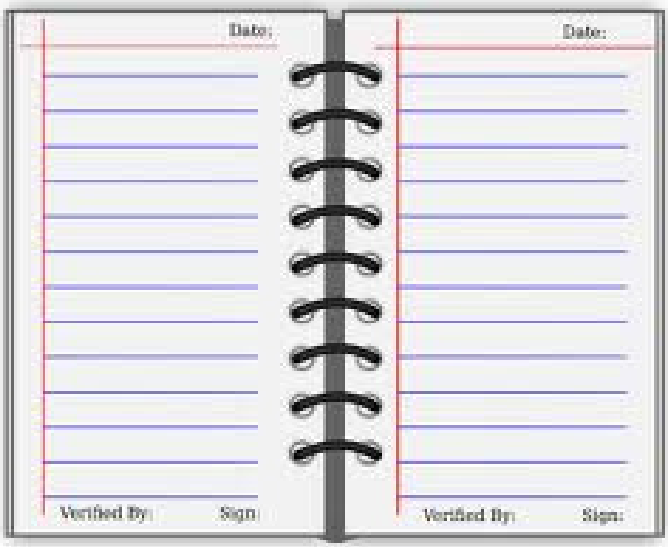
Student Team Challenge Journal



Supporting Science Investigation 1: It's a Drag

Concept

Every object that falls due to gravity will ultimately fall at a constant speed. In order to stop an object or to slow it down, a certain amount of drag needs to be applied to oppose the acceleration. As drag increases, an object will slow its rate of fall.

In this activity, you will see the effects of drag on a falling object by shaping a large sheet of paper and measuring the time it takes to fall from a fixed distance.

Figure 17. Space Shuttle Endeavour's drag chute deploys to slow the orbiter as it lands at Edwards Air Force Base at the conclusion of the STS–111 mission to the International Space Station in 2002. (NASA)

Materials

For each pair of students:

- Meter stick
- Large sheet of paper
- Stopwatch
- Table

Procedure

1. Working with a partner, take turns dropping or timing the falling object.
2. Place the meter stick on top of the table so that it stands upright. The meter stick should be placed at the edge of the table. You will drop the paper from the top of the meter stick to the floor.
3. One student in each group folds the paper in half and holds the sheet of paper horizontally at the top of the meter stick.
4. Release the paper while your partner times how long it takes to fall to the floor.
5. Record the time on your Data Collection Sheet.
6. Repeat this drop two more times for a total of three iterations. Record the times on your Data Collection Sheet.
7. Calculate the average of the three drops and record it on your Data Collection Sheet.
8. Fold the sheet of paper into quarters.
9. Drop the paper three times using the method described in steps 3 and 4. Record all of the times and the average on your Data Collection Sheet.
10. Repeat this experiment multiple times, trying different shapes of paper. There is no constraint as to how the paper is folded or unfolded.
11. Answer the questions provided on the Data Collection Sheet.

