

Mayday on Mars

Gathering and Displaying Data to Support Engineering

The Tech Challenge 2018 Lesson 2: Math

Developed by The Tech Academies of Innovation

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I. Lesson Overview

Engineers often run into technical issues with their devices and engineering solutions can be helpful in these emergency situations. Can you build a device to help engineers move their device to a specific target without using any powered sources?

Lesson Description:

During this lesson, student engineers will build and test a balloon-powered device that will help an astronaut on Mars reach a drill site. Students will then analyze data gathered from the test trials of various devices in order to iterate their designs. Data will be displayed in line plots, and students will look to see what patterns, if any, have emerged.

Grade Levels: 4-8

Education Outcomes

Students will:

- Build and test a device which uses stored energy in a balloon to reach a specified target.
- Construct a line plot (dot plot) displaying a data set of measurements in fractions of a unit.
- Look for recognizable patterns between test trials, as well as between groups.
- Compare and contrast data sets from multiple groups in order to identify similarities and differences.



Education Standards Met: (Note: bolded parts of the standards are fully met by this lesson)

Common Core State Standards (CCSS);

[4-5th] CCSS.MATH.CONTENT.5.MD.B.2 **Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$).** Use operations on fractions for this grade to solve problems involving information presented in line plots.

[6-8th] CCSS.MATH.CONTENT.6.SP.B.4 **Display numerical data in plots on a number line, including dot plots, histograms, and box plots.***

**"line plot" and "dot plot" are used interchangeably in Common Core Standards at different grade levels and refer to the same data display.*

NGSS Science and Engineering Practices (SEP):

Analyzing and Interpreting Data

[4-5th] **Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.**

[6-8th] Analyze and **interpret data to determine similarities and differences in findings.**

NGSS Crosscutting Concepts (CCC):

Patterns

[4-5th] **Patterns can be used as evidence to support an explanation.**

[6-8th] **Graphs, charts, and images can be used to identify patterns in data.**

Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

Common Core Standards:

[4-5th] CCSS.ELA-LITERACY.SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

NGSS Science and Engineering Practices (SEP):

[4-5th] (5-PS2-1) Support an argument with evidence, data, or a model.

NGSS Crosscutting Concepts (CCC):

[4-5th] (5-PS1-4) Cause and effect relationships are routinely identified, tested, and used to explain change.

Standards for Mathematical Practice

[4-8th]

- SMP.1 Make sense of problems and persevere in solving them.
- SMP.6 Attend to precision.

English Language Development Standards:

[4-5th]

- ELD.PI.5.1.Em Contribute to conversations and express ideas by asking and answering yes-no and wh- questions and responding using short phrases.
- ELD.PI.5.1.Br Contribute to class, group, and partner discussions, including sustained dialogue, by following turn-taking rules, asking relevant questions, affirming others, adding relevant information, building on responses, and providing useful feedback.
- ELD.PI.5.2.Em Collaborate with peers on joint writing projects of short informational and literary texts, using technology where appropriate for publishing, graphics, and the like.

[6-8th]

- ELD.PI.6.1.Br Contribute to class, group, and partner discussions by following turn-taking rules, asking relevant questions, affirming others, adding relevant information and evidence, paraphrasing key ideas, building on responses, and providing useful feedback.
- ELD.PI.6.2.Em Engage in short written exchanges with peers and collaborate on simple written texts on familiar topics, using technology when appropriate.

II. Advanced Prep & Set-up for Lesson

Standard Setup for Design Challenge Learning:

1. Set up the classroom so that students can work in groups of 2–4 students at group stations.
2. Place the materials in an area that is accessible to students. Organize the materials so that it is easy for students to see the types and quantity of items available. Depending on the size of the class, it may be important to limit the number of students going up to the materials table at one time. One idea is to only allow one student from each team to come to the materials table.

Advance Set-Up

Materials (per approximately 30 students)

Materials for Initial Experiment

- 3 kits: RAFT “Car on a Roll.” (see <http://www.raftbayarea.org/ideas/Car%20on%20a%20Roll.pdf>)
- 3 kits include:
 - 120 foam wheels of uniform size and shape
 - 60 thin straws (i.e. coffee stirrers)
 - 60 drinking straws (non-flexible)
 - 30 3x5” corrugated plastic pieces (for base of vehicle)
- 90+ balloons (if reusing balloons between tests, more if replacing after each test)
- Binder clips
- Several rolls blue painter’s tape or masking tape (mailing labels are a good substitute for tape as they are pre-cut)
- 8-10 pieces of string, 4 feet long each
- 8-10 rulers





- Balloon hand pump
- Additional Materials for iteration (suggested)
 - Items for wheels, such as:
 - CDs
 - Plastic spools (from ribbon, string, etc.)
 - Corks
 - Bottle caps
 - Items for different types of axles, such as:
 - Straws
 - Binder clips
 - Wooden skewers
 - Cardboard tubes
 - Items for bases, such as:
 - Lunch trays
 - Craft sticks
 - Cardboard sheets (recycled food boxes, cut up)
 - Foam sheets

Set-Up

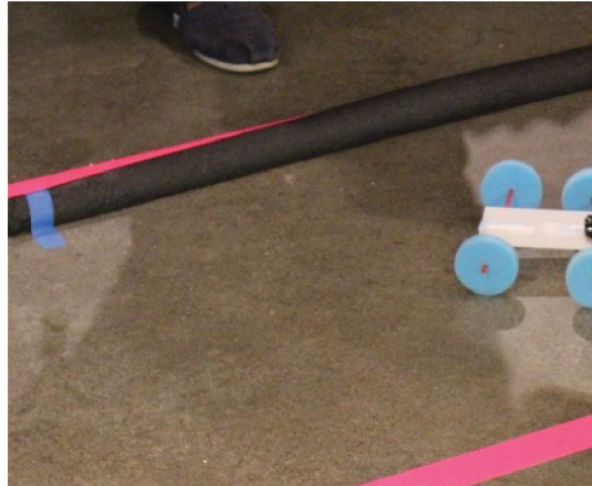
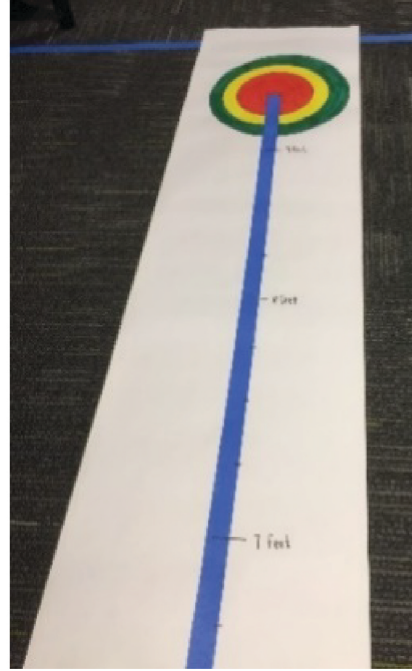
Organize the room with a space for the materials table, work stations for each group and a testing area.

