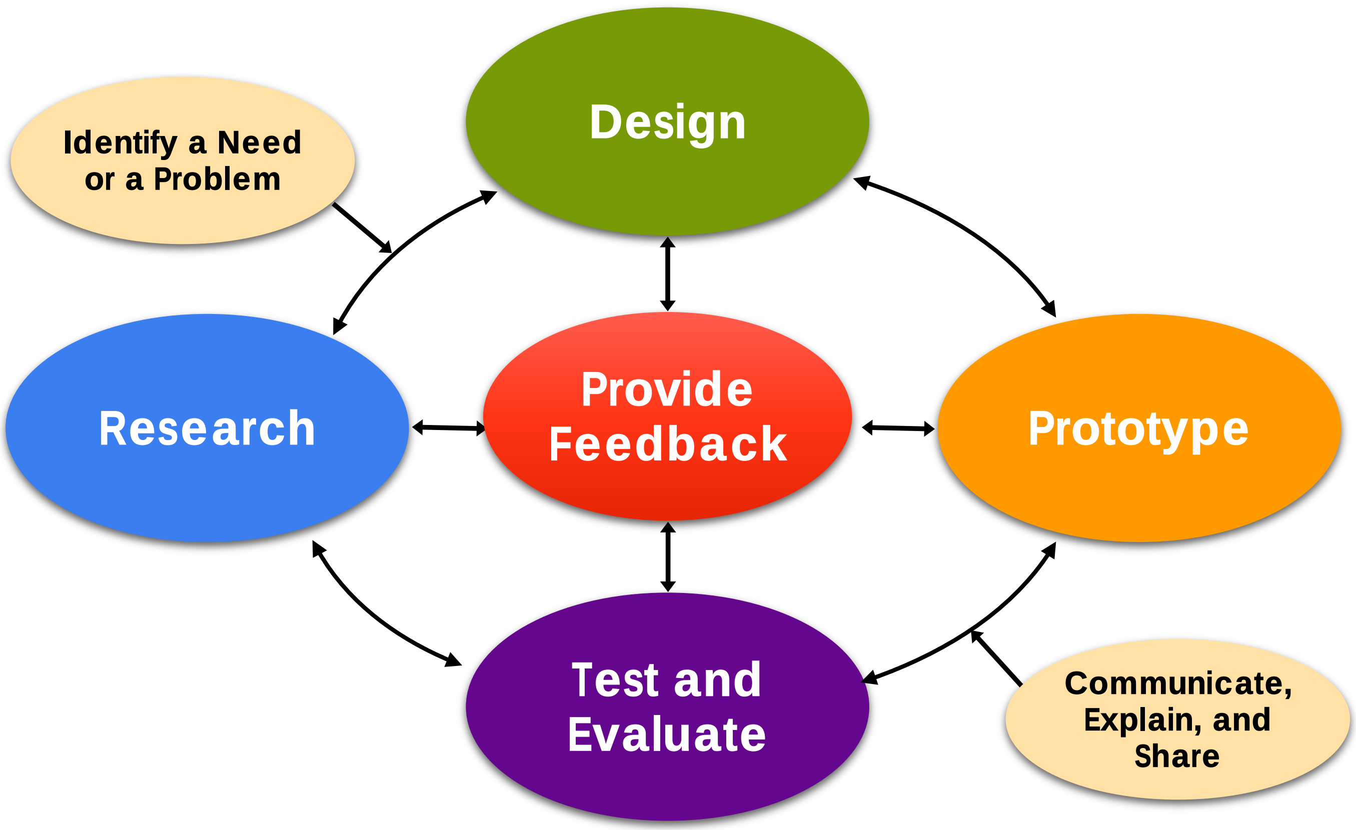
National Aeronautics and Space Administration

NASA Glenn Research Center Engineering Design Challenge

EDC-04: Spacecraft Safety

The Engineering Design Process



Introductory Video

https://youtu.be/pgRW4SHpNR4

Supporting Science Investigations

Spacecraft Safety includes two Supporting Science Investigations to assist students in understanding the science behind the challenge.