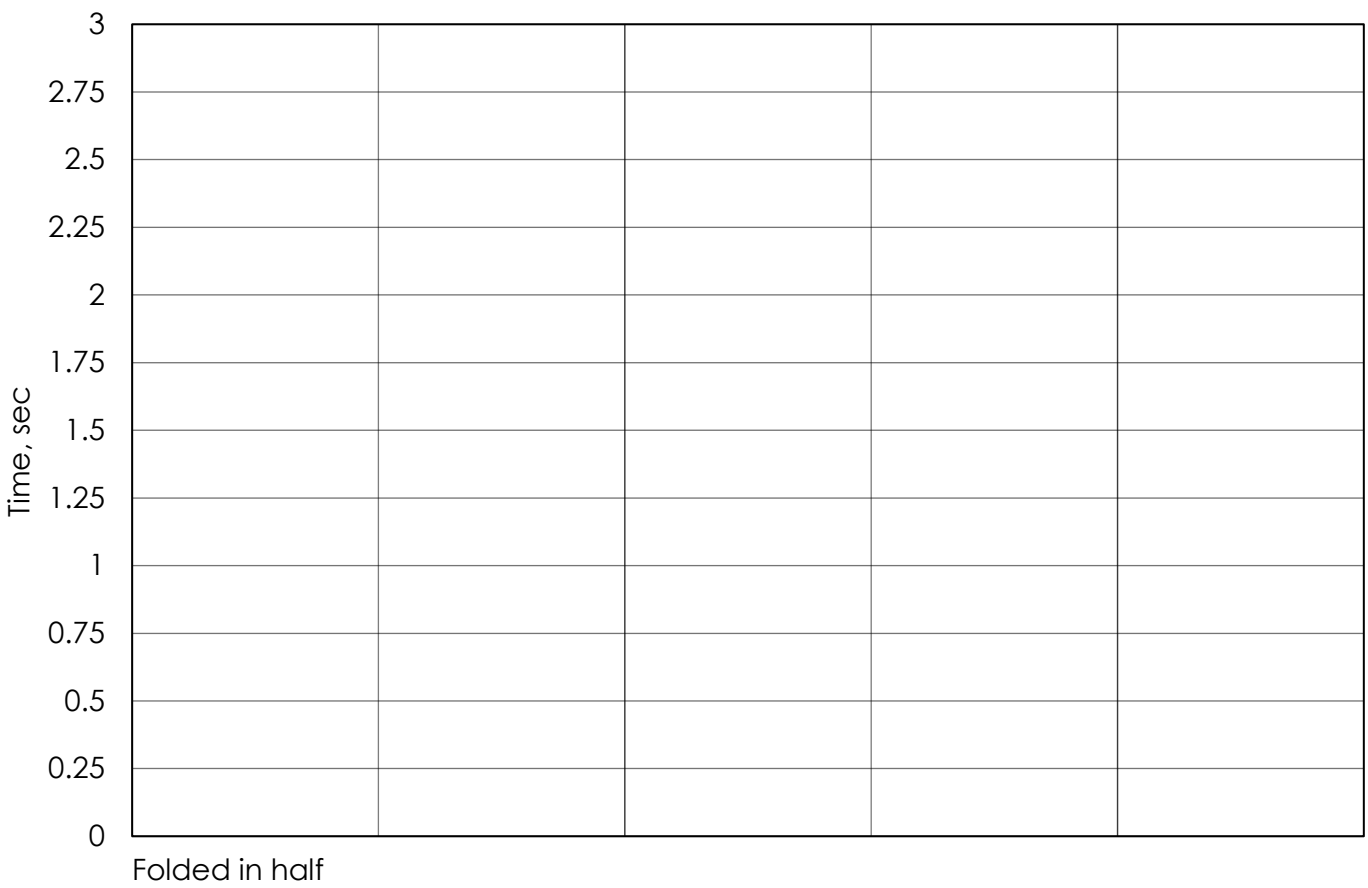
Data Collection Sheet

Complete the table below using the results from your experiments.

Paper shape	Drop 1 time, sec	Drop 2 time, sec	Drop 3 time, sec	Average drop time, sec	Observations
Folded in half					

Using a different color for each test, create a bar graph of the average results from your experiments below. Remember to label each bar at the bottom.

Title:_____



Parachuting Onto Mars

1. Describe the graph. How did the shape of the paper affect the speed at which it fell? Use the data in your answer.

_____

_____

_____

_____

_____

2. Why do you think that happened?

_____

_____

_____

_____

_____

Discussion Questions

It's a Drag used different shapes of paper to simulate the effects of drag on a moving object.

1. If we were to perform the same activity on Mars, would the results be the same, faster, or slower than here on Earth? Why?

_____

_____

_____

2. If the goal was to produce as much drag as possible, how could you achieve this?

_____

_____

_____

3. How will you apply what you learned in this investigation to your design?

_____

_____

_____

_____

_____

Supporting Science Investigation 2: Touchdown

Concept

The Mars 2020 rover mission is part of NASA's Mars Exploration Program. The mission is not only seeking signs of habitable conditions on Mars but is also searching for signs of past microbial life. The mission will gather information to aid future human expeditions to Mars. This includes improving landing techniques; identifying resources to enable human habitation; and characterizing weather, dust, and other environmental conditions that could affect how future astronauts live and work on Mars.