1. Display the design problem, criteria, and constraints using a whiteboard or a projector.
2. Materials
 - Use bins to hold all of each type of material, except for balloons, needed to build the transport device (vehicle).
 - Instruct one member of each team to retrieve the materials: 4 foam wheels, 2 small straws (i.e. coffee stirrers), 1 straw, 1 plastic base.
3. Construction
 - Instruct students to cut the larger straw in half.
 - Have students construct the team's transport device at their group table.
 - After the device is constructed, give students a balloon to attach to their device.
 - Teams should use the air pump to inflate the balloon.
 - Teams may pinch the valve OR attach a binder/bag clip while the balloon size is measured and then release the valve for the test trial.



4. Test site

- Place a runway with a fixed target at the end.
- Draw marking measurements of 1/4 foot down the length of the runway.
- Ensure that the total distance of the runway is between 8 and 10 feet.
- If possible, place “curbs” to control device’s lateral movement.
- Ideally the runway curbs should be 5 to 6 inches tall; however, a shorter height is sufficient. Ideas for possible curbs are: textbooks lined along the runway, rolled butcher paper, pool noodles, etc.



III. Mayday on Mars Lesson Guide

Guiding Question: Engineers often run into technical issues with their devices and engineering solutions can be helpful in these emergency situations. Can you build a device to help engineers move their device to a specific target without using any powered sources?

A. Introduction (45 minutes)

1. Hook the students by showing videos, websites, and providing readings on space exploration and the possibility of manned missions to Mars. Some suggested resources may include the following:
 - Suggested videos:
 - Curiosity Has Landed <https://www.youtube.com/watch?v=N9hXqzkH7YA&feature=youtu.be>
 - "Watch all SpaceX landings in 60 seconds."
<https://www.youtube.com/watch?v=BXlpwx3FBYc&feature=youtu.be>
 - Suggested websites:
 - MarsTrek <https://marstrek.jpl.nasa.gov/>
 - Mars planet facts news & images | NASA Mars rover mission info <https://mars.nasa.gov/>
 - Mars Rover Game <https://mars.nasa.gov/gamee-rover/>
2. Lead a discussion about Mars exploration. Possible discussion questions include:
 - *Why would we want to send astronauts to Mars? What are possible reasons against sending a manned mission to Mars?* (Possible reasons to send astronauts include: to see if we can start a settlement there, to see if there is life, technological advancements made to make the trip possible might benefit us on Earth.
Possible reasons against sending astronauts include: it is dangerous and expensive, we can send robots instead, it's difficult to return to Earth.)
 - *What do you notice about the transport devices that have been sent to Mars?* (Possible answers include: they have big wheels, there are a lot of parts, there are solar panels, etc.)
 - *What are the roles of the astronauts and those assisting the mission from Earth; what does Mission Control do?* (Possible answer: astronauts conduct experiments in space and Mission Control monitors and helps the astronauts stay safe.)
 - *Why is it important to have an entire team of people working on a manned mission to Mars?* (Possible answers include: they have the benefit of many brains working on many hard problems, they can support and learn from each other, they can iterate faster, different individuals can focus on specific problems/aspects of a problem that falls within their individual area of expertise, etc.)



3. Introduce the engineering design challenge scenario.
 - *One of Earth's advanced spacecrafts has just landed on Mars. Justin Case, the pilot, has been sent to lead a mission to determine the possibility of supporting human life on the planet. Unfortunately, the spacecraft had a rough landing and he is unable to start the spacecraft's onboard battery – the landing has damaged everything beyond repair. Justin has a basic rover vehicle to move around the planet, but it doesn't have any power now! Luckily, Justin Case is a handy engineer who is brilliant at tinkering and reusing materials. Nights are extremely cold on Mars – sometimes down to minus 100 degrees F – so Justin Case needs to quickly use the rover base to build a device to reach a suspected water source, so he can make the trip and return to base camp before the temperature drops too low for his spacesuit to handle.*
 - *As part of Mission Control back on Earth, your goal is to create and test a device that will allow Justin Case to move from the landing site to the suspected underground water source using only the materials that we know Justin Case has available in his spacecraft on Mars.*
 - Tell students they will be engineers and will need to develop a transport device using limited supplies, in order to get a drill to the suspected water source.

4. Review the mechanics of a wheel and axle with students. Building a wheel and axle from scratch can be difficult for students, so, depending on their experience with this, more time may need to be spend here.
 - Consider some of the following resources:
 - Wheel and Axle – Simple Machines (<https://www.youtube.com/watch?v=ndT35aqDfAQ&feature=youtu.be>)
 - Wheel and Axle by BrainPop (<https://www.brainpop.com/technology/simplemachines/wheelandaxle/>)
 - Bill Nye Simple Machines (<https://youtu.be/yOxc3Bmr60A>)
 - Ask students where they see wheel and axles in their daily lives. (Possible answers include: cars, bicycles, Ferris Wheels, doorknobs, wagons, fishing poles, fans, rolling pins, etc.)
 - Give students some tinkering time to explore different materials that could be used to make a combination that spins freely and could be part of a wheel and axle system. Give each group of students a bag or box of materials that lend themselves to that movement and challenge them to come up with as many ways as possible to make something that spins freely. Sharing the component combinations with the class from each team will give all students prior knowledge for building a wheel and axle in the design challenge.

B. First Engineering Experiment (45 Minutes)

NB: This “experiment” is specifically designed to NOT correctly control for variables. This will allow students to use the inquiry process to determine that without controlling variables, the information they gather in an experiment is not as useful.

1. Review definitions of criteria and constraints. If criteria and constraints have not been covered in class, see [The Tech Challenge 2018 ELA Lesson, “Escape the Lava”](#) for direct introduction of the concepts of criteria and constraints.



