Activity Two: Track the Altitude of a Rocket

Educator Notes

Challenge

Students will construct and use an altitude tracker and altitude calculator to estimate the height of a rocket at apogee (the highest point of the trajectory of the rocket).

Suggested Time

120 minutes

Learning Objectives

Students will

- Construct and use an altitude tracker to collect and analyze data from the flight of a rocket.
- Construct and use an altitude calculator to estimate the height of a rocket at apogee.
- Use a tangent table to estimate the height of the rocket at apogee and compare the result to that of the altitude calculator.

Curriculum Connection

Science and Engineering (NGSS)	
Crosscutting Concepts • Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. *Science and Engineering Practices* • Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.	*Science and Engineering Practices (continued)* • Using Math and Computational Thinking: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships. • Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.
Technology (ISTE)	
Standards for Students • Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others. – 3d: Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions. • Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.	*Standards for Students (continued)* – 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem solving. • Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally. – 7c: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.
Mathematics (CCSS)	
Content Standards by Domain • CCSS.MATH.CONTENT.6.NS.B.3: Fluently add, subtract, multiply, and divide multidigit decimals using the standard algorithm for each operation. • CCSS.MATH.CONTENT.7.NS.A.2: Apply and extend previous understandings of multiplication and division and of fractions to multiply and divide rational numbers. – CCSS.MATH.CONTENT.7.NS.A.2.C: Apply properties of operations as strategies to multiply and divide rational numbers.	*Content Standards by Domain (continued)* • CCSS.MATH.CONTENT.7.NS.A.3: Solve real-world and mathematical problems involving the four operations with rational numbers. *Mathematical Practices* • CCSS.MATH.PRACTICE.MP4: Model with mathematics. • CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically. • CCSS.MATH.PRACTICE.MP6: Attend to precision.

Preparation Time

15 minutes

- Read the Introduction and Background, Educator Notes, and Student Handout to become familiar with the activity.
- Gather and prepare all supplies listed on the materials list.
- Print the two templates for the altitude calculator onto heavyweight paper or glue the templates onto lightweight posterboard for each team. (Templates can be found at the end of the Educator Notes.)
- A teacher aide or older student should place the front template for the altitude calculator on a cutting surface and cut out the three oval windows. A sharp knife or razor works best.
- Students will be constructing the altitude trackers for this activity, so no preparation work is needed for this item.

- Determine which rocket activity you would like to pair with this challenge (e.g., Activity One foam rocket, Activity Four water rocket, or NASA's online Pop! Rocket activity).
- Set up tracking station locations at 5-m intervals from the launchsite. The more powerful the rocket, the farther away each station should be from the launchsite. Depending upon the expected altitude of the rocket, the tracking station should be 5, 15, or 30 m away. (Generally, a 5-m distance is sufficient for foam or Pop! Rockets, a 15-m distance is sufficient for water rockets, and a 30-m distance is sufficient for model rockets.)

Materials

- ☐ Altitude tracker template
- ☐ Altitude calculator template
- ☐ Copy of tangent table
- ☐ Copies of Student Handout and blank paper
- ☐ Thread or lightweight string
- ☐ Cardboard or posterboard
- ☐ Glue
- ☐ Clear tape
- ☐ Small washers
- ☐ Milkshake straws
- ☐ Brass paper fasteners
- ☐ Scissors
- ☐ Razor blade knife and cutting surface
- ☐ Meterstick or metric tape measure
- ☐ Rocket and launcher (e.g., water rocket, foam rocket, or Pop! Rocket)

Introduce the Challenge

- Introduce any new terminology (e.g., altitude, angle of elevation, apogee, baseline tangent, and trajectory).
- Discuss different methods for determining the height of a rocket during launch.
- Explain that determining the altitude of a rocket is a team activity. While part of the team prepares and launches the rocket, the other team members will measure the angle of elevation of the rocket at the highest point of its trajectory from a tracking station. The angle measurement is then used with an altitude calculator and/or tangent table to determine the height at apogee. Roles should be reversed so everyone gets a chance at both activities.
- Distribute the Student Handout and blank paper and explain the challenge.