- Investigation 1: Egg Drop Challenge
- Investigation 2: Wall Smashers

Supporting Science Investigation 1: Egg Drop Challenge

- In this activity, you will discover how to protect a falling object using readily available classroom materials.
- Your team will create a package to contain and successfully land a raw egg, unbroken, from a fall to the ground.
- Think about how velocity and acceleration from falling objects relate to force on landing.

Supporting Science Investigation 1: Egg Drop Challenge

Procedure

1. Work with your partner to design a prototype of your container and the materials you will use.

2. Select one type of packing material for your container.

3. Put the egg into a zip-top bag and seal the bag, removing as much air as possible.

4. Using the selected packing material, wrap the egg to protect it during its fall.

Supporting Science Investigation 1: Egg Drop Challenge

5. Once your team has contained and sealed the egg, hold the meter stick vertically and drop the egg from a height of 30 cm.

6. One team member will time how long it takes for the egg to fall. Report findings on the Data Collection Sheet in the Student Team Challenge Journal.

7. Repeat the drop at additional 10-cm increments (40 cm, 50 cm, etc.) until the egg breaks.

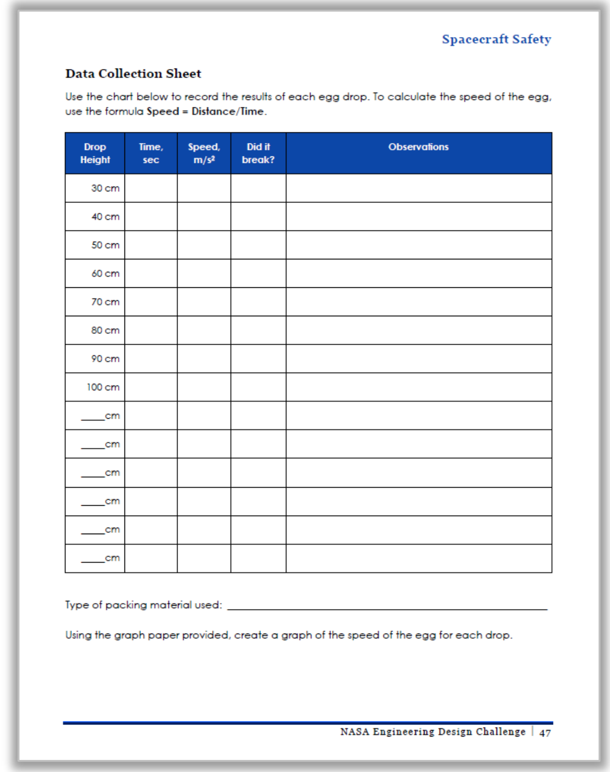
8. Record all times on the Data Collection Sheet and calculate the speed using this formula :

Speed = Distance ÷ Time

Supporting Science Investigation 1: Egg Drop Challenge

9. Next, answer the questions on the Data Collection Sheet.

10. Report findings to the whole group. Review the results from each packing material to determine the best- and worst-performing materials and discuss the reasons why they performed as they did.



Spacecraft Safety

Data Collection Sheet

Use the chart below to record the results of each egg drop. To calculate the speed of the egg, use the formula **Speed = Distance/Time**.

Drop Height	Time, sec	Speed, m/s²	Did it break?	Observations
30 cm				
40 cm				
50 cm				
60 cm				
70 cm				
80 cm				
90 cm				
100 cm				
___cm				
___cm				
___cm				
___cm				
___cm				
___cm				

Type of packing material used: ____________________

Using the graph paper provided, create a graph of the speed of the egg for each drop.