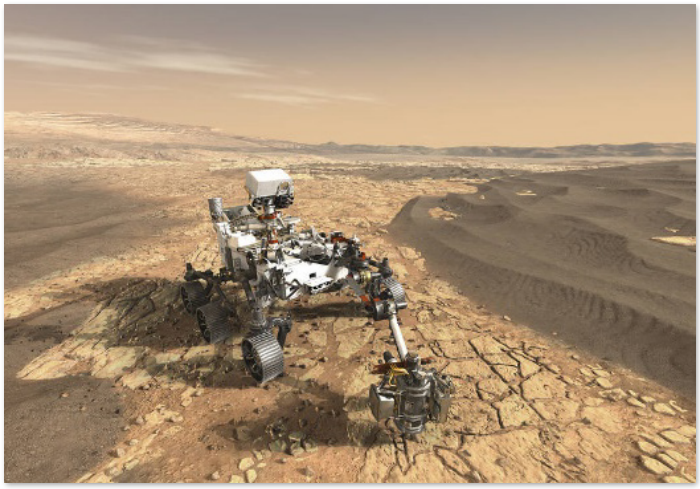


Figure 18. Artist's rendering of the Mars 2020 rover on the surface of Mars. (NASA/JPL–Caltech)

NASA will use the proven landing system used to land the Curiosity rover. However, with heavier science equipment, the spacecraft will need to have a way to absorb the extra energy of impact from the landing while also protecting the cargo.

Each team will design and build a vehicle imitating the Mars 2020 rover landing vehicle. Your team will develop a shock-absorbing system that will keep marshmallows (cargo) inside a cup (cargo hold) upon landing during a drop test. Teams will not be allowed to secure the cargo with tape. The challenge is to make a shock-absorbing system that absorbs the transfer of energy so the marshmallows stay in the cup on landing.

Materials

For each pair of students:

- Piece of stiff paper or cardboard, approximately 10 x 13 cm
- Small paper or plastic cup
- 4 small index cards
- Tape measure
- 2 regular-size marshmallows
- 10 miniature marshmallows
- 3 rubberbands
- 8 plastic straws
- Scissors
- Tape

Procedure

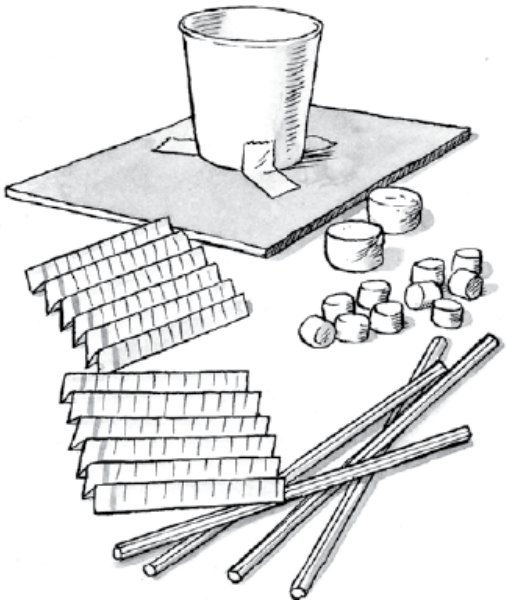


Figure 19. Materials used in the "Touchdown" investigation.

1. Secure the cargo hold (cup) on the lander (cardboard). Draw a circle around the bottom of the cup. You can either leave the cup in place during the design and build or you can remove it to assist in the construction of the shock-absorbing system. In either case, the cargo hold must be secured prior to testing.
2. Work in pairs to design a shock-absorbing system with the materials provided.
3. Build your designed shock-absorbing system and attach it to the cardboard lander.
4. With the cargo hold secured to the lander, put two pieces of cargo (the large marshmallows) in the cargo hold. They cannot be secured with tape.
5. Drop the lander from heights of 50 cm, 100 cm, and 150 cm.
6. If the cargo does not stay in the cup, work with your team to redesign the shock-absorbing system as time allows.

Data Collection Sheet

	Cargo protected? Yes/No	Modifications Needed
50 cm		
100 cm		
150 cm		

1. Describe the team's test results. Did your initial design meet the criteria? If not, describe the modifications your team had to make to continue working on the problem.

_____

_____

_____

_____

_____

2. Was your team able to create a shock-absorbing system that held together for a 150-cm drop? If not, what prototype ideas did you have to revisit to try to meet the criteria?

_____

_____

_____

_____

Discussion Questions

1. Touchdown used a shock-absorbing system to protect the cargo in a landing vehicle. What do you think would happen if this investigation was performed on Mars?