Facilitate the Challenge

Ask, Imagine, and Plan

Engage the students with the following discussion questions:

- At what angle should you launch your rocket for maximum altitude?
- What would happen if you changed the launch angle?
- Besides launch angle, what other factors will impact the trajectory of your rocket?
- What are some possible sources of error in this activity? How could your team eliminate or reduce them? (One recommendation is to set up multiple tracking stations and average the results from those measurements.)

Share With Students

Brain Booster

The markings on the outside of the SLS's solid rocket boosters look like black-and-white checkerboards and serve as "targets" for cameras located in strategic locations on and around the vehicle. These markings will be used for photogrammetry, the science of using photography to help measure distances between objects. These targets will enable photogrammetrists to measure critical distances during spaceflight, including booster separation from the core stage.

Learn more: https://www.nasa.gov/exploration/systems/sls/space-launch-system-solid-rocket-boosters-on-target-for-first-flight.html

On Location

The Boeing Company in Huntsville, Alabama, is building the SLS core stage, including the avionics that will control the vehicle during flight. Towering more than 60 m (200 ft) with a diameter of 8.4 m (27.6 ft), the core stage will store 2,760,000 L (730,000 gal) of super-cooled liquid hydrogen and liquid oxygen that will fuel the RS–25 engines.

Learn more: https://www.nasa.gov/sites/default/files/atoms/files/sls_core_stage_fact_sheet_01072016.pdf

Create

- Tip: The altitude tracker is simple enough for everyone to make their own, but they can also be shared.

Test

- Ask the teams to determine the maximum altitude that can be measured with their altitude tracker at each of the three tracking station locations (5, 15, and 30 m).

Share

Engage the students with the following discussion questions:

- What was the greatest challenge for your team today?
- Were there any differences in the measurement of the altitude of the rocket for each trial using the altitude calculator versus the tangent table? Why or why not?
- What factors affected your team's ability to determine the rocket's altitude? How might you adjust this experiment to get more accurate results?

Extensions

- Challenge your students to demonstrate their proficiency with altitude tracking by sighting on a fixed object of known height and comparing their results.
- Employ two or more tracking stations from different perspectives or different distances. Compare measurements from each station and calculate the average.
- Apply basic trigonometry to calculate the height of the rocket at apogee. Compare the results to those of the altitude calculator and tangent table.
- Experiment with different launch angles and graph angle versus altitude.