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Supporting Science Investigations Discussion

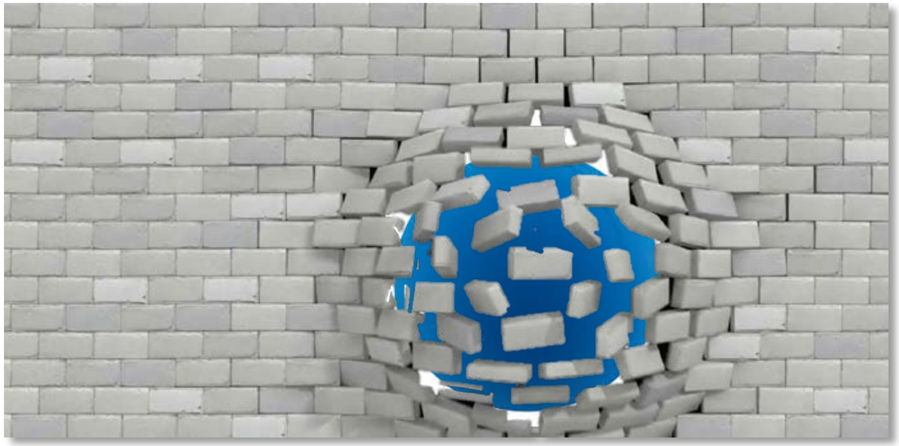
Investigation Discussion 1: Egg Drop Challenge

The Egg Drop Challenge activity showed that an object gains energy (speed) as it falls due to gravity pulling downward on the object. In order to prevent the egg from being damaged on landing, we had to protect it using energy-absorbing materials.

- If your team designed a new iteration of the container, how would you apply what you learned in this investigation to your design?
- We know that gravity is less on Mars than on Earth. How do you think your container would hold up if your team performed this investigation on Mars?

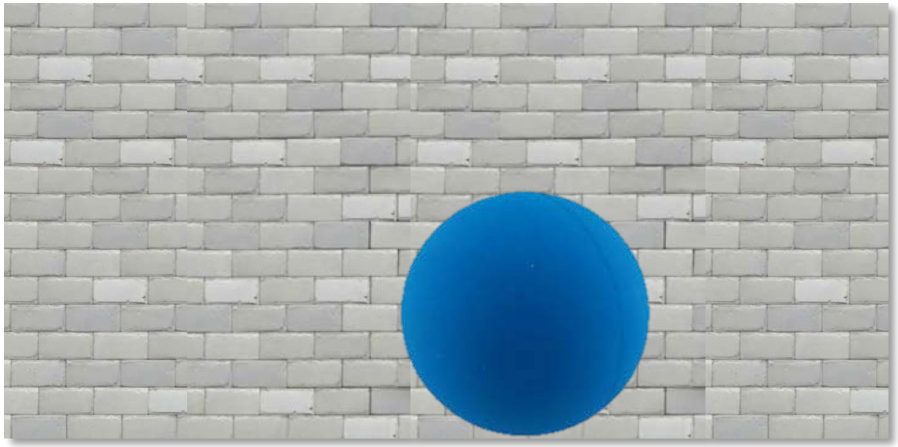
Supporting Science Investigation 2: Wall Smashers

The key to stopping an object safely is to disperse its energy. For example, if a ball was released on a ramp and hit a wall at the bottom of the ramp, the speed of the ball would drop to zero almost instantly. In terms of energy, this means that the energy of the ball would transfer to the wall quickly, causing damage to both the wall and the ball.