- What is criteria in engineering?
 - *Criteria are the goals or requirements for a project – what you want the device or solution to be able to do.*
 - *Justin has no power from the spacecraft battery and limited materials to and from a possible water source. What do you think are possible criteria for this engineering design challenge? (Possible answers include: designing a transport device propelled by non-electrical energy, the ability to travel a certain distance and/or over a certain type of terrain.)*
 - What are constraints in engineering?
 - *Constraints are the rules or limits for a project based on real-world limitations that exist around the challenge. Constraints always include budget and schedule. Budget is the cost (or in our case, the materials available) and schedule is how much time you have to complete a challenge.*
 - *What do you think some possible constraints are for this engineering design challenge? (Possible answers include: Justin's schedule is to get to the water source and back before nightfall, the team's schedule might be a few minutes or hours to come up with a solution that he can build, Justin's budget is the materials available in Justin's spacecraft.)*
2. Introduce the engineering design challenge – in this case an experiment – to the students. Include the real world problem or experimental question, criteria, and constraints for the challenge, as well as the parameters around testing they will use.

Design Problem:

- *Using the basic rover Justin has already, design a device to move Justin from the landing site to the suspected underground water source using the materials from the test rig in the lab.*
- *As part of Mission Control back on Earth, your goal is to create and test a solution for Justin Case to use to move from the landing site to the suspected underground water source using only the materials we have from the test rig in the lab, which we know Justin Case has in the spacecraft.*

Criteria (Design Requirements/Desired Features):

- Use a car built to the kit specifications (RAFT's *Car on a Roll* kit, see <http://www.raftbayarea.org/ideas/Car%20on%20a%20Roll.pdf>) for your base device.
- Device must be moved only by a balloon, blown up to the size the team decides.
- Once the team decides on a balloon size, they must use the same size for all their recorded trials.

Constraints (Design Limitations):

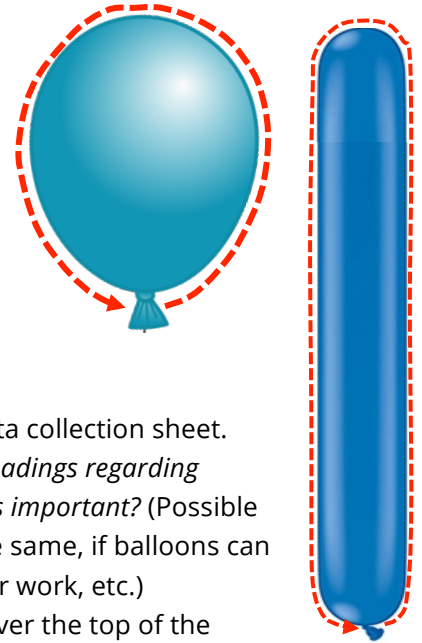
- Budget: 1 base vehicle and only the materials provided to attach the balloon and complete your device
- Schedule: 15 minutes to build and test device

Testing:

- All teammates must participate and answer questions about the team's experiment.
- Teams are encouraged to test their ideas and devices as they build
- Each team must conduct 5 trials with their final prototype design and the same size balloon and record the distance data for these 5 trials – no modifications in between these trials!



3. Demonstrate and discuss the materials to build the base vehicle that they will use. It may be helpful to give students the instructions to build the device so they can easily assemble the base vehicle ([RAFT, Car on a Roll Idea Sheet](#)).
 - Base vehicle materials
 - foam wheels of uniform size and shape
 - thin straws (i.e. coffee stirrers)
 - drinking straws (non-flexible)
 - 3x5" corrugated plastic sheet (for chassis of vehicle)
 - tape or label stickers
4. Model success for the students.
 - Show students an example of a device created for the base vehicle.
 - Model how to measure distance travelled and record it on the data collection sheet.
 - *It is very important that each team does its best to get precise readings regarding distance travelled with air propulsion. Why do you think this is important?* (Possible answers include: so we can figure out if all balloons work the same, if balloons can consistently move our device a specific distance, to check our work, etc.)
 - Model how to measure circumference of air balloon from valve over the top of the balloon and back around to the valve. Suggest that It may be helpful to create strips of paper or lengths of string that are the circumference they decide on for their balloons to make repeated inflation of the balloon easier.
5. Distribute the data collection worksheet. (See Appendix E, First Challenge Data Collection Worksheet.)
 - Have students record the balloon circumference they will use for their test.
 - Explain that students will be asked to **predict** what they think will happen in the trials. To **predict** means to tell in advance what will happen based on observation, experience, or reasoning.
 - Have teams write down their first prediction with their reasoning or evidence to support the prediction.
6. Have students begin the engineering design challenge.
 - Give students 15 minutes to build and test their devices. It may be helpful to designate one member of each group to be responsible for getting materials to avoid crowds.
 - [4-5th grade] Ensure that the measurements that are being taken are in fractions of a foot (1/2, 1/4, 1/8).
 - [6-8th grade] This activity could be a good opportunity to practice measurements using the metric system, as the standard for this grade level does not include specifications on measuring using fractions of a unit. Have students measure using meters, centimeters or even millimeters for very exact measurements.





- As students are working, circulate and ask facilitative questions to guide their thinking and support perseverance through the entire build time. Possible questions to ask students while they design include:
 - *What can you do to get the wheels to move?*
 - *How can you attach the balloon to the device so it will stay attached as it moves?*
 - *How did you decide which direction the balloon should face?*
 - *What do you already know about air propulsion to help move your device?*
 - *How do you think the size of the balloon will affect the distance the vehicle will travel?*
- 7. Ensure that all students are testing their devices appropriately and recording their data for 5 trials using their final prototype.
- 8. Lead class discussion on student findings.
 - *Is there anything you noticed or learned about air propulsion that we might want to share with Justin Case?*
 - Have teams share their data with the class.

C. Content Learning (45 Minutes)

1. Review or introduce key math vocabulary words for measurement and data.
 - Explain to students that as engineers they need to be able to make sense of the data they have gathered. One way to do that is to use **line plots**. A **line plot** is a graph that shows frequency of data along a number line.
2. Introduce Jigsaw activity. Explain to students that they are going to jigsaw into groups to learn more about ways to use frequency charts to visualize measurement and data. For more information on using a jigsaw method in the classroom see Appendix C, Jigsaw Method.
 - Break the class up so that you have minimally 4 groups. In a class of 32 students you may want to create 8 groups with 2 groups covering each topic. Assign the groups a letter: a, b, c, d. Distribute the Jigsaw Worksheet (see Appendix E, Jigsaw Notes for Line Plot Elements).
 - *Look for your team's letter on the worksheet. As a class we are going to watch two videos. Everytime you hear or see something about your topic, write it down in your notes. After we watch the video each team will work together to present on their topic to the rest of the class.*
3. Show videos of line plots to the whole class.
 - Fraction Rap Song (https://www.youtube.com/watch?v=i_5Ve6a5viM&feature=youtu.be)
 - Intro to Line Plots - Khan Academy Video (<https://www.khanacademy.org/math/cc-2nd-grade-math/cc-2nd-measurement-data/cc-2nd-line-plots/v/introduction-to-line-plots>)
4. Give student teams fifteen minutes to discuss their topic, confirm understanding, and develop their presentation.
 - *Letter teams will be given 15 minutes to work together to confirm their understanding of the topic and develop what they will share with their jigsaw team. It is really important that each member has a good understanding, so they teach the correct information to their jigsaw team.*