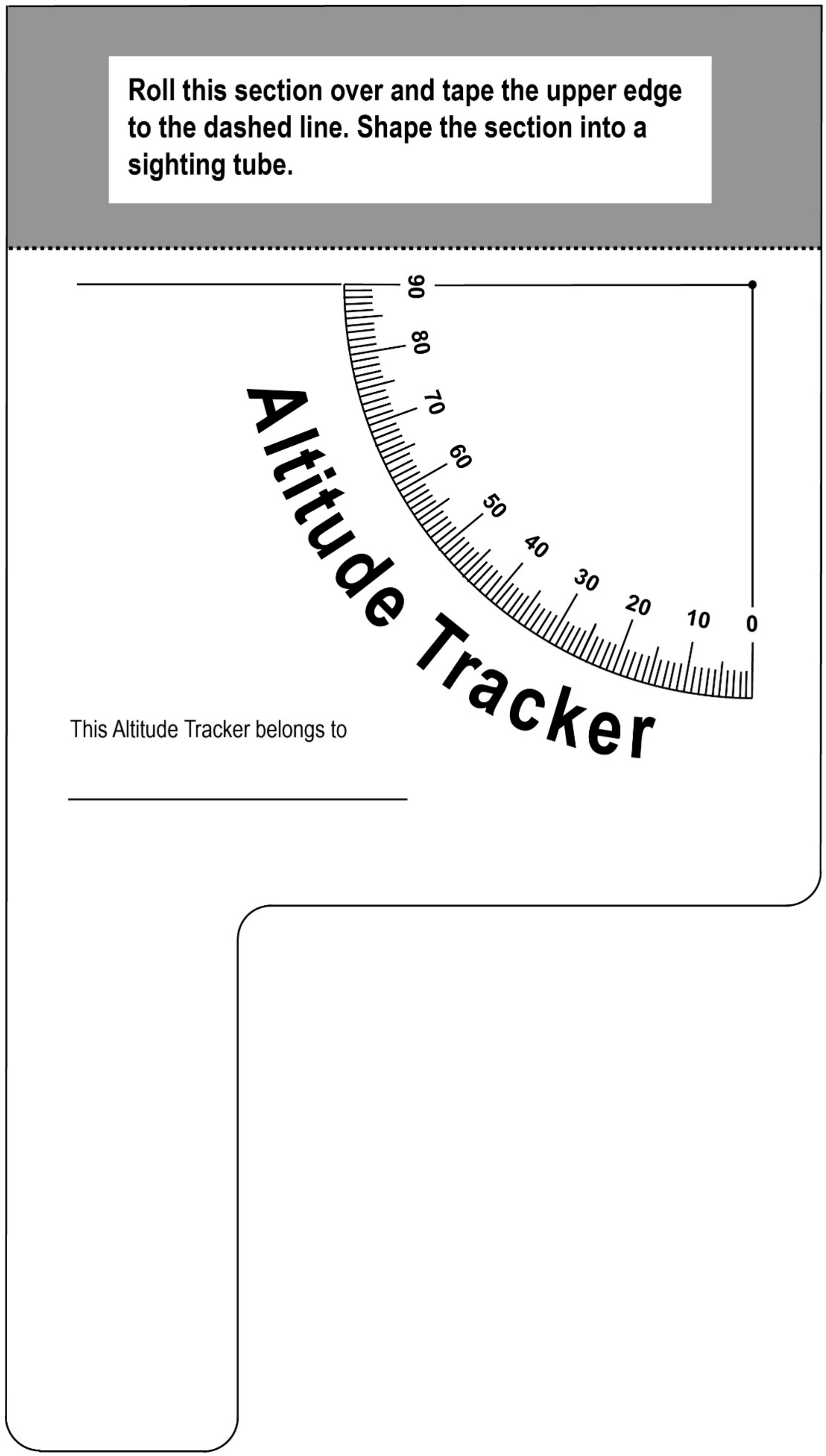
Reference

Modified from Altitude Tracking: https://er.jsc.nasa.gov/seh/Altitude_Tracking.pdf