_____

_____

_____

2. Would the results be the same, better, or worse than here on Earth? Why?

_____

_____

_____

_____

3. How will you apply what you learned in this investigation to your design?

_____

_____

_____

_____

The Engineering Design Process

The engineering design process (EDP) consists of a series of steps, each designed to help you develop a solution to a problem. Start with "Identify a Need or Problem" and use the EDP diagram shown here to help solve this challenge.

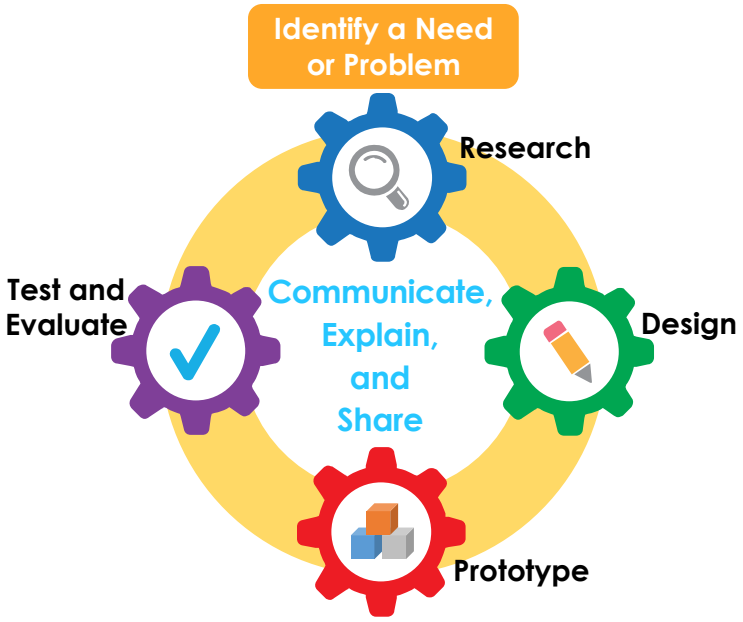


Figure 20. Engineering design process model. Model and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

Identify a Need or Problem. Identify a need or problem to be solved, improved, or fixed. Identify the criteria and constraints that will need to be met to solve the problem.

Research. Use resources from the internet, the library, or discussions with NASA scientists and engineers to learn more about the need or problem and possible solutions. Investigate how this problem is currently being solved or what efforts scientists and engineers are making to find a solution.

Design. Use all information gathered to create the design(s). Design includes modeling possible solutions, refining models, and choosing the model(s) that best meets the original need or problem.

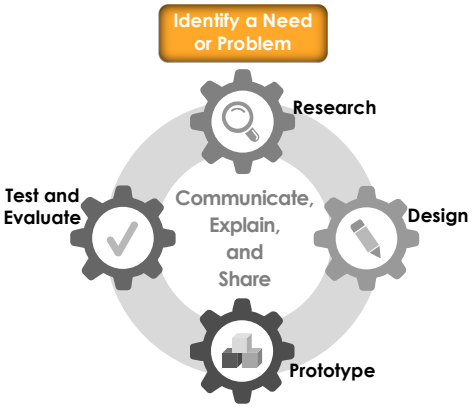
Prototype. Construct a prototype, or physical model, based on the design model(s). Prototypes are used to test proposed solutions.

Test and Evaluate. Test prototype to determine how effectively it solves the need or problem. Collect data to use as evidence of success or need for improvement. Redesign and refine prototypes to continue looking for possible solutions.

Communicate, Explain, and Share. Communicating, explaining, and sharing the solution and design is essential to tell others how it works, how it solves (or does not solve) the identified need or problem, and how it meets (or fails to meet) the criteria and constraints. Determining how to communicate and act on constructive criticism is critical.

The Engineering Design Process: Identify a Need or Problem

As NASA plans new robotic missions and human expeditions to Mars, it becomes more important for spacecraft that carry payloads to be able to accommodate heavier and larger payloads to support an extended stay on the Martian surface. NASA seeks to use atmospheric drag as a solution for planetary atmospheric decelerations, deploying next-generation drag devices at high supersonic speed to safely land crew, cargo, and vehicles. NASA is conducting full-scale, stratospheric testing of breakthrough technologies high above Earth to test their value for future missions to Mars.



