Rocket STEM

Implementation Guide

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1. IMPLEMENTATION GUIDE AND INSTRUCTIONAL RESOURCES

This implementation guide provides an overview of resources to support the challenge problems and activities. The challenge problems and activities included in this Teacher's guide are stand-alone problems, but complement one another. Therefore, the unit can be customized to include any number of challenge problems and activities that suit the instructional objectives or time constraints.

Consistent with the philosophy of problem-based learning, teachers should only facilitate as students progress through the assigned activities or challenges. This ensures that students are actively engaged in the learning and problem-solving process.

The resources in this unit are unique, but are not exhaustive or comprehensive. Many other rocket activities exist, some of which are included in Supporting Resources (Section 1.2).

1.1. ENGINEERING LOGBOOKS

Students should use engineering logbooks as a personal reference about project learning and results. Logbooks help monitor and control where students have invested their time, knowledge learned, resources, and problem solving. Educators can also use logbooks as a resource for grades for educators.

Teachers should have the following general expectations for logbook entries:

- Date for each entry
- Log of personal activity, communications, and team activity
- Research and engineering analysis
- Review of individual/team performance
- Include everything contributed towards the solution
- Sketches
- Class and meeting notes
- Math calculations
- Design process
- Project reflections
- Rationale for decisions
- Decision criteria
- Design alternatives
- Project requirements
- Links to helpful resources

Note: Include everything that contributed towards the solution: the good, the bad, and the ugly.

1.2. SUPPORTING RESOURCES

The resources identified below have been recognized as being helpful in guidance towards challenge problem solutions and completing activities. These resources are neither exhaustive nor comprehensive and should not be treated as tutorials. Rather, they should be used by the teacher to help guide and scaffold instruction.

Table 5: Educational Resources

Title	URL	Brief Description
NASA Beginner's Guide to Rockets	http://exploration.grc.nasa.gov/education/rocket/bgmr.html	Comprehensive site containing information about the basic math and physics that govern the design and flight of rockets. Includes information on many types of rockets.
NASA All About Water Rockets	http://exploration.grc.nasa.gov/education/rocket/BottleRocket/about.htm	In depth site about water bottle rockets that also serves as a walk-through for principles of rocketry.
Rocket Modeler III	http://www.grc.nasa.gov/WWW/k-12/rocket/rktsim.html	Rocket flight simulator that allows one to modify rocket design and launch variables.
NASA Rockets Educator Guide	http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html	This guide includes information on the background of rockets and basic rocket science as well as rocket activities and lesson plans for all grade levels.

National Physics Laboratory Water Rocket Challenge	http://www.npl.co.uk/educate-explore/water-rocket-challenge/	Site for the challenge that contains many helpful resources including a comprehensive booklet about water bottle rockets.
Bottle Rocket Unit Plan	http://engineeringyourworld.pbworks.com/w/page/27462921/Bottle%20Rocket%20Unit%20Plan	Alternative unit plan; includes learning plan and assessments.
SECME Water Rocket Competition	http://secme.secme.org/docs/competition/2014%20SECME%20National%20Student%20Competition%20Guidelines_FINAL%20(WBR%20Only).pdf	Includes rules and guidelines for water rocket competition and judging/ grading rubrics.
Air Command Water Rockets	http://www.aircommandrockets.com	General water rocket site that contains tutorials, articles, links, etc.
Smooth-On FlexFoam-iT!®	http://www.smooth-on.com/Rigid-and-Flexible/c10_1121/index.html	Additional information on FlexFoam-iT!® including Material Safety Data Sheet (MSDS).

Table 6: Modeling and Simulation Software

Title	URL	Brief Description
SketchUp	http://www.sketchup.com/	3D modeling software. (Free)
Autodesk Inventor	http://www.autodesk.com/education/free-software/inventor-professional	3D modeling software. (Free for students)
Autodesk Flow Design	http://www.autodesk.com/education/free-software/flow-design	Virtual wind tunnel software. (Free for students)

Table 7: Wind Tunnel Resources

Title	URL	Brief Description
NASA Rocket Wind Tunnel	http://www.nasa.gov/pdf/295793main_Rockets_Wind_Tunnel.pdf	From the NASA Rockets Educator Guide: plans for a simple rocket wind tunnel.
Apogee Rocket Wind Tunnel	http://www.apogeerockets.com/downloads/Newsletter252.pdf	Inexpensive wind tunnel plans; alternate method to identify center of pressure.
Simple Drag Test for Water Rockets	http://www.seeds2lrn.com/WaterRocketLab.pdf	Very basic, wind tunnel-based method to measure rocket drag.