- While students work with their teams walk around to check in with the teams, possible questions to ask include:
 - *How can fractions be displayed on a line plot?*
 - *How are data points represented?*
 - *What variables are being represented in the video?*
 - *How are points plotted?*
 - *How is the range for a line created?*
 - *How are fractional parts of each whole number identified on the line?*
 - *What needs to be added to the line plot before it is finished?*
- 5. Divide letter teams into jigsaw teams that have one student from each letter group.
 - Each student will teach their topic to the students in their jigsaw team.
 - While one student is teaching, the others are taking notes so that each students finishes with notes on all topics.
 - At the end of each presentation, students are encouraged to ask questions to clarify and deepen understanding.
 - Once all of the presentations are done, students return to their desks.
- 6. Have each student construct a line plot using their team’s data from the Engineering Design Challenge. (See Appendix E, Displaying Data in a Line Plot.)
 - Distribute the Line Plot Worksheet.
 - *For the next five minutes, every student will work independently to plot the data from their team’s device.*
 - As students are creating line plots, monitor the classroom and help any students that may be confused.
- 7. *After each student has completed their gallery walk and left post-its, please return to your team to discuss what you have observed and interpreted by looking at the line graphs.*
 - Have students return to their Engineering Design Challenge Teams (from section B) to edit and display their line plots.
 - Tell students they will be using **compare and contrast** to analyze the information they gathered in the engineering challenge. **Compare and contrast** means to look for similarities (compare) and differences (contrast) between two things to better understand them.
 - Ask student teams to compare their line plots and analyze the data.
 - *Do the line plots look the same?*
 - *Is anything different between the line plots? Why is it different?*
 - Student teams are ready for the next step when all graphs within the team are identical. Have teams raise their hand when they are ready and give them poster paper for their final draft. If possible, use grid paper for the posters.



- While students are working, ask facilitative questions to support their work. It may help to know which student in each team was the 'expert' in each area from the jigsaw – they can be the lead for helping the team with anything that is part of that topic. Some possible questions to ask the teams include:
 - *Are the data plotted on the line graph correctly? How do you know?*
 - *Are there any elements of the line plot that are missing? Anything that needs to be changed?*
 - *Is the line plot clear and precise?*
 - Ensure that teams are only using *their own final prototype* data for the line plot and not combining data from multiple prototypes.
8. Lead a class gallery walk of team's final line plot posters.
- Distribute post-it notes to all students
 - *Next we are going to do a SILENT gallery walk of the line plots your teams have created. Each of you will be expected to leave at least one post-it note for each team. Leave feedback on the post it note which can include: a plus – something they did well, a delta – something they may want to consider changing, or both.*
 - Direct students as they complete the gallery walk. Depending on their experience with the activity they may need structure to help them know when to rotate to a new poster and what order to move through the posters.
 - Silence is important in this activity to allow all students to process the information and give quality feedback.
9. Remember that at this point the data students have collected cannot be combined with other team data because of the multiple variables involved (balloon size, balloon shape, and device design). This conversation, in which students try to determine what their data shows as a class, will allow students to come to understand about controlling variables in experimental investigations.
10. Lead students in a discussion about the data they collected and what it might tell them about the designs they came up with.
- *We have all these data now about our designs and how far they traveled, what (if anything) do the data tell us about our designs and how to improve them?*
 - *Do we have enough data to make a statement about the relationship of balloon circumference and distance travelled? Why or why not?*
 - *Is there a relationship between circumference of the balloon and distance travelled? How would we be able to tell?*
11. Students may want to compare data between teams/devices, but lead them towards the following conclusions through the discussion:
- *There are too many variables – different teams used different balloon sizes, design of how the balloon is attached to the device varied from team to team.*
 - *We didn't take enough data – teams may have used a string to measure the balloon but not measured the actual length of the string to know the size quantitatively.*
 - *We can't combine data from different groups because they didn't all use the same size balloon OR the same design.*



- *We can't draw conclusions on the design or the balloon size because we don't know which caused devices to go different distances – we need to control our variables!*
- Stress to students that in engineering it's important to make only one change at a time to our designs in order to know what improved a given solution.

12. As a class, decide how to control variables so the data can be more useful.

- Standardize the balloon shape size for all groups. Decide as a class what the ideal size balloon will be (and which shape balloon if the class used round and long balloons in the first challenge).
- Once the class comes to consensus about the size of the balloon, have each group measure and cut a piece of string to use as a template for their balloon during the iteration of the engineering challenge.
- Review the variables in the experiment now that the size of the balloon has been controlled – the only variables should be the device design and how the balloon is attached.

D. Iterating Design Solutions (30 Minutes)

1. Review the modified engineering challenge to the students. Include the real-world problem, criteria, and constraints for the challenge, as well as the parameters around testing they will use.

Design Problem:

- *Using the basic rover Justin has already, design a device to move Justin from the landing site to the suspected underground water source using the materials from the test rig in the lab.*
- *As part of Mission Control back on Earth, your goal is to create and test a solution for Justin Case to use to move from the landing site to the suspected underground water source using only the materials we know Justin Case has in the spacecraft. Iterate your design to improve on what we built in the first design challenge, incorporating what you learned during our first tests and your new knowledge of the data we gathered.*

Criteria (Design Requirements/Desired Features):

- Use a car built to the kit specifications (RAFT's *Car on a Roll* kit) for your base device.
- Device must be moved only by a balloon, **blown up to a circumference of _____**.

Constraints (Design Limitations):

- Budget: 1 base vehicle and only the materials provided to attach the balloon and complete your device.
- Schedule: 15 minutes to build and test device.

Testing:

- All teammates must participate and answer questions about the team's design.
- Teams are encouraged to test their ideas and devices as they build.
- Each team must conduct 5 trials with their final prototype design and record the distance data for these 5 trials – no modifications in between these trials!