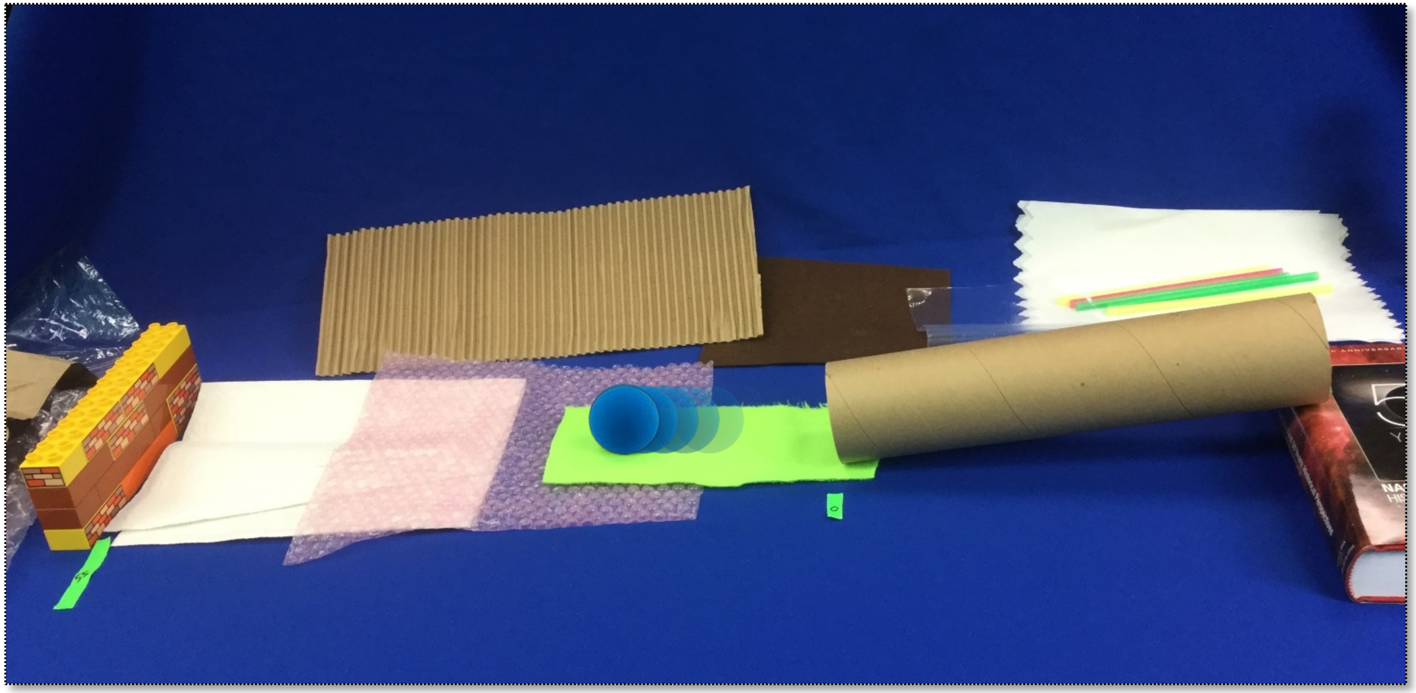
Supporting Science Investigation 2: Wall Smashers

In contrast, if the ball was slowed down on the ramp prior to hitting the wall so that it was barely moving by the point of impact, the energy would have been slowly released by the ball before it hit the wall. This would result in a safe bump against the wall, and no damage would occur.



Supporting Science Investigation 2: Wall Smashers

The goal of this investigation is to create friction where the ball meets the tube so that the ball will roll down the ramp and slow to a complete stop just as it touches the wall.