Table 8: Physics Video Analysis Software

Title	URL	Brief Description
Tracker	https://www.cabrillo.edu/~dbrown/tracker/	Physics video analysis and modeling tool. (Free)
Vernier Video Physics	https://itunes.apple.com/us/app/vernier-video-physics/id389784247?mt=8	Physics video analysis app for iPhone, iPod, and iPad. ($4.99)
Vernier Logger Pro	http://www.vernier.com/products/software/lp/	Physics data collection and analysis software. ($229)

1.3. KIT MATERIALS

For convenience and accessibility, a kit has been developed containing nearly all of the physical materials necessary for the activities and challenges. If this kit is not available, the materials used are listed below.

This kit was assembled with a grant from Battelle. Part of the grant requirements include reporting information such as number and location of students that were served. Please fill out the Survey (Section 1.3.2) following the Kit Inventory.

Because this is a shared resource, your comments and suggestions are valuable for improving this resource. Additionally, please feel free to contribute your lessons or activities to this kit. To add anything, please contact Angie Wendel (angela_wendel@darke.k12.oh.us).

1.3.1. KIT INVENTORY

If borrowing the kit, please check to ensure all materials and remaining consumables are returned.

Tote A: Rocket Launch Equipment

- ☐ 1 x rocket launcher (1" PVC pipe)
- ☐ 4 x launcher feet (spikes in PVC caps)
- ☐ 3 x launch tubes (1" PVC pipe with rocket release mechanism)
- ☐ 1 x launch rope
- ☐ 1 x floor bicycle pump
- ☐ 1 x ticker (graduated 1.5" PVC pipe)
  - 4 x 1 m PVC pipes
  - 3 x couplers
  - 3 x tees
  - 6 x 0.5 m PVC pipes
- ☐ 2 x Teflon tape

Tote B: Rocket Build Kit

- ☐ 1 x Teacher Resources booklet
- ☐ 1 x Teacher Resources flash drive
- ☐ 1 x NASA Educator Guide
- ☐ 1 x spherical nose cone mold
- ☐ 1 x conical nose cone mold
- ☐ 6 x packing tape w/ dispensers
- ☐ 1 x brick Gulf wax
- ☐ 1 x box latex gloves
- ☐ 2 x chemical mixing scoops
- ☐ 1 x 1000 mL plastic graduated cylinder
- ☐ 4 x heavy duty shears
- ☐ 2 x large speed squares
- ☐ Flex Foam iT! X (2 x gallon jugs)
- ☐ Clear plastic cups
- ☐ Large red plastic cups
- ☐ Popsicle sticks
- ☐ 1/16" polycarbonate fin material

Tote C: Measuring Kit

- ☐ 10 x Estes Inclinometers
- ☐ 10 x stopwatches
- ☐ 1 x 100' tape measure

Tote D: Rocket Sleeves

- ☐ 5 x conical nose cone sleeves
- ☐ 5 x spherical nose cone sleeves
- ☐ 10 x tail fin sleeves

1.3.2. SURVEY

School:		Teacher name and email:	
Grade:	Course:	# of students:	Time it took to complete the unit:
Outline of activities completed:			
Comments or suggestions:			

1.4. ROCKET LAUNCH PROCEDURES

The following procedures detail how to launch a rocket and analyze the launch using the items provided in the Kit.

1.4.1. CASTING NOSE CONES

FlexFoam-iT! is a two-part, nontoxic, odorless polyurethane foam. Each of the two components come in a gallon container and will supply at least three expansion coefficient labs as well as casting nose cones for 100 rockets.

This foam is very safe to work with (see the Material Safety Data Sheet available at http://www.smooth-on.com/msds/files/FlexFoam_It_Series.pdf); however, it is very sticky and messy if it gets onto skin or clothes. Water and soap are the suggested clean-up methods.

A video tutorial is on the DVD included in the kit.