The Challenge

Because spacecraft that land on the surface of Mars travel at extremely high speeds, they need some sort of drag device to slow them down to prevent them from crashing into the planet and becoming damaged. As missions increase in complexity, landers and rovers become heavier and require even more effective drag devices. Engineers must work within the limits (or constraints) of mass, weight, and space on a rocket to successfully accomplish the mission. Your team will work to design and construct a drag device that will **slow down** the cargo bay when it is dropped from a consistent height.

Figure 21. The Low-Density Supersonic Decelerator (LDSD) test vehicle is one of several drag devices NASA has engineered for landing large payloads on Mars. (NASA/JPL–Caltech)

Criteria and Constraints

1. The drag device must connect to a team-built cargo bay that is assembled using the template provided in this guide.
2. The entire device must be deployed from 2 m and remain intact throughout the drop.
3. The cargo bay must hold 10 g.
4. The overall mass cannot exceed 50 g.

Based on this information and the challenge's introductory video, answer the following questions.

1. Using your own words, restate the problem in this form: "How can I design a _____ that will _____?" Be sure to include all expected criteria and constraints.

_____

_____

_____

2. What general scientific concepts do you and your team need to consider before you begin solving this need or problem?

_____

_____

_____

The Engineering Design Process: Research

Page Number_____

Conduct research to answer the following questions related to the challenge. Cite where you found your information on the lines labeled "Source(s)."

1. Who is currently working on this problem (or a similar problem)? What solutions have they created? What solutions are they currently working on?

_____

_____

_____

Source(s): _____

2. What questions would you ask an expert who is currently trying to solve problems like this one?

_____

_____

_____

_____

3. Who in our society will benefit from this problem being solved? How could this relate to everyday use?

_____

_____

_____

_____

Source(s): _____

4. What have you learned from the Supporting Science Investigations that you can apply to this challenge?

_____

_____

_____

The Engineering Design Process: Design

Page Number_____

Sketch your initial design in the space below and label each part of your drawing.

Notes

_____

_____

_____

_____

The Engineering Design Process: Select the Best Possible Solution

Page Number_____

Collaborate with your team to analyze each team member's final drawing using the table below. Based on a team discussion, determine which design elements will be used to solve the problem and what features will be included to create the team's prototype. The most promising solution should include elements from more than one design.

Designer Name	Does this design meet all problem criteria and constraints?	What are the strongest elements of this design?	What elements need to be improved?
1			
2			
3			
4			

The Engineering Design Process: Prototype

Page Number_____

Make a team drawing of your prototype. Prior to building, have it approved by your facilitator. Include labels and a key.

Approved by _____

List what resources will need to be gathered.

_____

_____

For which part of the build will each team member be responsible?

Team Member				
Responsibilities in the building process				

The Engineering Design Process: Test and Evaluate

Page Number_____

1. Does the drag device function as intended?

   YES NO

2. If not, explain why. Provide details.

_____

_____

_____

_____

_____

_____

3. Does it meet all of the criteria and constraints? (Check the box for each one that is met.)

   - ☐ The drag device must connect to a team-built cargo bay that is assembled using the template provided in this guide.
   - ☐ The entire device must be deployed from 2 m and remain intact throughout the drop.
   - ☐ The cargo bay must hold 10 g.
   - ☐ The overall mass cannot exceed 50 g.

4. If not, explain why. Provide details.

_____

_____

_____

_____

_____

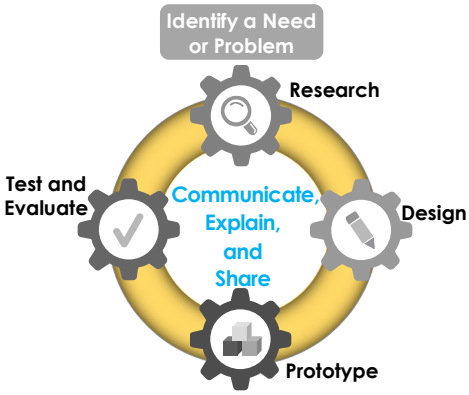
Parachuting Onto Mars

Perform three tests of your design. Record the times and calculate the average time for each iteration. Note any modifications that the team thinks need to be made.

