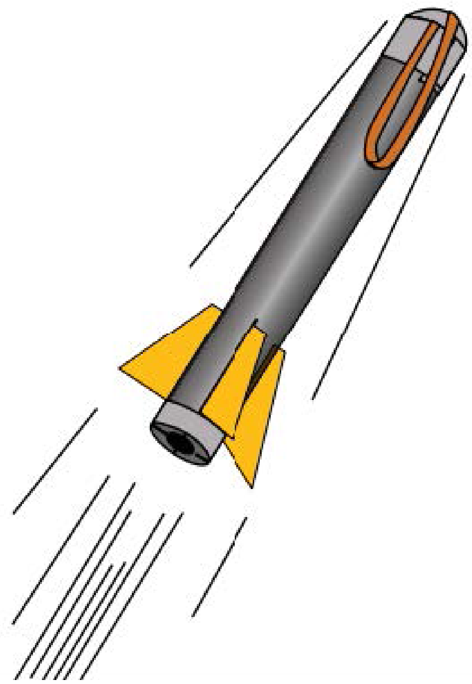
GODDARD ROCKETEERING

OBJECTIVE – Students will be able to learn about the history of Robert Goddard who pioneered liquid-propelled, controlled rocket flight. Students will also build a flying, rubber band-powered, foam model of Goddard's 1931 rocket.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- PS2.A: Forces and Motion
- PS3.B: Conservation of energy and energy transfer
- PS3.C: Relationship between energy and forces

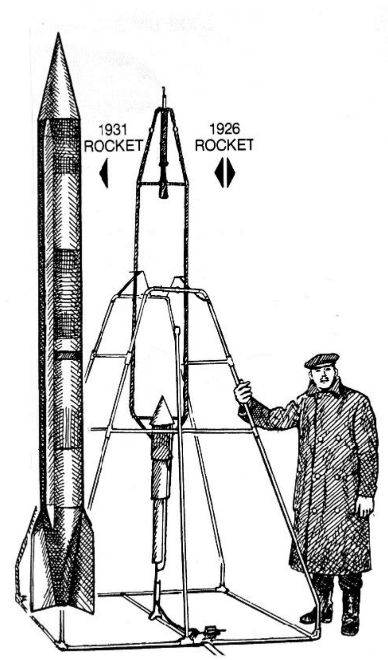
Crosscutting Concepts

- Systems and system models
- Energy and matter
- Structure and function

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

BACKGROUND– Rockets have been known to exist for centuries, but all of the thrust devices employed in these primitive "fire arrows," as the Chinese called them, were made of solid materials and once ignited, were uncontrollable.



Robert Hutchings Goddard, who is considered to be the Father of Modern Rocketry, was born in Worcester, Massachusetts, and as a boy, developed an interest in space travel. Later, as a scientist, he pioneered the technology of using liquids for thrust power instead of the uncontrol-lable solid fuels. By using a combination of liquids, rather than solids, Goddard was able to vary the volume of fuel flow and thus, get control of the amount of thrust produced. This paved the way for manned, rocket-powered craft.

In 1926, near Auburn, Massachusetts, Dr. Goddard successfully launched the world's first liquid-propelled rocket. To give a comparison of its potential, a liquid-fueled rocket the size of an automobile engine, produces approximately 3,000 times more power. Goddard's research opened the "door to space flight." To be able to go into space, man had to first break the sound barrier. On October 14, 1947, Charles E. "Chuck" Yeager accomplished this feat when his rocket-powered Bell XS-1 exceeded the speed of sound.

During his lifetime, Robert Goddard's work received little attention from his country and from his fellow scientists; however, after his death, the government recognized his great contributions and awarded his family the Congressional Gold Medal. For more information please visit Robert Goddard by SciShow Space (https://youtu.be/jSIq1XsdUqA). ROCKET SCIENCE 101 - (From the NASA Rockets Educators Guide: Foam Rocket https://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf)

The foam rocket flies ballistically. It receives its entire thrust from the force produced by the elastic rubber band. The rubber band is stretched. When the rocket is released, the rubber band quickly returns to its original length, launching the foam rocket in the process. Technically, the foam rocket is a rocket in appearance only. The thrust of real rockets typically continues for several seconds or minutes, causing continuous acceleration, until propellants are exhausted. The foam rocket gets a quick pull and then coasts. Furthermore, the mass of the foam rocket doesn't change in flight. Real rockets consume propellants and their total mass diminishes. Nevertheless, the flight of a foam rocket is similar to that of real rockets. Its motion and course is affected by gravity and by drag or friction with the atmosphere. The ability to fly foam rockets repeatedly (without refueling) makes them ideal for classroom investigations on rocket motion.

The launch of a foam rocket is a good demonstration of Newton's third law of motion. The contraction of the rubber band produces an action force that propels the rocket forward while exerting an opposite and equal force on the launcher.