2. Begin the second round of iterations.
 - Give teams 5 minutes to look at the materials table and brainstorm new iterations to their solutions. Consider allowing students to:
 - Write ideas down and share with their teammates.
 - Sketch ideas individually or as a team.
 - Provide students with 15 minutes to build and test their second iteration.
 - As teams build, circulate and ask facilitative questions that will help guide their work without giving solutions. Possible questions to ask students while they build include:
 - *How will you propel your device?*
 - *What new materials are you incorporating into this design?*
 - *What other changes are you making to the device to optimize its performance?*
 - *What worked for the design in the first iteration that will be kept the same in this prototype?*
 - *What failure point in your previous iteration are you addressing in this iteration?*
3. Ensure that teams are collecting data for every prototype they make of their design. Teams may be able to test multiple prototypes during one build period, and they should capture that data (just as they did in the first challenge) as they make changes. Print out as many of the data collection sheets for this challenge as students may need for their prototypes (see Appendix E, Iterating Your Design Data Collection).
4. After the 15 minute build time, have students share their design with another team.
 - Pair groups up to demonstrate their devices and give feedback. Before groups begin sharing, as a class review the information each team will share and the questions the observing team could ask. Have students think about the kinds of information that might be important for the group to present, as well as the questions they had to answer during their previous demonstrations.
 - Team discussions can include:
 - Identifying strengths and weaknesses in designs.
 - Brainstorming ideas for iteration.
 - Sharing design strategies.
5. If possible, give another round of build time for teams to repeat the second design challenge for further iterations, including:
 - Brainstorming one variable to change.
 - Building a prototype iteration.
 - Team share-outs with feedback.
6. At the end of the provided build times, debrief the activity as a whole class. Possible questions to ask include:
 - *What changes did your team make?*
 - *What worked well in the iterative designs?*
 - *What did not work as well as in previous iterations?*
 - *If we had more time, what would you want to do in an additional iteration?*




E. Evaluation (60-90 minutes)

1. Prepare students for the final assessment.
 - To prepare for the final assessments, students will be completing line plots for the data they collected during Section D, “Iterating Design Solutions” (see Appendix E, “Displaying Data”).
 - Students will also complete a planning sheet for their final assessment project (see Appendix E, “Final Assessment Planning”). This worksheet will help students plan content for their final assessment, which is the same across all of the assessment options.
 - Read over the worksheet with the students.
 - Students may collaborate with their team and classmates to fill out this worksheet, but the final assessment project will be done and graded individually. This worksheet will set each student up to meet the standards for final project. Give students at least 30 minutes to work on completing this worksheet before going over the final assessment project options and the rubric.
2. Give each student the rubric for the final project (see Appendix E, Rubric).
 - Review the rubric with the students (see Appendix C, Evaluating Student Learning using a Rubric).
 - Some possible questions to ask students to aid in making connections, include:
 - [4-5th] *The rubric states that meeting standards for analyzing and interpreting data includes comparing and contrasting data with accuracy. Where does the final assessment worksheet address comparing and contrasting data?*
 - [6-8th] *The rubric states that meeting standards for analyzing and interpreting data includes explaining the similarities and differences in findings using appropriate academic language. Where does the final assessment worksheet address similarities and differences?*
3. Hand out final assessment options for students (see Appendix E, Final Assessment Project Choice).
 - Read over the assessment with students.
 - Discuss connections to the final assessment planning worksheet and rubric and the final assessment project assignment.
4. Give students 45 minutes to pick and begin working on their final assessment project. Depending on the students, the project may take time outside of class to finish, or may require time in class across more than one day. Be sure to take into account students’ experience levels with working on projects of this type and plan accordingly.

IV. Appendices

A. Vocabulary

Term	Definition
Cause	A person or thing that gives rise to an action or phenomenon.
Circumference	The distance around something.
Constraint	The limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions.
Control	In an experiment it is a test where one variable is changed at a time in order to isolate the results.
Criteria	The requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
Data	Facts and statistics collected for analysis.
Data analysis	The process of taking data and turning it into usable information. For example, plotting data points in some form of graph or line plot.
Design problem	The identified challenge, goals, or needs that a design addresses; What you are trying to solve.
Design process	<p>A series of steps that engineers use to guide them as they solve problems. The process is nonlinear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating. These are steps used to come up with solutions:</p> 
Dot plot	A graph that shows the frequency of data occurring along a number line. Also referred to as a line plot.
Effect	A change that is a result of a cause.
Engineer	A person who designs and builds innovative solutions (machines, systems, or structures) to solve a problem or meet a need.
Engineering	The process that engineers go through to create, design, test, and build a solution.
Experiment	A science procedure followed to make a discovery or test a hypothesis.



Failure point	A place where the design or system failed.
Fair test	A fair test is when one factor, or variable, is changed at a time and all other conditions are kept the same.
Fraction	A number that is not a whole number. For example: 1 ½, one and a half, 1.5 are all fractions.
Function	The action or purpose of an object including how it moves or interacts with other objects.
Graph	A diagram that shows the relationship between variable quantities (typically two variables are shown).
Iteration	When you try different solutions (create, test, reflect, imagine) over and over.
Line plot	A graph that shows the frequency of data occurring along a number line. Also referred to as a dot plot.
Load	Another word for force, or what the structure has to hold up to; in a machine doing work, like simple machines, a load is the weight or mass being supported and/or moved.
Measurement	The size, length, or amount of something.
Optimal design	The design or device that best meets the criteria and constraints.
Outlier	An observation point that is distant from the other observations. This can be due to measurement differences or an experimental error.
Pattern	A regular/repeated form or predictable phenomenon.
Predict	Estimate that a specific thing will happen in the future or will be a consequence of something
Propulsion	The action of pushing or driving forward.
Prototype	The models that you build to test before you get to your final solution.
Simple machine	A device that alters the magnitude or direction of a force.
Structure	The material or arrangement of parts in an object to make up the whole.
Trade-off	A situation in which you must choose between or balance two things that are opposite or cannot be had at the same time.
Unit	A standardized term to measure a quantity.
Variable	The thing (factor, trait, condition) that is changed or is not consistent in an experiment.
Wheel & axle	A simple lifting machine consisting of a rope that unwinds from a wheel onto a cylindrical drum or shaft joined to the wheel to provide mechanical advantage.