2-m Drop Height Test	Vehicle Mass, including 10 g cargo	Drop Time, sec	Average Drop Time, sec	Modifications To Increase Drag (slow vehicle down)
Control Trial		Trial 1:		
		Trial 2:		
		Trial 3:		
Iteration 1		Trial 1:		
		Trial 2:		
		Trial 3:		
Iteration 2		Trial 1:		
		Trial 2:		
		Trial 3:		
Iteration 3		Trial 1:		
		Trial 2:		
		Trial 3:		

The Engineering Design Process: Communicate, Explain, and Share

Page Number_____



Indicate the step you are discussing.

_____

1. What did YOU think about your team's solution at the end of this step?

_____

_____

_____

2. What did OTHER MEMBERS of your team think about the team's solution at the end of this step?

_____

_____

_____

3. Was your personal feedback different from your team's feedback? If so, in what way was it different?

_____

_____

_____

4. Which step of the engineering design process (EDP) will your team move to now?

_____

_____

_____

_____

5. Explain why your team chose this step.

_____

_____

_____

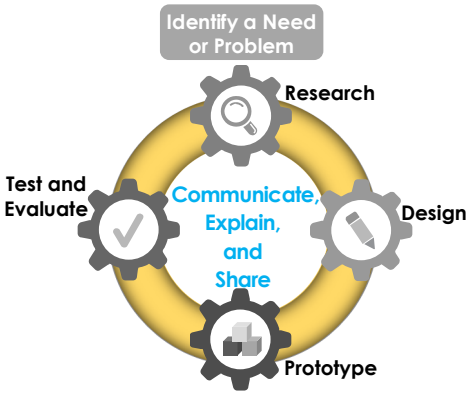
_____

The Engineering Design Process: Communicate, Explain, and Share

Student Presentation Organizer

Use the organizer below to plan how your team will present its final solution. Keep track of the engineering design steps you take so you can tell your audience how your team accomplished the process.

Keep in mind that these steps may have happened in any order or may have been repeated. Use additional sheets if necessary.

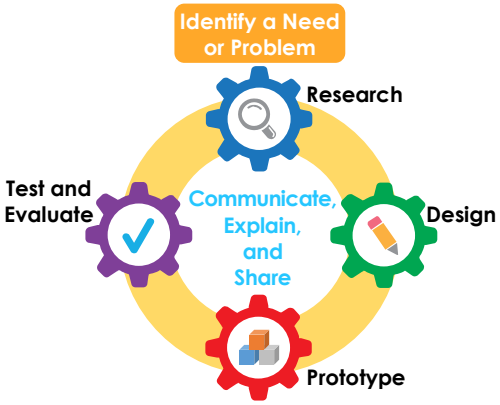


Welcome	Share your team name, which challenge you worked on, and the title of your presentation.	
Engineering Design Process (EDP) Practice	**Ideas for what should be included in each step of the presentation**	**Use this space to organize notes and think about the evidence to present. Make note of what your team wants to show and say in the presentation.**
Identify a Need or Problem	Talk about the problem. Discuss the criteria and constraints that will need to be met to solve the problem.	
Research	Discuss what your team discovered during the research and through your interaction with a NASA subject matter expert (SME). Who did you speak with? What did you learn? Where did you find answers to your questions?	
Design	Show each team member's original designs. Show what each team member contributed to the original team drawing.	

Prototype	Show materials used and how you put the prototype together.	
Test and Evaluate	Talk about how your team tested the design and discuss the results. Using the data, discuss the strengths and weaknesses of your team prototype.	
Communicate, Explain, and Share	Talk about your data. Was your team able to solve the problem or not? What improvements did your team make to reach your final solution? Discuss any further action your team would take to improve this solution. Describe how your team members communicated with each other to improve the solution. Also describe how you discussed options with people outside your group.	

Engineering Design Process Team Progress Chart

Use the table below to keep track of which practices your team did, and in what order. This table, along with your Student Presentation Organizer, will help you in summarizing your team's entire process from beginning to end.



Practice Order	Which engineering practice did your team do?	Notes on what your team did or learned during this practice
1	**Identify a Need or Problem**	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Solution Presentation

The final stage of the challenge is to document your progress for sharing with other groups who have completed this engineering design challenge. Your journey may be documented using video or slide presentations.

The finished presentation must meet the following guidelines:

- The introduction must say this: "This is team (team name), and we worked on the (name of challenge). The title of our presentation is (presentation title)."

