Rockets on a Shoestring Budget Activity – Trial Data Worksheet

Pop Rocket Design Trial

Check the boxes for the material choices you made for your trial budget:

Normal Paper

Construction Paper

Scotch Tape

Masking Tape

Crushed Antacid

Solid Antacid

Hot Water

Cold Water

How many Blast-Off Bucks did you have left over? _____ (may be zero)

Height reached on first launch (in feet): _____

1. Describe what happened during your launch:

2. After watching all the trial rocket launches, what ideas do you have for improving your design? Write down at least two:

Name: _____ Date: _____

Company Name: _____

Height reached on second launch (in feet): _____

3. Describe what happened during your final launch? Did the rocket improve?

4. If you had more Blast-Off Bucks, would the rocket have gone higher? Why?

Final Recommendation

Based on your results and the results you observed from the other teams, what combination of materials would you recommend for a successful and profitable rocket?

Name: _____ Date: _____

Rockets on a Shoestring Budget Activity – Budget and Sketch Worksheet

Material	How many do you want?		Cost (per item)		_____	Starting Blast-Off Bucks	
					-		
Canister with lid	1	*	2	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
Construction Paper (1 sheet)	_____	*	1	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
Paper (1 sheet)	_____	*	2	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
Masking Tape (10 inches)	_____	*	1	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
Scotch Tape (10 inches)	_____	*	2	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
½ Antacid Tablet (solid)	_____	*	1	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
½ Antacid Tablet (crushed)	_____	*	2	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
1/3 canister of water (cold)	_____	*	1	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
1/3 canister of water (hot)	_____	*	2	=	$\begin{array}{r} \underline{\hspace{1cm}} \\ \Downarrow \end{array}$	Subtract	
						$\begin{array}{r} \underline{\hspace{1cm}} \\ - \\ \hline \end{array}$	Sub-Total
						$\begin{array}{r} \underline{\hspace{1cm}} \\ \hline \end{array}$	Extra Blast-Off Bucks

Name: _____ Date: _____

Pop-Rocket Trial Concept Sketch

Must include:

- 1. Dimensions (height).
- 2. Show engine position.
- 3. Show lid orientation (which direction engine is pointing).



Administrator Approval Signature: _____