Supporting Science Investigation 2: Wall Smashers

Procedure

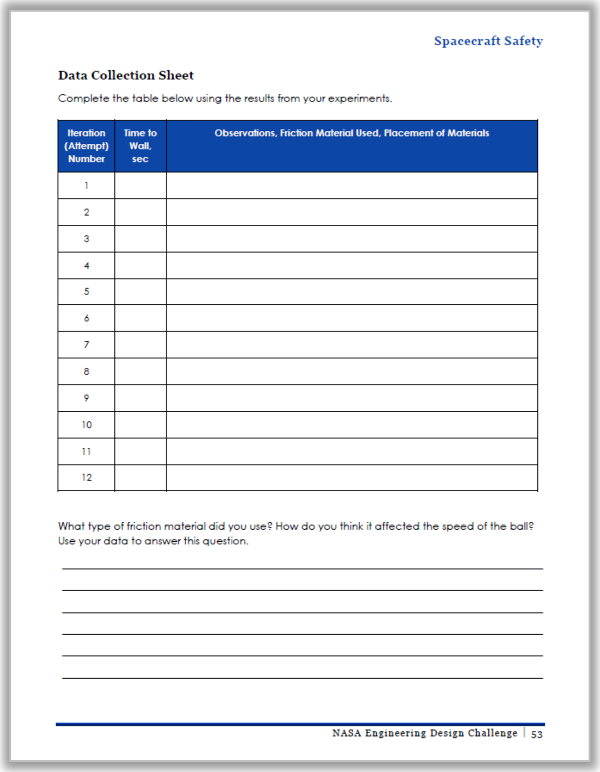
1. Place one end of the mailing tube on book or books to create a ramp 5 cm high that the ball can roll down. Secure using tape as needed.
2. Using the toy bricks, build a wall 55 cm from the lower end of the tube. Use tape to mark the location for the wall to be rebuilt as necessary.
3. Place the ball at the top of the ramp and allow it to roll down the tube. Make an observation. Record the control time on the Data Collection Sheet.
4. Use different materials to create friction to slow the ball as it rolls down the ramp. Materials can be placed inside the tube and also on the surface between the end of the tube and the wall.

Supporting Science Investigation 2: Wall Smashers

5. Record the materials and the time on the Data Collection Sheet for each iteration.

6. Continue trying various combinations and amounts of friction materials in order to achieve the stated goal of the ball slowing to a stop just as it touches the wall.

7. Complete the remaining questions on the Data Collection Sheet.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Data Collection Sheet

Complete the table below using the results from your experiments.

Iteration (Attempt) Number	Time to Wall, sec	Observations, Friction Material Used, Placement of Materials
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

What type of friction material did you use? How do you think it affected the speed of the ball? Use your data to answer this question.

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Supporting Science Investigations Discussion

Investigation Discussion 2: Wall Smashers

The Wall Smashers activity used a ball traveling down a ramp to simulate an object entering the atmosphere from space, with the wall simulating the surface of the planet.

- When an object reenters the atmosphere, it is not on a ramp, so how could you use friction material to help slow down the object?
- Why was it important to find just the right mix of friction materials in order to make the ball "just" touch the wall?
- How might you apply what you learned in this investigation to your design?

Creating a Solution Presentation

Presentation submissions should showcase solutions and the process from initial design to final solution. A Student Presentation Rubric is included to assess and score each presentation based on the following criteria:

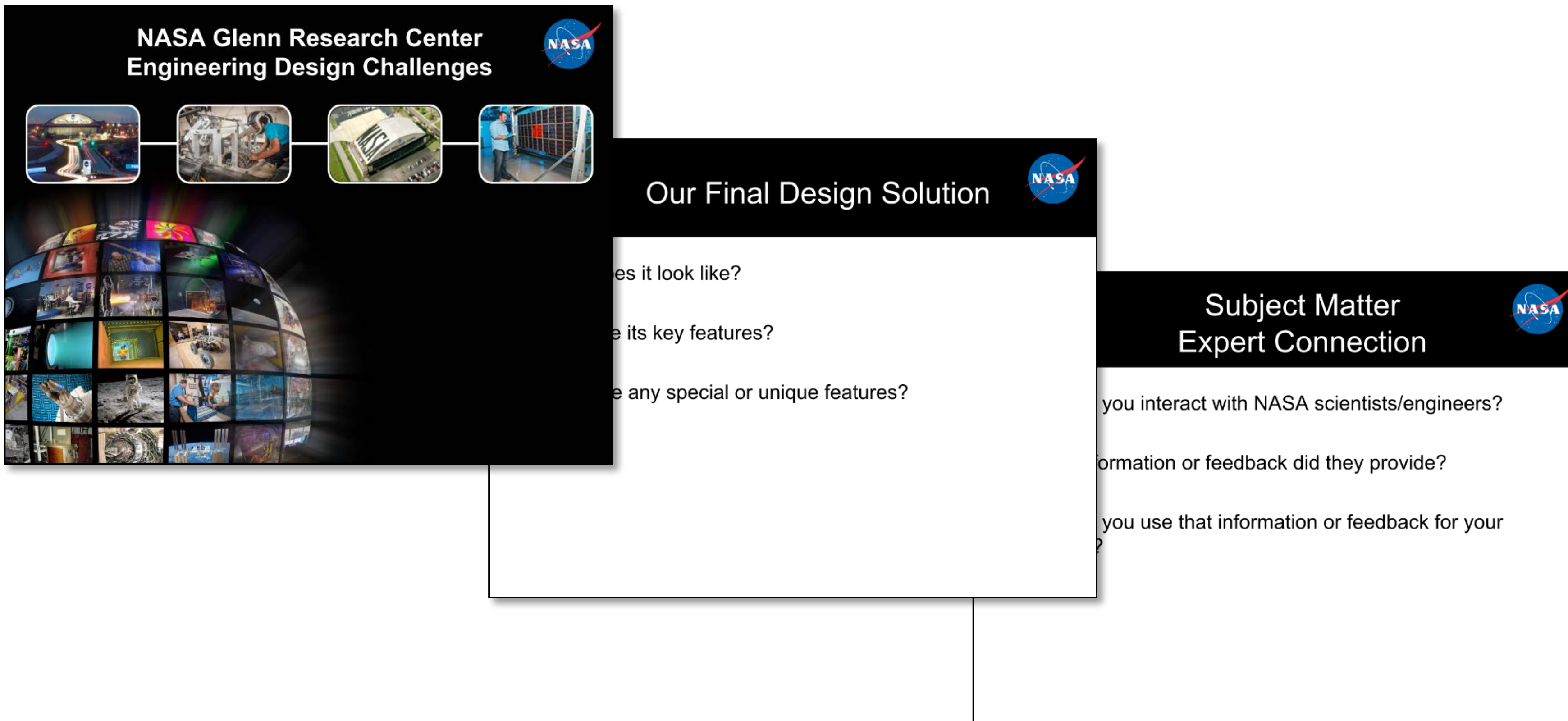
1. Introduce the presentation:
   - "This is team (team name) and we worked on the 'Spacecraft Safety' challenge. The title of our presentation is ____________."
   - Do not identify the name of any student, teacher, school, group, city, or region.
2. The presentation should document every step teams took to complete the challenge, including Supporting Science Investigations.
3. Identify information provided by NASA scientists and engineers.
4. Explain which characteristics of the design provided the most reliable results and why.
5. Keep the total presentation length between 3 and 5 minutes.

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 3s as you can!

Engineering Design Process Practices	Exemplary = 3	Proficient = 2	Novice = 1	Not Included = 0
We can **identify** the challenge and the criteria.	Challenge restated and all criteria and constraints described.	Challenge restated with only the challenge criteria.	Challenge story only was stated.	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 criteria 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.	The team design includes the best from each member's design to represent the challenge and the criteria.	The team design includes ideas from two team members' designs to represent the challenge and the criteria.	The team design includes ideas from one team member's design to represent the challenge and the criteria.	The team was not able to provide a design to meet the challenge and the criteria.
Our team constructed a **prototype** to represent the challenge criteria and constraints.	A prototype was completed that met all the criteria and the constraints of the challenge.	A prototype was completed that met only two of the criteria and constraints of the challenge.	A prototype was completed that met only one of the criteria and constraints of the challenge.	A prototype was completed that did not meet the criteria or the constraints of the challenge.
Our team collected and recorded data to **test and evaluate** solutions of our model.	Data was collected by testing to represent all the criteria and constraints.	Data was collected by testing to represent only two criteria.	Data was collected by testing to represent only one criteria.	No data was collected and/or no testing was completed.
Our team is able to explain our design, gather **feedback**, and explain how we solved the challenge.	Difficult issues were explained and their solutions described.	Difficult issues were explained with no solutions offered.	Difficult issues were unclear and no solutions were presented.	No difficult issue discussion was included.
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 followed the **presentation process** to communicate our team **design**.	All the video requirements and procedures were met.	Some of the video requirements and procedures were met.	One of the video requirements and procedures was met.	The video requirements and procedures were not met.