B. Resources

- "The Jigsaw Classroom." Jigsaw.Org, 2017, <https://www.jigsaw.org/#steps>.
- Spring, Sarah. "Construct And Interpret A Line Plot." 2017, https://learnzillion.com/lesson_plans/8497-construct-and-interpret-a-line-plot.
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- "Mars, Mars Information, Red Planet Facts, News, Photos -- National Geographic." Nationalgeographic.Com, 2017, <https://www.nationalgeographic.com/science/space/solar-system/mars/>.
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C. Background Information

Brainstorming:

Getting ideas out of our heads and building on them with a team is one of the great strengths of group work. There are many web-based resources to explain techniques to maximize on effective brainstorming in the classroom. Here are a few if you want help, or want to try something new:

- Iowa State University “14 Creative Ways to Engage Students”
<http://www.celt.iastate.edu/teaching/teaching-format/14-creative-ways-to-engage-students>
- IDEO.org Design Kit “Brainstorm Rules”
<http://www.designkit.org/methods/28>

Engineering Design Process:

Introduce the engineering design process graphic with students to show how engineers engage in fun, creative, problem-solving that is core to their work.

- Explain to students that as engineers go about solving problems and coming up with creative and innovative solutions to challenges, they follow the **design process**.
 - **Design Process:** a series of steps that engineers use to guide them as they solve problems. The process is non-linear but cyclical, meaning that engineers can follow the steps in no particular order, repeat the steps as many times as needed, and make improvements along the way of imagining, creating, reflecting, testing and iterating.
- We represent this process with a graphic that shows the main steps someone goes through as they solve a problem.
 - Define your problems: What is the problem you are trying to solve? What are the criteria (design requirements that will determine the success of your solution)? What are the constraints (real-life limitations like budget and schedule) that you have to work within?
 - Test/reflect – imagine – create: This is the main part of the process that is cyclical. This is where engineers go through multiple designs as they have ideas, try something out, test it, have new ideas, and incorporate it all into more building and testing. This process can go through many rounds as an engineer gets more information from each test and design that is tried.
 - Sharing solutions: Engineering is about teamwork, and engineers frequently learn from each other as they solve problems. It’s important for students to communicate and share throughout the process so that—just like real engineers—they can learn from each other and improve their solutions. It’s particularly important to culminate a project with a formal sharing of solutions and perhaps even a showcase or other authentic ways to share lessons learned with the broader community (e.g. community members, family members, principal, younger students, etc.).
- When you see the design process in action, you’ll notice that it’s rarely the smooth succession of steps that the diagram implies. The steps often overlap and blur, and their order is sometimes reversed – it’s a creative, fluid way of working that must be adapted to each individual situation.
- As you guide students through the design process, you’ll want to be flexible and receptive to the different approaches your students may try.
- Ask students to notice where they are in the design process and even to trace their path through the steps, so they can see how messy it can be.



Evaluating Student Learning using a Rubric:

Review the rubric with students at the introduction of the project so they know what their learning goals are. It is important to allow students to begin with the end in mind, just as teachers “backwards plan”, using standards and assessments to inform units, topics, and day-to-day activities.

The rubric in the lesson guide is designed to evaluate student mastery of the “met” standards using the categories *Below Standard*, *Approaching Standard*, *Meeting Standard*, and *Above Standard*. This allows teachers to give individual feedback particularly for the students who are *Below Standard* or *Above Standard* in particular areas.

- In the Below and Above Standards sections of the rubric, the idea is that no student should be receiving these scores without personalized attention from the teacher – either as remediation or as extension to reach students where they are.
- With that in mind, the descriptions and observations in these two sections are simply examples of what you might see for students performing at that level. The comments and notes in these sections should be tailored to the specific student and should accompany individualized support and conversations.
- To learn more about Understanding by Design and rubrics, see ASCD’s Understanding by Design in the reference section. (See Appendix D, References.)

Journaling

Science or engineer journaling can be a powerful learning tool for students. Encouraging students to use their writing skills across subjects and to use both graphic and written forms of expression can help integrate different learning styles. Below are some ideas on how to integrate journaling as a part of scientific discovery.

- “Keeping a Journal as a Scientific Tool” from Claudine Kavanagh on the Science Integration Institute <http://www.scienceintegration.org/Resources/journals.html>
- “Science Notebooks” by Carole Cox on Reading Rockets <http://www.readingrockets.org/article/science-notebooks>
- “Teaching Students to do Quality Work in Science Notebooks” by Ari Mosquera on The Science Penguin <https://www.youtube.com/watch?v=W1K08D2aMG4>

Scaffolding Strategies

Helping students access content and interact with new knowledge can often include scaffolding in your teaching practice. Here are two web based resources that have some tips and tricks for scaffolding in the classroom.

- “6 Scaffolding Strategies to Use With Your Students” by Rebecca Alber on Edutopia <https://www.edutopia.org/blog/scaffolding-lessons-six-strategies-rebecca-alber>
- “Scaffold Questions to Scaffold Answers” by Marzano Research Laboratory <https://soltreemrls3.s3-us-west-2.amazonaws.com/marzanoresearch.com/media/documents/ASOT-Gothenburg-NE-81214-60-120.pdf>



Teaching Presentations

Engaging audiences is a necessary skill in the classroom, boardroom, and on the playground. How does a teacher engage and encourage quality presentation skills in the classroom that will translate into real-life experiences? There are many resources and lesson plans designed to help a teacher do this in a wide variety of ways. Consider reviewing one of the following:

- “Using TED to Develop Presentation Skills” by Kate Perry based on the ideas of Marina Broeder <http://www.thetechclassroom.com/home/usingtedtodeveloppresentationskills>
- “Teaching Presentation Skills” by Simon Parker of Albion International <http://www.beta-iatefl.org/cogitoergosum/wp-content/uploads/2010/09/2008-Simon-Parker-Presentation.ppt>
- “TEDs Secret to Great Public Speaking” by Chris Anderson of TED https://www.ted.com/talks/chris_anderson_teds_secret_to_great_public_speaking

Jigsaw Method

If you’re interested in running a jigsaw activity in your classroom, follow this simple six-step guide (or check out a similar 10-step guide by the Jigsaw Classroom, <https://www.jigsaw.org/#steps>):

Step 1: Organize students into groups of 4-6 people.

Step 2: Divide the day’s reading or lesson into 4-6 parts, and assign one student in each group to be responsible for a different segment.

Step 3: Give students time to learn and process their assigned segment independently.

Step 4: Put students who completed the same segment together into an “Expert group” to talk about and process the details of their segment.

Step 5: Have students return to their original “Jigsaw” groups and take turns sharing the segments they’ve become experts on.

Step 6: Have students complete a task or a quiz that’s reliant on them having understood the material from the contributions of all their group members.

During this whole process, where’s the teacher? At first, the teacher facilitates the arranging of groups, explaining of roles, and timing for each portion. Notice that the teacher doesn’t have to lecture or be the focal point of attention. When the students are in groups for steps 4 and 5, the teacher should walk amongst the groups and lend support or explanation where necessary.