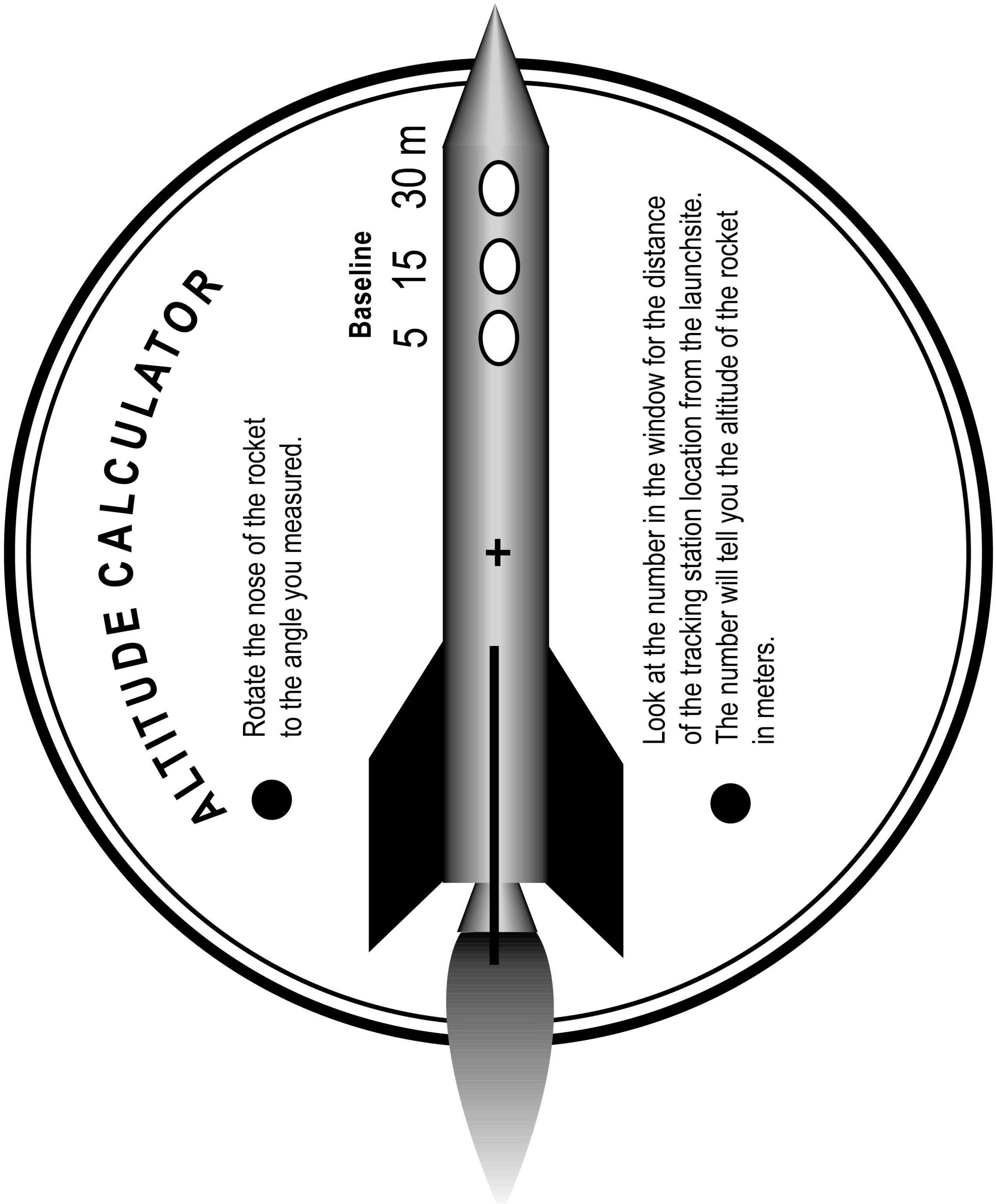
Additional Resource

- Activity: Pop! Rocket. https://www.nasa.gov/stem-ed-resources/pop-rockets.html
- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