Materials

- ☐ Nose cone mold
- ☐ 2L bottles
- ☐ Graduated cylinders (100 mL and 1000 mL)
- ☐ FlexFoam-iT!®
- ☐ Gulf wax
- ☐ Hot plate and metal pan
- ☐ Clear plastic cups
- ☐ Disposable party cups (e.g. Solo cups)
- ☐ Stirrers
- ☐ Timer

Procedure

1. Determine the volume of the nose cone mold. **To add an additional math component, students can determine volume by measuring the dimensions of the nose cone and using the appropriate formula to calculate volume. Compare the calculated results to the method below.
    a. Pour water into the mold.
    b. Submerge the end of a 2L bottle into the mold to displace excess water.
    c. Measure remaining water with a graduated cylinder; this is the total volume of FlexFoam-iT!® needed for casting nose cones.
2. Coat the mold with wax.
    a. Melt Gulf wax on low heat.
    b. Pour the wax into mold and rotate mold to generously coat the mold.
    c. Let wax cool completely.
3. Calculate the volume of each component of FlexFoam-iT! needed for the nose cone**. FlexFoam-iT! X expands approximately 5.5X its original volume.
    a. Add 10% to account for product lost during pouring.
    b. Mix FlexFoam-iT! X Part A and Part B 1:1 by volume.
    c. Use the following example calculation:
        - Nose cone volume: 500 mL

- Add 10% extra: 550 mL
- Divide by expansion coefficient (550 mL/5.5): 100 mL
- Divide by 2: 50 mL
- Use 50 mL Part A and 50 mL Part B

4. Prepare molding area and materials.
   a. Cover work area with paper or plastic.
   b. Mark clear plastic cups (supplied) with the volume determined in step 3.
      i. Measure that volume of water with a graduated cylinder, pour into the cup, and mark the meniscus with a Sharpie.
      ii. Dry cup completely, water will affect the foam reaction.
      iii. Use this cup as a template to mark other cups.
   c. Pour each component into smaller containers, which makes it easier to pour into the measuring cups.

      Note: Disposable plastic cups (e.g., Solo cups) are ideal, beakers are difficult to clean.
   d. After the activity, pour leftover components back into their respective containers. Make sure that you pour into the correct container, a mistake will ruin the product.
5. Cast the nose cone:
   a. Pour the appropriate amounts of parts A and B into the clear plastic cups. Optional: add a few drops of food coloring to Part B.
   b. Pour Part A (less viscous) into Part B (more viscous).

      Note: Use a separate mixing container if the total volume will greater than that of the cup.
   c. Stir vigorously for one minute.
   d. Pour into mold, scraping all contents into mold.
   e. Place the bottom of the 2L bottle in the mold—hold applying downward pressure for four more minutes. It is imperative to make sure the 2L bottle is level in the mold, otherwise the nose cone will be offset causing the rocket to not fly straight.

      Note: The reaction starts immediately after pouring into the mold and will complete in approximately four minutes. The reaction does not produce any vapors or fumes, but it does evolve heat (not enough to cause discomfort or burns)
   f. Allow the foam to cure for two or more minutes and then remove the mold.

When the supply of FlexFoam-iT!® it runs low, please contact Philip Bottelier at the Dayton Regional STEM school, (philip.bottelier@wright.edu phone 937.479.9944), he will order more. Please allow a week or two for the order to arrive.