Glenn EDCs Student Presentation Template

http://tinyurl.com/Glenn-EDC-Template



Spacecraft Safety

The Challenge

- The spacecraft must carry two astronauts safely. Each astronaut is 3 to 7 cm tall. You must design and build secure seats for both astronauts. The astronauts should stay in their seats during each drop test of at least 2 m without being glued or taped in place.
- The spacecraft must have one hatch that opens and closes and is sized so that your astronauts can enter or exit easily. The hatch should remain closed during all drop tests.
- The spacecraft must fit within the simulated rocket.
- The spacecraft must include an internal holding tank for fuel with a volume of 30 cm^3.
- The total mass cannot exceed 100 g.

Identify a Need or Problem

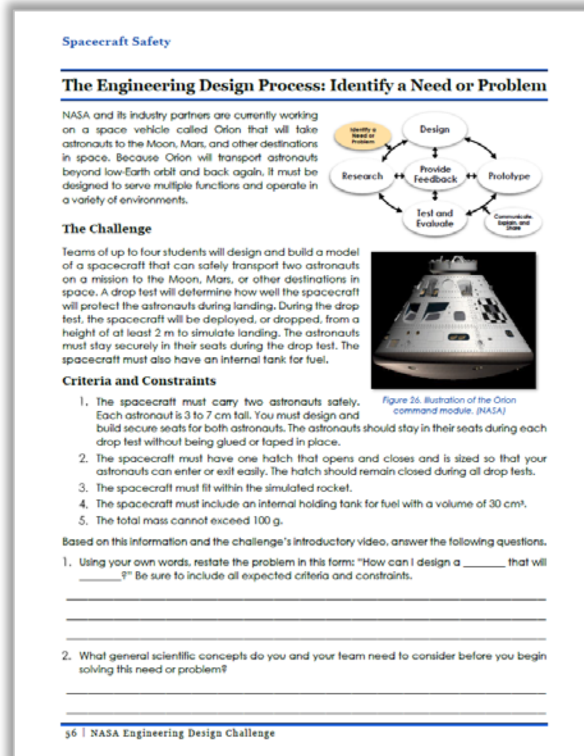
- State the problem in your own words.

  Example: "How can I design a __________ that will _________?"

- Determine what general scientific concepts you will need to consider before beginning to solve the problem.

- What needs to be solved or improved?

- What are we trying to accomplish?



Spacecraft Safety

The Engineering Design Process: Identify a Need or Problem

NASA and its industry partners are currently working on a space vehicle called Orion that will take astronauts to the Moon, Mars, and other destinations in space. Because Orion will transport astronauts beyond low-Earth orbit and back again, it must be designed to serve multiple functions and operate in a variety of environments.

The Challenge

Teams of up to four students will design and build a model of a spacecraft that can safely transport two astronauts on a mission to the Moon, Mars, or other destinations in space. A drop test will determine how well the spacecraft will protect the astronauts during landing. During the drop test, the spacecraft will be deployed, or dropped, from a height of at least 2 m to simulate landing. The astronauts must stay securely in their seats during the drop test. The spacecraft must also have an internal tank for fuel.

Figure 26. Illustration of the Orion command module. (NASA)

Criteria and Constraints

1. The spacecraft must carry two astronauts safely. Each astronaut is 3 to 7 cm tall. You must design and build secure seats for both astronauts. The astronauts should stay in their seats during each drop test without being glued or taped in place.
2. The spacecraft must have one hatch that opens and closes and is sized so that your astronauts can enter or exit easily. The hatch should remain closed during all drop tests.
3. The spacecraft must fit within the simulated rocket.
4. The spacecraft must include an internal holding tank for fuel with a volume of 30 cm^3.
5. The total mass cannot exceed 100 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?