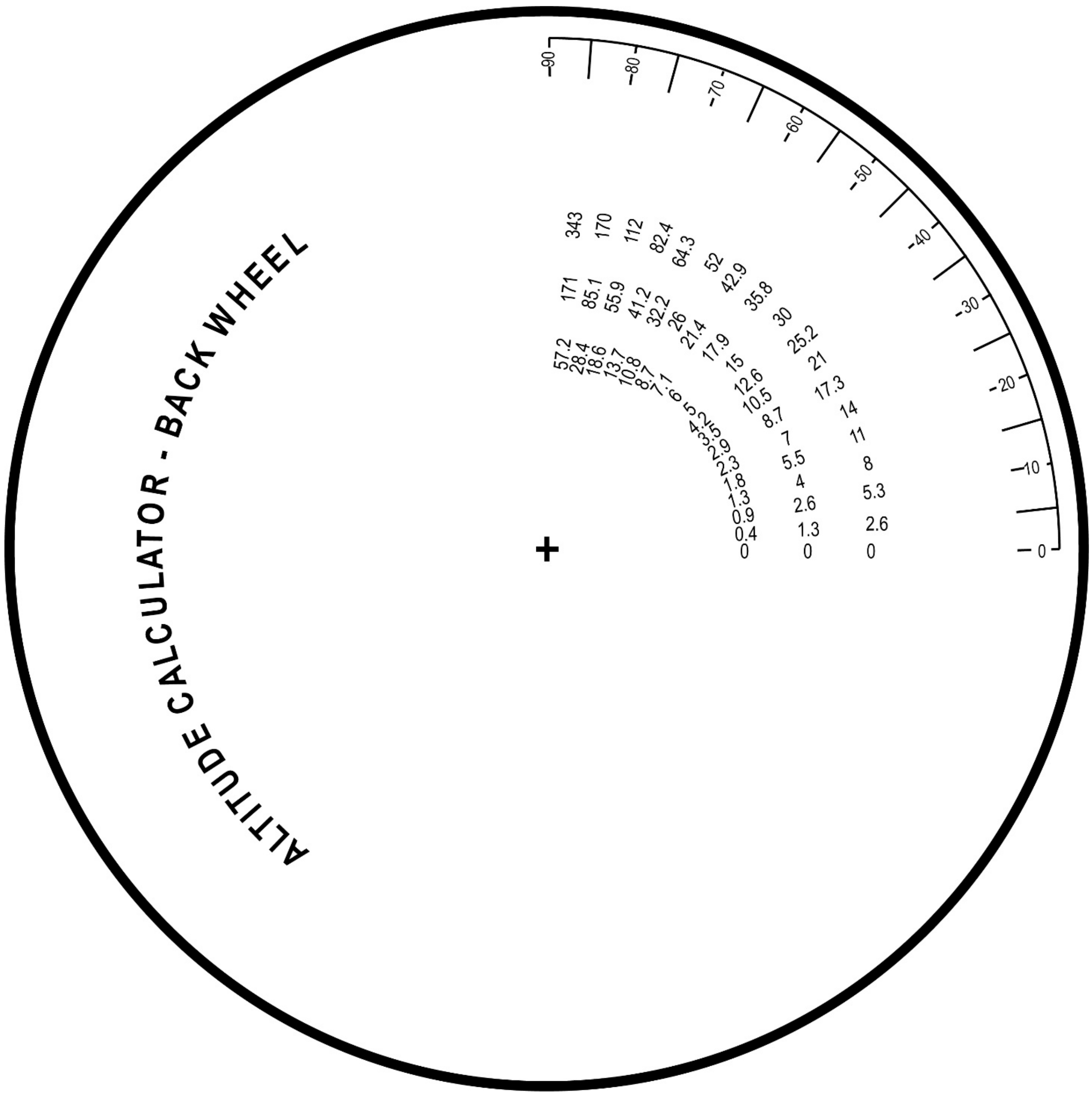
Altitude Tracker Template



Altitude Calculator Template—Front



Altitude Calculator Template—Back



Tangent Table

Degree	Tan	Degree	Tan	Degree	Tan
0	0.0000				
1	0.0174	31	0.6008	61	1.8040
2	0.0349	32	0.6248	62	1.8807
3	0.0524	33	0.6494	63	1.9626
4	0.0699	34	0.6745	64	2.0603
5	0.0874	35	0.7002	65	2.1445
6	0.1051	36	0.7265	66	2.2460
7	0.1227	37	0.7535	67	2.3558
8	0.1405	38	0.7812	68	2.4750
9	0.1583	39	0.8097	69	2.6050
10	0.1763	40	0.8390	70	2.7474
11	0.1943	41	0.8692	71	2.9042
12	0.2125	42	0.9004	72	3.0776
13	0.2308	43	0.9325	73	3.2708
14	0.2493	44	0.9656	74	3.4874
15	0.2679	45	1.0000	75	3.7320
16	0.2867	46	1.0355	76	4.0107
17	0.3057	47	1.0723	77	4.3314
18	0.3249	48	1.1106	78	4.7046
19	0.3443	49	1.1503	79	5.1445
20	0.3639	50	1.1917	80	5.6712
21	0.3838	51	1.2348	81	6.3137
22	0.4040	52	1.2799	82	7.1153
23	0.4244	53	1.3270	83	8.1443
24	0.4452	54	1.3763	84	9.5143
25	0.4663	55	1.4281	85	11.4300
26	0.4877	56	1.4825	86	14.3006
27	0.5095	57	1.5398	87	19.0811
28	0.5317	58	1.6003	88	28.6362
29	0.5543	59	1.6642	89	57.2899
30	0.5773	60	1.7320	90	------------

Activity Two: Track the Altitude of a Rocket

Student Handout

Your Challenge

Construct and use an altitude tracker and altitude calculator to estimate the height of a rocket at apogee (the highest point of the trajectory of the rocket).