Teachers often skip Step 4 – putting students into temporary expert groups – but it is an essential step. When students encounter information on their own, they gain a limited perspective on it or may feel confused. The expert group is an opportunity for students to share their ideas so they each reach a greater understanding of their same segment. This helps confused students clarify their understanding and lean on more able peers. It also helps each student articulate the importance points of their segment better when reporting to their jigsaw group.

The teacher may find it valuable to appoint one student in each group as the “Leader” who can manage time, make sure each student contributes their part, and ensure the group is accomplishing the goals. The most mature student in each group might be the best option; however, teachers should consider how the disengaged, the diffident, or the problem students might benefit from being the leader



D. References

- ASCD. "Understanding by Design®." Understanding by Design® framework - Videos, Articles, Resources, Experts. Web. Accessed 18 Aug. 2017. www.ascd.org/research-a-topic/understanding-by-design-resources.aspx
- "Curiosity Has Landed." YouTube, NASA Jet Propulsion Laboratory, 6 Aug. 2012. Accessed 12 Sept. 2017. www.youtube.com/watch?v=N9hXqzkH7YA&feature=youtu.be
- "Fractions on a Line Plot Rap Video | Number Line Song for Kids." *YouTube*, Numbalumba, 29 Sept. 2016. Accessed 12 Sept. 2017. www.youtube.com/watch?v=i_5Ve6a5viM&feature=youtu.be
- "Intro to line plots." *Khan Academy*. Accessed 12 Sept. 2017. www.khanacademy.org/math/cc-2nd-grade-math/cc-2nd-measurement-data/cc-2nd-line-plots/v/introduction-to-line-plots
- "Mars planet facts news & images | NASA Mars rover mission info." NASA, NASA. Accessed 12 Sept. 2017. <https://mars.nasa.gov/>
- "Mars Rover Game." NASA, NASA. Accessed 12 Sept. 2017. <https://mars.nasa.gov/gameee-rover/>
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- "Watch all SpaceX landings in 60 seconds." YouTube, Tech Insider, 8 Mar. 2017. Accessed 12 Sept. 2017. www.youtube.com/watch?v=BXlpwx3FBYc&feature=youtu.be
- "Wheel and Axle." BrainPOP. Accessed 12 Sept. 2017. www.brainpop.com/technology/simplemachines/wheelandaxle/
- "Wheel and Axle - Simple Machines | Mocomi kids." YouTube, Mocomi Kids, 10 July 2012. Accessed 12 Sept. 2017. www.youtube.com/watch?v=ndT35aqDfAQ&feature=youtu.be
- "RAFT Idea Car On A Roll - Resource Area For Teaching." Raftbayarea.org. N. p., 2017. Web. 17 Oct. 2017. <http://www.raftbayarea.org/ideas/Car%20on%20a%20Roll.pdf>



E. Lesson Handouts

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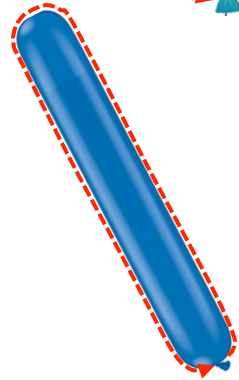
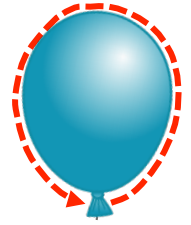
Engineering Design Process and Innovator Mindsets





First Challenge Data Collection

1. Determine what balloon your team will use and how large you will inflate it.
2. Measure the circumference of balloon with string, from the tie over the top, and back to the tie.
3. Record your distance traveled
 - a. Make a prediction before you perform each trial
 - b. Using the test trial measurements, record the distance your vehicle traveled to the nearest fraction of a foot ($1/2$, $1/4$, $1/8$).



Trial #1	Trial #2	Trial #3	Trial #4	Trial #5
Prediction:	Prediction:	Prediction:	Prediction:	Prediction:
Reasoning:	Reasoning:	Reasoning:	Reasoning:	Reasoning:
Actual:	Actual:	Actual:	Actual:	Actual:



Jigsaw Notes for Line Plot Elements

1. Fill in notes of important information you learn in your assigned section.

<p>A. How to plot points on line plot</p>	<p>B. How to find/create the range for the line plot</p>
<p>C. How to identify the fractional parts of each whole number unit on the line</p>	<p>D. How to label a line plot</p>

2. When your group comes back together, fill in notes in the other sections as your teammates teaches you the information.



Iterating Your Design - Data Collection

Prototype # _____

1. What change did you make to your design for this test? Include any measurements that will help you have more information about these changes.

2. What do you predict about the data for the trials of this test?

3. Record your distances for 3 trials. Record the distance your vehicle traveled to the nearest fraction of a foot.

Trial #1	Trial #2	Trial #3	Trial #4	Trial #5

4. What worked well in this prototype? What parts of the design will you keep?

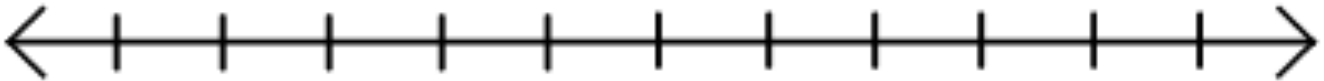
5. What is one change that you will make for your next prototype?



Displaying Data in a Line Plot

1. Using your data collection worksheet, create an appropriate range for your dot plot.
2. Plot your team's data points.
3. Color code your data and record colors in key, and include a title for dot plot.

Title: _____



Key:



Final Assessment Planning

1. Our design challenge was to _____

_____.

The materials we used were _____

_____.

2. The criteria for the engineering challenge were:

-
-
-
-

3. The constraints for the engineering challenge were:

-
-
-
-

4. The real-world connection to this challenge is _____

_____ and it is important to investigate because

_____.



5. As we looked at the results of our data, we notice that _____

_____.

6. We noticed that the failure points or difficulties of each trial were _____

_____ and from the failure points we learned

_____.

7. After looking at the data we collected, we changed _____

_____.

8. When we retested our device, we noticed the following changes in our data: _____

_____.

9. After the first iteration (change), we predicted that _____

_____ based on the reasoning _____

_____.



Name: _____

Date: _____ Class: _____

10. From our prediction and the results, we decided to _____

_____.

11. The patterns that were noticed were _____

_____.

12. After seeing the devices other groups made, we _____

_____.

13. The best thing about this challenge was _____

_____.

14. Something we would suggest changing or adding to the challenge is _____

_____.



Final Assessment Project Choice

Final Assessment Choice Board – choose which way you would like to demonstrate your learning from this engineering challenge!

