Heavy Lifting Rocket Challenge

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Objectives

Students will:

- Construct balloon-powered rockets to launch the greatest payload possible to the classroom ceiling.
- Carry your rocket the highest, with the most "mass" (paperclips).
- Launch 50 grams to the ceiling.

Suggested Grade Level

9^{th} – 12^{th}

Subject Areas

Engineering, Science

Timeline

60 Minutes

Standards

Argumentation from Evidence

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5)
- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). (HS-ESS3-2)

Constructing Explanations and Designing Solutions

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (MS-ESS1-6)
- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5)
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories,

simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1)
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4

Using Mathematical and Computational Thinking
- Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4)
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

Obtaining, Evaluating, and Communicating Information
- Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)

Developing and using models
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1), (HS-ESS2-3), (HS-ESS2-6)
- Use a model to provide mechanistic accounts of phenomena.
- Use and/or develop a model of simple systems with uncertain and less predictable factors.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.
- Design a test of a model to ascertain its reliability

Asking questions and defining problems
- 6-8: Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables and clarifying arguments and models.
  - Questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

- that challenge the premise(s) of an argument or the interpretation of a data set.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
- 9-12: Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
  - Questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
  - to determine relationships, including quantitative relationships, between independent and dependent variables.
  - o to clarify and refine a model, an explanation, or an engineering problem
- Evaluate a question to determine if it is testable and relevant.
- Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.

21st Century Essential Skills

- **Learning Skills**
  - Critical thinking/problem solving
  - Creativity/imagination
- **Literacy Skills**
  - Constructing explanations
  - Organizing concepts
- **Life Skills**
  - Collaboration and teamwork
  - Global awareness

Background

NASA's Constellation program for the next generation of space rockets includes a heavy lift launcher called the *Ares V*. *Ares V* will carry heavy payloads into orbit, such as very large, scientific satellites, space station replacement modules and supplies, and Earth departure stages that will propel human spacecraft to the Moon and Mars. Raising heavy payloads to orbit is challenging. Rockets require powerful engines and massive amounts of propellants. NASA's Ares V will be able to accomplish eh job. It will be one of the largest and most powerful rockets ever built. However, Ares V won't be the only heavy lift vehicle needed. There will be a market for commercial delivery of propellants and modules and robots for constructing tourist hotels, supply delivery, and more.

Vocabulary

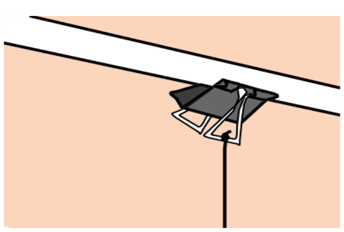
Payload, Newton's Laws

Materials

- Large binder clips (1 per launch pad)
- Fishing line or smooth string
- 2 balloons
- Dixie Cup (optional)
- 2 straight drinking straws
- 50 small paper clips (start with 5)
- Sandwich size plastic bag (optional)
- Masking tape
- Balloon hand pumps (buy with Starbuck)