Ask, Imagine, and Plan

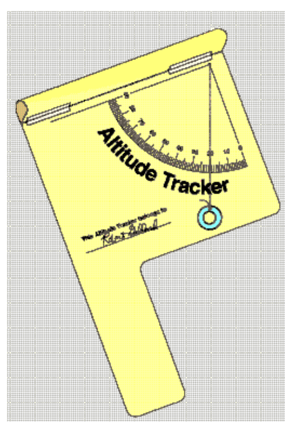
- At what angle should you launch your rocket for maximum altitude?
- What would happen if you changed the launch angle?
- Besides launch angle, what other factors will impact the trajectory of your rocket?
- What are some possible sources of error in this activity and how can your team mitigate them?
- Discuss the best location for a tracking station to determine the altitude of your rocket. Depending upon the expected altitude of the rocket, the tracking station could be 5, 15, or 30 m away. What is the maximum altitude that can be measured with the altitude tracker at each of the three tracking station locations (5, 15, and 30 m)? What distance will your team select for your tracking station and why?

Create

Construct both the altitude tracker and the altitude calculator using the following instructions. (Some of these steps may have already been completed by your teacher.)

Constructing the Altitude Tracker

1. Glue the altitude tracker template onto a piece of cardboard. Do not glue the portion of the tracker above the dashed line.
2. Cut out the template and cardboard along the outside edges.
3. Roll the part of the template not glued to the cardboard (shaded portion) around a milkshake straw and tape it along the top edge of the altitude tracker as a scope or sighting tube.
4. Punch a tiny hole in the apex of the protractor quadrant (the point at the upper right-hand corner).
5. Slip a thread or lightweight string through the hole. Knot the thread or string and tape it on the backside.
6. Complete the tracker by hanging a small washer from the other end of the thread as shown in the illustration.



Constructing the Altitude Calculator

1. Carefully cut out the front and back templates for the altitude calculator.
2. Join the two templates together where the center marks are located. Use a brass paper fastener to hold the pieces together. The pieces should rotate smoothly.

Test

Using the Altitude Tracker

1. Create a data table like the one that follows here on your sheet of paper.

Fun Fact

Hot gases exit the nozzle of the RS–25 engine at 13 times the speed of sound, or fast enough to travel from Los Angeles to New York in 15 minutes!

Learn more: https://www.youtube.com/watch?v=kJo157o_qaw

Career Corner

Mechanical engineers design, develop, build, and test mechanical devices, including tools, engines, and machines. NASA's SLS rocket needs mechanical engineers to work on the many different components of the rocket. One of the components designed by NASA engineers is used to steer the rocket. This part moves the nozzle of the rocket engine to point the SLS in the right direction.

Learn more: https://www.nasa.gov/exploration/systems/sls/outreach/engineering.html

Trial	Baseline distance, m	Angle of elevation, deg	Altitude using altitude calculator, m	Tangent of the angle	Altitude using tangent table, m
1					
2					
3					
4					
5					
6					
7					
8					

2. Select a tracking station location a short distance away from the rocket launchsite to measure the maximum height of the rocket using the altitude tracker. In your data table, record the baseline distance from the tracking station to the launch pad for each trial.
3. As the rocket launches, the person doing the tracking will hold the tracker at eye level and tilt the tracker upward, following the trajectory with the sighting tube. Stop and hold the tracker steady when the rocket reaches apogee, its highest point before falling back to Earth. Have another team member read the angle the thread or string makes with the quadrant protractor and record the angle of elevation for each trial in the data table.
4. Use the altitude calculator and/or tangent table to determine the altitude of the rocket in meters.

Using the Altitude Calculator

1. Rotate the inner wheel of the calculator so that the nose of the rocket pointer is aimed at the angle measured with the altitude tracker for each trial.
2. Read the altitude of the rocket by looking in the appropriate window associated with the baseline distance from the tracking station to the launch pad. The altitude the rocket reached will be in the window beneath the markings for 5, 15, or 30 m.
3. To achieve a more accurate measure of altitude, add the height from the ground to the eye level of the person holding the tracker.
4. If the angle falls between two degree marks, average the altitude numbers above and below those marks.

Using the Tangent Table

1. Identify the tangent of each launch angle using the tangent table and record it in your data table.
2. Multiply the tangent of the angle with the baseline distance to determine the altitude of the rocket for each trial.

Share

- Compare the values of the altitude of the rocket for each trial using the altitude calculator versus the tangent table. Were there any differences? Why or why not?
- What factors affected your team's ability to determine the rocket's altitude? How might you adjust this experiment to get more accurate results?