Create a digital presentation, such as a slide show	Video reenactment between Mission Control and Justin Case	Create a Reader's Theater script, such as an interview between Justin Case and a reporter
Create a poster	Student Choice (with teacher approval)	Board Game
Write and illustrate a picture book.	Write a newspaper article.	Create a comic strip.

ALL projects must include:

- Display of test trial data:
 - Data recorded in fractions of unit.
 - Analysis of data.
- Analysis of data:
 - Compare and contrast data with at least one other group.
 - Description of patterns affecting device performance supported by evidence in the graphs.
 - [4-5th] Predictions of device performance based on patterns of other groups' data.
 - [6-8th] Identification of the cause and effect results based on patterns in the data from changes made to prototypes.
- Correct usage of the following vocabulary: circumference, constraint, criteria, data, failure point, fair test, line plot, prototype, variable.

Mayday on Mars Rubric [4-5th Grade]

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Measurement and Data Represent and Interpret Data (CCSS.MATH.CONTENT.5.MD.B.2) Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Use operations on fractions for this grade to solve problems involving information presented in line plots.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Constructing a line plot utilizing unit fractions with precision. Plotting data points collected in test trials on a line plot. Creating a complete data table. 	<ul style="list-style-type: none"> Construct a line plot utilizing fractions of a unit accurately. Plot 1-2 points from the results of their data collected in test trials. 	<ul style="list-style-type: none"> Construct a line plot utilizing fractions of a unit with at least 90% accuracy. Plot a minimum of 5 data points from the results collected in test trials. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Construct a line plot utilizing fractions of a unit with 100% accuracy. Plot 5 points from the results of their data collected in test trials. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Expand on display of data frequencies by using histograms and/or box and whisker plots. Calculate measures of central tendency for the data collected.
<p>Analyzing and Interpreting Data (SEP 4, ES) Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Using appropriate academic language for comparing and contrasting data. Comparing and contrasting data collected by different groups. Completing at least 1 trial. 	<ul style="list-style-type: none"> Use basic academic language for comparing and contrasting data. Compare and contrast data collected by different groups with few errors. Completed minimum of 1-2 trials. 	<ul style="list-style-type: none"> Use appropriate academic language (e.g. data, outlier, variable) to discuss similarities and differences in their data (e.g. A is similar to B because...; The differences between A and B are...). Compare and contrast data collected by another group with 90% accuracy. Completed minimum of 3 trials within the time constraint. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Use precise academic language to discuss similarities and differences in their data. Accurately compare and contrast data collected by different groups with no mistakes. Completed 5 trials. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Use appropriate vocabulary to describe similarities and differences in the findings. Explain how each mark on the graph represents the collected data in relationship to the independent and dependent variables.



	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Patterns (CCC 5, ES) Patterns can be used as evidence to support an explanation.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Recognizing patterns that affect the performance of the device. Identifying evidence used to make a prediction. 	<ul style="list-style-type: none"> Able to recognize patterns that affect the performance of device with little facilitation by the teacher. Predictions are made but are not substantiated with evidence. 	<ul style="list-style-type: none"> In device presentations and written work describe patterns that affects the performance of the device supported with logical evidence with minimal to no facilitation by the teacher. After each iteration, record predictions about the distance the device will travel based upon patterns noted from the results of other groups. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Able to recognize patterns that affects the performance of device with no facilitation by the teacher. Able to make predictions without facilitation. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Able to recognize patterns that affect the ability of the device to meet performance criteria when creating and analyzing data.

Mayday on Mars Rubric [6-8th Grade]

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Statistics and Probability Summarize and Describe Distributions (CCSS.MATH.CONTENT.6.SP.B.4) <i>Display numerical data in plots on a number line, including dot plots, histograms, and box plots.</i></p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> • Displaying numerical data on a dot plot 	<ul style="list-style-type: none"> • Accurately display numerical data in plots on dot plots with few errors • Areas to strengthen might include: <ul style="list-style-type: none"> ○ Proper labeling of data representations ○ Appropriate intervals ○ Logical organization of data 	<ul style="list-style-type: none"> • Construct a line plot utilizing fractions of a unit with at least 90% accuracy. • Plot a minimum of 5 data points from the results collected in test trials. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> • Accurately display numerical data with precision using two different data displays (e.g. dot plot). • Demonstrate an understanding of which type of graph would be the most useful for displaying the resulting data and why they think so. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> • Have students gather data from trials using two materials for propulsion and compare the results
<p>Analyzing and Interpreting Data (SEP 6, MS) <i>Analyze and interpret data to determine similarities and differences in findings.</i></p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> • Using appropriate academic language for determining similarities and differences in the data • Creating or completing graphs for interpretation and analysis • Conducting more than one trial to have an adequate amount of data for analysis 	<ul style="list-style-type: none"> • Evidence of data and analysis does not include all criteria and/or constraints. • The Analysis is not supported by data. • Areas to strengthen might include: <ul style="list-style-type: none"> ○ More trials providing accurate data to support analysis ○ Refined graphs for interpretation of data ○ Accuracy of data for in-depth analysis 	<p><i>After completing a minimum of 3 trials, but no more than 5 maximum.</i></p> <ul style="list-style-type: none"> • Use appropriate academic language to describe similarities and differences in the findings. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> • Describe patterns such as clusters, outliers, positive or negative association, linear association, and nonlinear association in the analysis. • Include flaws in design in analysis that may affect the data. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> • Allow students to include recommended design improvements in the analysis



	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Patterns (CCC 6 Patterns, MS) Students describe patterns revealed when graphing data, and identify cause and effect relationships.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Recognizing and describing patterns Identifying the cause and effect relationships Connect observations to design improvement 	<ul style="list-style-type: none"> Pattern descriptions do not show clear cause and effect relationships Areas to strengthen explanations might include: <ul style="list-style-type: none"> Recognition and descriptions of patterns from the graphical representations Cause and effect relationships using evidence from the data representations Connections to design improvement 	<ul style="list-style-type: none"> In device presentations and written work describe patterns that affects the performance of device supported with logical evidence with minimal to no facilitation by the teacher Explanations of the cause and effect relationships are clearly connected to the graphical representations. Connections and/or recommendations to design improvements based on the cause and effect relationships are clearly stated 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Patterns revealed are analyzed and interpreted to re-engineer the design to improve the device <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Allow students to explore the different tension created by using rubber bands of varying thickness and length. Challenge students to research PSI and how to determine the amount in a hand-blown balloon. Challenge students to research devices that can be used in testing the maximum PSI of air in different sized balloons.