  Do not identify by name any student, teacher, school, group, city, or region in your presentation. Submissions that do not follow these directions will be disqualified.

- The presentation must document every step you took to complete the challenge, including the Supporting Science Investigations. Use every page of your Student Team Challenge Journal to help complete this presentation.
- Identify any information provided by NASA subject matter experts (SMEs) that helped you in your design or testing.
- Explain which characteristics of the design provided the most reliable results and why.
- The total length of the presentation should be 3 to 5 minutes.

Student Presentation Rubric

This rubric will be used to assess your final presentation. Use it as a checklist to make sure you have included something from every category. Try to achieve as many 3's as you can!

Engineering Design Process	Exemplary = 3	Proficient = 2	Novice = 1	Not Included = 0
We can **identify** the challenge and the criteria.	Challenge was restated and all criteria and constraints were described.	Challenge was restated with only the challenge criteria.	Only the challenge story was stated.	Team did not include a description of the challenge or the criteria.
We can discuss the results of our **research**, the Supporting Science Investigations, and connections with a NASA scientist or engineer.	Three or more facts relating to the challenge were discussed.	Two facts relating to the challenge were discussed.	One fact relating to the challenge was discussed.	No facts relating to the challenge were discussed.
Each of our team members sketched an original **design** that demonstrated the challenge criteria and constraints.	All criteria and constraints were represented (sketches and photos) in each team member's design.	Two criteria were represented (sketches and photos) in each team member's design.	One criterion was represented (sketches and photos) in each team member's design.	No criteria were represented.
Our final team **design** represented elements from each team member's original design.	Team design included the best from each member's design to represent the challenge and the criteria.	Team design included ideas from two team members' designs to represent the challenge and the criteria.	Team design included ideas from one team member's design to represent the challenge and the criteria.	Team was not able to provide a design to represent the challenge and the criteria.
Our team constructed a **prototype** to represent the challenge criteria and constraints.	A prototype was completed that met all of the challenge criteria and constraints.	A prototype was completed that met only two of the challenge criteria and constraints.	A prototype was completed that met only one of the challenge criteria and constraints.	A prototype was completed that did not meet the challenge criteria or constraints.
Our team collected and recorded data to **test and evaluate** our model's solutions.	Data were collected by testing to represent all of the criteria and constraints.	Data were collected by testing to represent only two criteria.	Data were collected by testing to represent only one criterion.	No data were collected and/or no testing was completed.
Our team made **design** improvements after testing the prototype.	All improvements to the prototype were described.	Two improvements to the prototype were described.	One improvement to the prototype was described.	No improvements to the prototype were described.
Our team was able to **communicate and explain** our design and how we solved the challenge.	Difficult issues were explained and their solutions described.	Difficult issues were explained with no solutions offered.	Discussion of difficult issues was unclear and no solutions were presented.	No discussion of difficult issues was included.
Our team was able to **share** our work through the **presentation process**.	All the presentation requirements and procedures were met.	Three or more of the presentation requirements and procedures were met.	One or two of the presentation requirements and procedures were met.	The presentation requirements and procedures were not met.

Vocabulary List

Aerodynamics. The qualities of an object that affect how easily it is able to move through the air

Capsule. A pressurized modular compartment of an aircraft or spacecraft, designed to accommodate a crew or to be ejected

Cargo. Freight carried by an aircraft or other transportation vehicle

Constraints. Limits placed on a design due to available resources and environment

Criteria. Standards by which something may be judged or decided

Decelerator. A mass or object that decreases the speed of another object

Descent. The downward incline or passage of an object

Drag. Resistance to motion through the air

Exploration. Systematic investigation for the purpose of discovery

Fragile. Easily broken or damaged

Gravity. The force that attracts a body toward the center of the Earth or toward any other physical body having mass

Iteration. One cycle of a repetitive process

Launcher. A device for firing rockets

Mass. A unified body of matter without any specific shape

Model. A small object, usually built to scale, that represents another larger object

Observation. The act of noting and recording something with an instrument

Orbit. The path of a celestial body or artificial satellite as it revolves around another object