1.4.2. PREPARATION

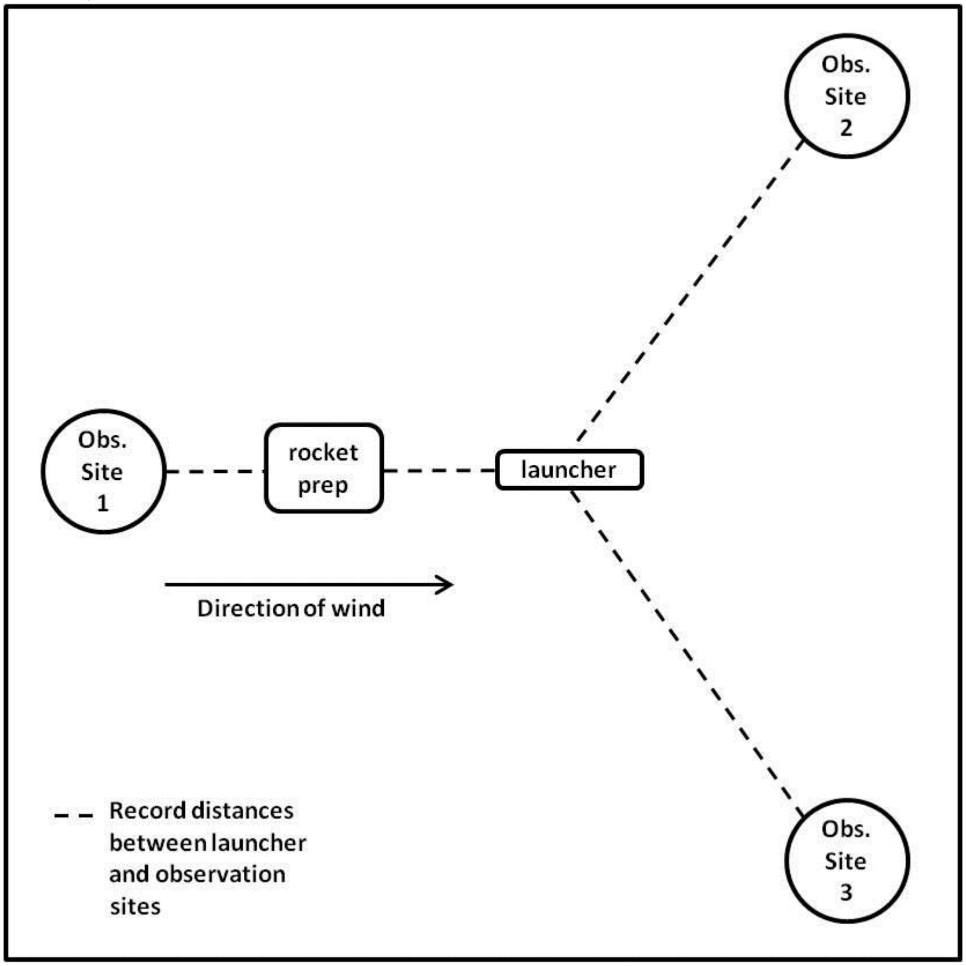
Student Preparation (complete prior to launch day)

1. Practice using the inclinometers and stopwatches.
2. Assign students their initial roles and discuss launch day.
    a. Students can rotate or trade stations after they launch their rocket.
    b. If running a strict experiment, students should keep the same roles throughout to eliminate variability.

Prepare the Launch Area

1. If possible, prepare the launch area well before launch time.
2. Set up launcher (see below) so that the person launching is upwind of the launcher.

3. Measure and mark three observation sites at least 100 feet away from the launcher and 120° apart relative to the launcher.



4. Setup rocket preparation area using water source with graduated cylinder

1.4.2.1. LAUNCH DAY

Notes:

- For safety, try to launch on a day that is not too windy.
- Always have students prepare their rockets and launch upwind from the launcher.
- Give students specific roles to keep them engaged.

Materials

- ☐ Launch field (e.g. football field, large parking lot)
- ☐ Students' rockets
- ☐ Safety glasses
- ☐ Launcher
- ☐ Launch tubes
- ☐ Launch rope
- ☐ Launch stake
- ☐ Bicycle pump
- ☐ 100' tape measure

- ☐ Bucket or other container of water (large drink dispenser works well)
- ☐ 1000 mL graduated cylinder
- ☐ Stopwatches
- ☐ Launch and Data Logs

Optional:

- ☐ Ticker pipe (if analyzing speed)
- ☐ Inclinometers
- ☐ Clipboards (1+ per observation site)

1.4.2.2. LAUNCH TIME

Teams of students can rotate around the different stations/roles so that everyone participates in every capacity. Extra teams could be distributed to the observation sites to collect data or should observe upwind from launcher.

Rocket Preparation Site

1. Inspect students' rocket for any defects that could cause unsafe flight; e.g., defects in the bottle, crooked nose cone or fins.
2. Fill bottle to the specified volume; determined with the simulator or according to the experiment.
3. Securely lock rocket onto launch tube.

Observation Sites

1. One person measures angle of the maximum height with the inclinometer.
2. One person measures the time of flight; from launch to landing or maximum height to landing (for free fall calculations).
3. One person records the data.

Tracking and Retrieval Team

- Responsible for tracking the rocket flight and warning others if they are in danger of the falling rocket.
- They should NOT try to catch the rockets—depending on height, rockets could be traveling up to 90 mph right before landing.

Launch Team

- *Must wear safety goggles
- Records parameters in launch log
- Ensures rocket is securely locked on launch tube and screws launch tube onto launcher
- Applies the prescribed pressure using the bicycle pump
- When everyone is clear of the launcher, clearly and loudly countdowns the launch, and pulls the rope from a safe distance

1.4.3. DATA COLLECTION OF ROCKET LAUNCH

The following section details the procedures for calculating velocity and acceleration, as well as height.