In flight, foam rockets are stabilized by their fins. The fins, like feathers on an arrow, keep the rocket pointed in the desired direction. If launched straight up, the foam rocket will climb until its momentum is overcome by gravity and air drag. At the very top of the flight, the rocket momentarily becomes unstable. It flops over as the fins catch air. The rocket becomes stable again when it falls back to the ground. When the foam rocket is launched at an angle of less than 90 degrees, its path is an arc whose shape is determined by the launch angle. For high launch angles, the arc is steep, and for low angles, it is broad. When launching a ballistic rocket straight up (neglecting air currents) the rocket will fall straight back to its launch site when its upward motion stops. If the rocket is launched at an angle of less than 90 degrees, it will land at some distance from the launch site. How far away from the launch site is dependent on four things. These are: gravity, launch angle, initial velocity, and atmospheric drag.

Gravity causes the foam rocket to decelerate as it climbs upward and then causes it to accelerate as it falls back to the ground. The launch angle works with gravity to shape the flight path. Initial velocity and drag affects the flight time.

MATERIALS
a. 30 cm –long pieces of polyethylene foam pipe insulation (for ½" size pipe)
b. Styrofoam food tray or Styrofoam plates
c. Rubber band (size 64)
d. Scissors
e. Rocket construction instructions
f. Student Data Sheet
g. Duct tape
h. Eye protection
i. Meter stick (optional—for use with NASA plans)
j. Thumb tack (optional—for use with NASA plans)
k. Trundle wheel or measuring tape (optional – for use by class)

MANAGEMENT TIP – Precut the foam pipe into 30 cm pieces. The launch area should be a large room with a high ceiling, like a cafeteria or gymnasium. If the wind is calm, this lesson could also be conducted outside. It also may be helpful to have the students sitting in collaborative groups of 3-4 to help with construction.

1. Engage the students by showing them the interactive animated rocket launch game (http://www.science netlinks.com/interactives/gravity.html) that has different challenges related to launching a rocket. Experiment with different launch angles and allow students to see how the flight path of the rocket is changed when different launch angles are used. Be sure to keep the thrust the same when showing the students how angles change the flight path.

2. Inform the students that they are going to create their own rockets today and experiment with changing the launch angle to have the rocket travel the greatest distance.

3. Use the background information to facilitate a discussion on Robert Goddard, the Father of Modern Rocketry. Explain to the students the historical significance of his invention of the liquid fueled rocket.

4. Pass out the materials needed to construct the rocket to the collaborative groups. There should be enough materials for each student to make his/her own rocket. Sitting in the collaborative groups will help with overall construction of the rockets.

5. Guide the class in the procedures for constructing a foam rocket (https://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf).

6. Taking the 30 cm length of pipe foam, cut four equally spaced slits at one end of the tube. The slits should be 8-10 cm long. The fins will be mounted through the slits.

7. Cut a 12 cm length of duct tape down the middle to make two pieces. Place one piece over the other,sticky to shiny side, to make the tape double-strong.

8. Slip a rubber band over the tape and press the tape around the nose end of the rocket (opposite the end with the slits). Press the tape tightly and reinforce it with another length of tape wrapped around the tube.

9. Cut the fin pairs from the foam food tray or foam plate. Refer to the fin diagram on the next page. Both fin pairs should be notched so that they can be slid together as shown in the diagram. Different fin shapes can be used, but they should still "nest" together.

10. Slide the nested fins into the slits cut in the rear end of the rocket. Close off the slits with a piece of duct tape wrapped around the foam tube. The rocket is finished.

11. Model for the students how to launch the Goddard Rocket.
- Put one thumb into the rubber band at the "nose end".
- Pull on the fin end of the rocket to stretch the rubber band to about 4 inches.
- To launch the rocket, let go of the fin end of the rocket. You can pitch it forward in a slight arc.

12. Direct the students to follow the Student Data Sheet to conduct the experiment on how the length of the stretched rubber band affects the distance that the rocket travels and record observations. Remind students to try to keep the launch angle the same for all the trials. Have the students complete the chart as well as answer the questions.

13. At the conclusion of the activity, have the students share and compare their results with the other group members and even as a class, discussing discoveries made during the experiment.