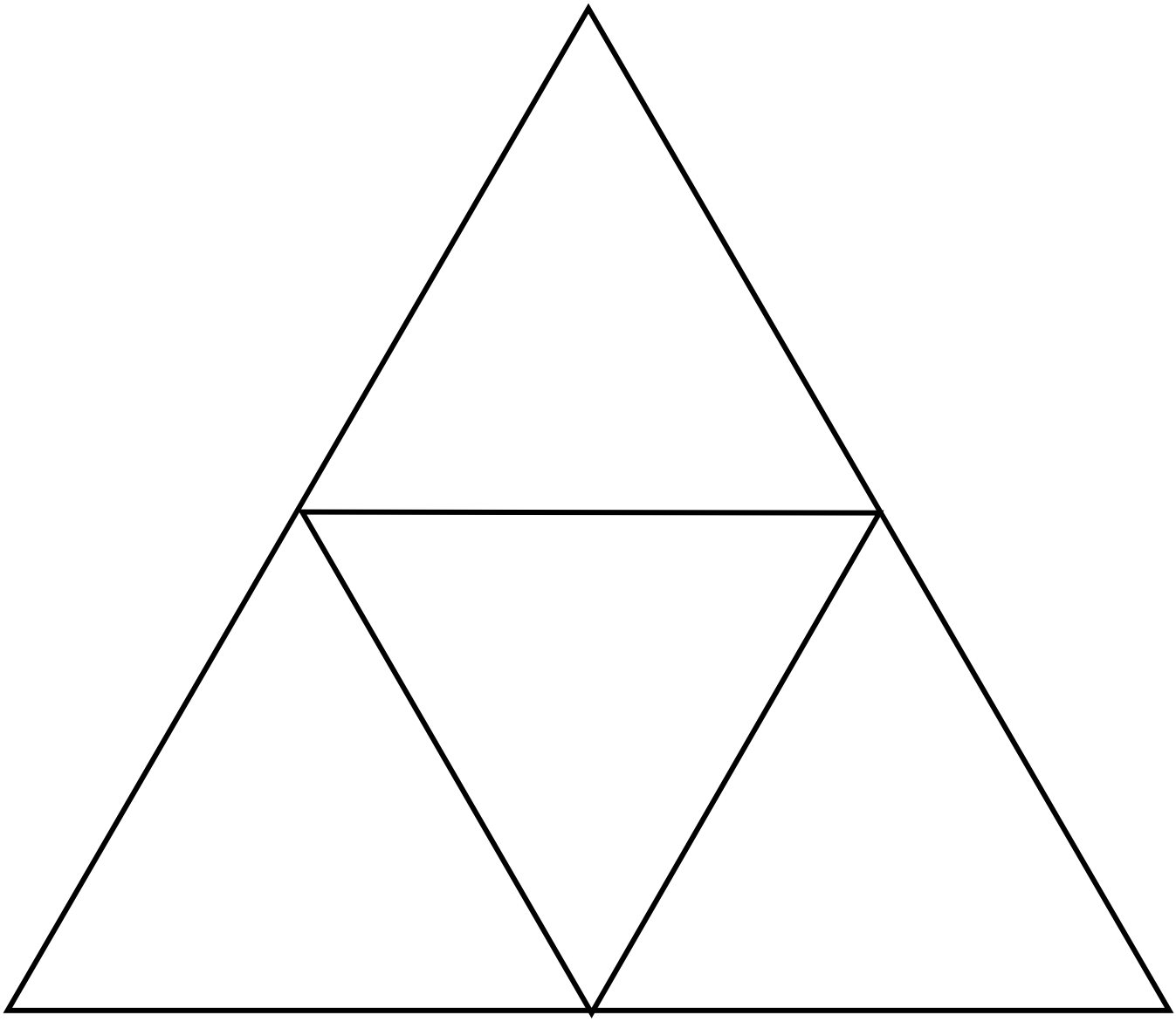
Payload. Things carried by a spacecraft

Template. A pattern used to guide in making something accurately

Volume. The quantity of three-dimensional space enclosed by some closed boundary; for example, the space that a substance (solid, liquid, gas, or plasma) or shape occupies or contains

Weight. The force on an object due to gravity

Appendix

Cargo Bay Template

Cut out the larger triangle and fold on the inner lines to create a pyramid shape. Put the simulated payload inside the pyramid and tape up the sides. Because you might need to adjust the weight of your capsule during testing, use a minimal amount of tape so it can be opened easily.