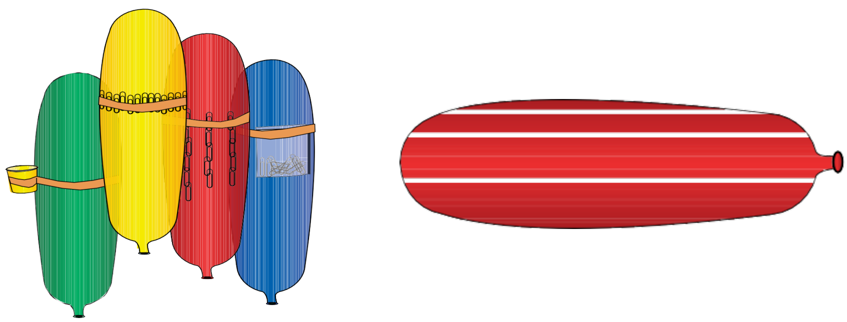
Lesson

1. Explain to students: "NASA is looking for creative ideas for launching heavy payloads into orbit. Payloads include parts and supplies for the International Space Station and spacecraft that will carry humans to the Moon and Mars. NASA is also interested in rockets that can transport large fuel tanks that will be used to power deep space rockets. You are challenged to build the most efficient heavy-lift rocket from the provided materials. The team that is able to lift the greatest payload into space (the ceiling) is the winner."
2. Set up the launch pad.
   a. Your launch pad will have a binder clip attached to the ceiling (see picture).
   b. Your string should be long enough to reach the floor.
   c. Tie the fishing line to the binder clip.



Binder clip attached to ceiling grid.

3. Feed the fishing line through the straw in order to guide your rocket. Be sure you are holding the lower end of the line to the floor! If there is slack in the line your rocket will have a very strange trajectory, and death will certainly follow.
4. Attach one or more balloons with masking tape. **DON'T TIE THEM!!!** (see pictures)



5. Use all or some of your materials. You may purchase extra balloons for 2 Starbucks. You may purchase the use of a hand pump for 1 Starbuck. You may attempt AS MANY LAUNCHES as you like.

Extensions

- Compare different rockets. How does Saturn V compare to SLS? How has technology improved modern day rockets?
- Ask students, "How can we modify our rockets to carry a heavier load?" Test different sizes of balloons and paper clips.
- Visit http://www.discoverspace.org/ for more innovative ideas and resources.

Resources

Educator Guide: Simple Rocket Science Continued. (2019, January 29). Retrieved from https://www.jpl.nasa.gov/edu/teach/activity/simple-rocket-science-continued/

Newton's Laws:
Identify how a rocket demonstrates each of Newton's laws. You may complete this at any point throughout the Activity.

Laws	Summarize the law	Draw or describe how YOUR rocket demonstrates this law.
1st Law		
2nd Law		
3rd Law		

3. **Testing: Indicate with a check how many balloons were used in each.**
4. **For simplicity purposes: small paper clip =1 g, large paperclip =2 g**

Trial	1 balloon	2 balloons	3 balloons	Distance (meters)	Number of paper clips	Total mass
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

1. Draw or describe the rocket that lifted the most mass.

2. Draw or describe the rocket with the most STABLE lift and trajectory.

3. What changes did you make to your rocket to increase the efficiency?

Application: Why is efficiency important?

Launch costs are expensive! The current Atlas V can **launch 8123 kg for $164 Million** to LEO (Low Earth Orbit) at an altitude of 160-2000km **per a 2015 about ULA's rocket building & launch business. That works out to** a cost of **1 kg for $20,200!**

1 liter of water weighs 1 kg. Humans need 2 liters per day. Any plans of colonizing another planetary body must account for this. Although there are plans to create water (think the Martian) on both the Moon and Mars, this process takes time.

- ★ **How much would a 3 day stay in a Space hotel cost, in water alone?** ________________

Let's pretend you send Mark Whatney (aka Matt Damon) back into space, because Hollywood loves to rescue him. This time, you want him to create drinkable water from Hydroxyl found in lunar craters. He estimates this will take approximately two weeks.

Using your HIGHEST LIFTING ROCKET DATA, and with the scale of **1 g =1 kg**, calculate the cost of sending Dr. Whatney's water to the moon in lieu of him creating his own.

- ★ Assume that your rockets' highest lift represents a single launch capacity.
- ★ Add 100,000 for every launch after your first.
- ★ Show all work.

Total mass from highest lifting rocket in **g**	Total mass from highest lifting rocket in **Kg**	Cost of 1 launch	Liters of water needed for 2 weeks	Launches needed to meet water needs	Additional launch costs	Total cost of launching 2 weeks of water
	If your rocket did NOT reach the ceiling, add $500,000 to purchase another booster. **Total Cost:**					