1.4.3.1. VELOCITY AND ACCELERATION

Velocity and acceleration can be calculated via analysis of high-speed video of the launch. A ticker device (graduated PVC pipe) is included in the kit to facilitate distance measurements. However, if no ticker is available, the rocket or launcher can be used as an object of known length for calibration in a physics analysis software.

Materials needed

- ☐ High-speed camera capable of ≥100 fps
  Note: iPhone 5s is capable of 120 fps in SLO-MO mode, apps (e.g. SloPro app by Sand Mountain Studios) can slow video to 1000 fps
- ☐ Tripod
- ☐ Physics analysis software or other media player capable of frame-by-frame advancement:
  - Tracker Video Analysis and Modeling Tool
  - Vernier Video Physics app for iPad, iPhone, and iPod Touch
  - Vernier LoggerPro
- ☐ Ticker (graduated PVC pipe, supplied in kit)

Procedure

1. Record the launch in high speed, making sure the rocket and whole height of the ticker pipe is in frame.
2. Open the video in a physics analysis software and use the software to calculate velocity and acceleration. You can also use any media player by advancing through the frames and using the ticks as reference for distance. You can determine frames per second (fps) of the video by right-clicking on the video file and selecting *Properties→Details→Frame Rate.*

Many of these programs are capable of producing different graphs (distance vs. time, speed vs. time, etc). Teachers can challenge students to produce these graphs either through the software or by hand.

1.4.3.2. HEIGHT

There are three different methods to determine maximum height:

1. Altimeter
2. Calculations using time
3. Calculations using trigonometry

These methods calculate maximum height only; not horizontal distance flown. Students can compare the methods and determine which are the most accurate or most precise. Students can also calculate the error associated with each method or variable tested.

Note: The simplest way to assess rocket flight is to record the time of flight of the rocket, from launch to landing. This is the method by which many water bottle rocket contests measure rocket flight. Students can then compare flight times to approximate height. This method is appropriate if math is not an integral part of the lesson. This method is also better suited for K-8 grades as to avoid confusion of the trigonometry and free fall kinematic equations.

Materials needed

- Altimeter
- Stopwatch
- Inclinometer: commercial (e.g., Estes), DIY inclinometer, or inclinometer smartphone app

Procedure

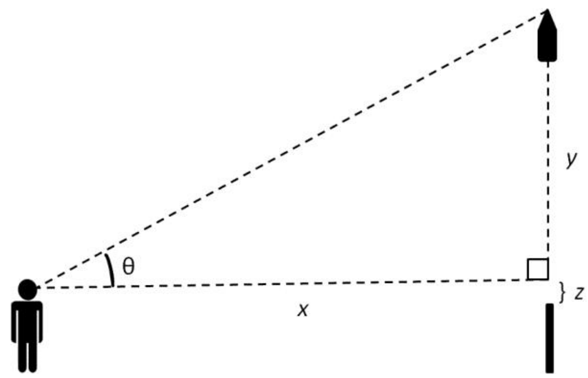
1. Altimeter
   A commercial altimeter can be encapsulated in the rocket and will record maximum altitude. Follow manufacturer's instructions.

   Note: In our experience, altimeters have not been shock-proof; they tend not to function after one rocket launch.

2. Time
   a. Have three students stand at a known distance from the rocket launcher forming a triangle with the launcher in the center.
   b. Using a stopwatch, each student should record the time of flight from maximum height to landing.
   c. Use the equation $d = v_i t + \frac{1}{2} gt^2$ to calculate maximum height; where:
      - d = distance
      - v_i = initial velocity = 0 m/s
      - t = time (in seconds)
      - g = acceleration due to gravity = 9.8 m/s^2
      - because v_i = 0 m/s, the equation can be simplified to $d = \frac{1}{2} gt^2$
   d. Average the three values.

      Note: This calculation does not account for air resistance.
3. Trigonometry
   a. Have three students stand at a known distance from the rocket launcher forming a triangle with the launcher in the center.
   b. Each student should record the maximum angle of the rocket using an inclinometer.
   c. Use the equation $y = x(\tan \theta)$ (see below); where
      - y = height
      - x = distance between student and launcher

- θ = measured angle



d. Optional: Account for the difference between launcher height and eye level of observer (*z*).
   - Either add or subtract the difference to the height obtained in step c.
   - You can consider this difference negligible in most cases and thus exclude it from the calculation for clarity.

e. Average the three values.

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