EXTENSIONS

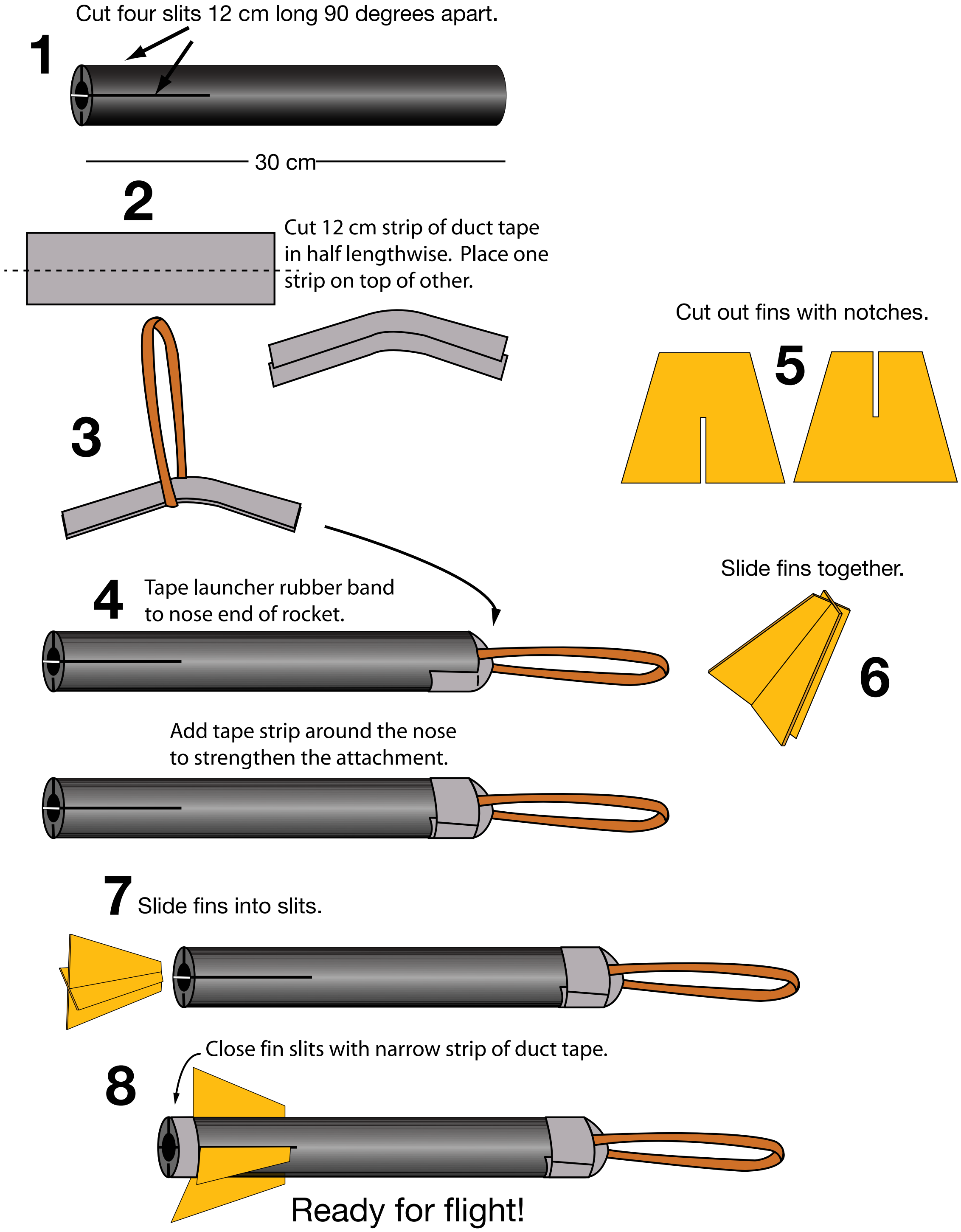
- Hold an accuracy competition and have the students aim the rockets at a target like a bucket or a paper bulls-eye.

- Have the students write about potential practical uses for the foam rocket (e.g. delivering messages).

- Challenge the students to create different kinds of fins for the foam rocket. Ideas could be a space shuttle orbiter or future rocket planes.

- Visit the following websites for more information on Goddard and rocketry.
  - o National Aviation Hall of Fame: Dr. Robert Goddard biography
    http://www.nationalaviation.org/goddard-robert/
  - o NASA Rockets Educator Guide
    http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Build a Foam Rocket



Source: http://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf

LAUNCH LOG: GODDARD ROCKETEERING

Name ______________________________ Date ______________________

Ask: What propels your rocket? ______________________________

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How does Newton's 3rd Law (for every action, there is an equal and opposite reaction) apply to your rocket?

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Imagine, Plan, Create: Draw a sketch of your rocket, including the details of your fins.

Number of Fins: ________________

Fin Shape Sketch:

Experiment: Adjust the length that you are pulling back on the rubber band according to the chart below. Try your best to keep the angle of release the same for each trial.

Length of Stretched Rubber band	Distance Traveled	Observations
1"		
2"		
3"		
4"		
5"		

Does the length of the stretched rubber band effect the distance the rocket travels after it is released? Explain.

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Improve: How could you improve on your rocket? What other variables could you test?

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