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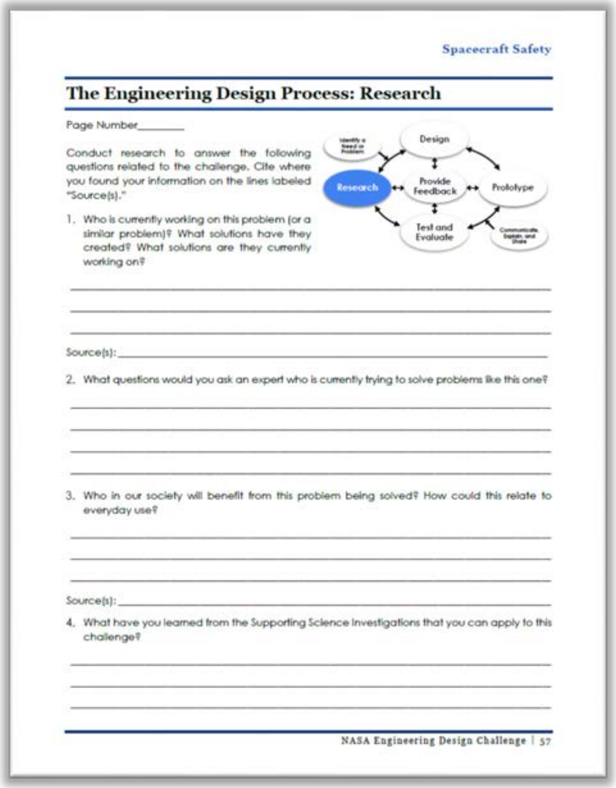
Research

- Examine how this problem is currently being solved or how similar problems are being solved.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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?

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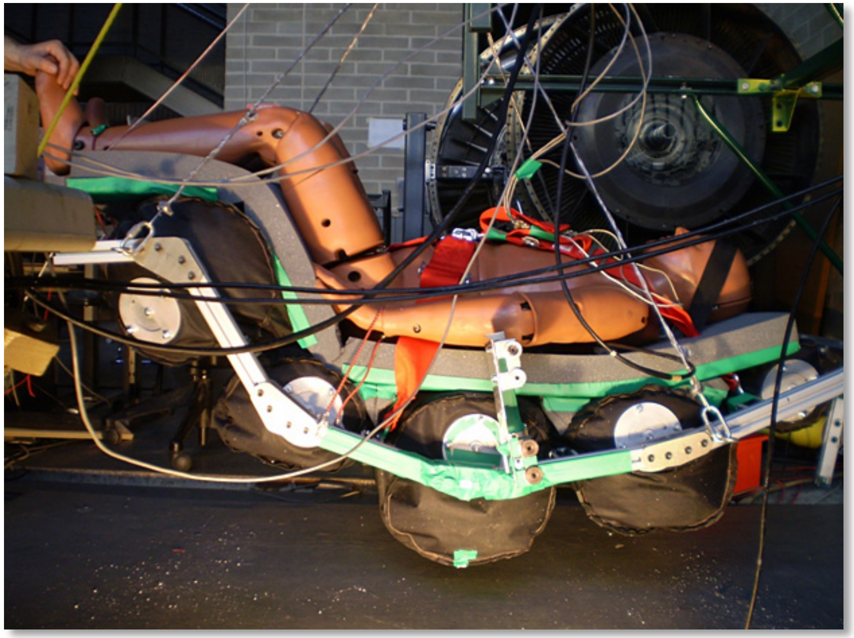
Testing for a Hard Landing

- An essential part of harness testing is to measure forces placed on a test dummy. A harness must restrain the astronaut and yet not cause harm in case of a hard landing instead of the usual water landing.



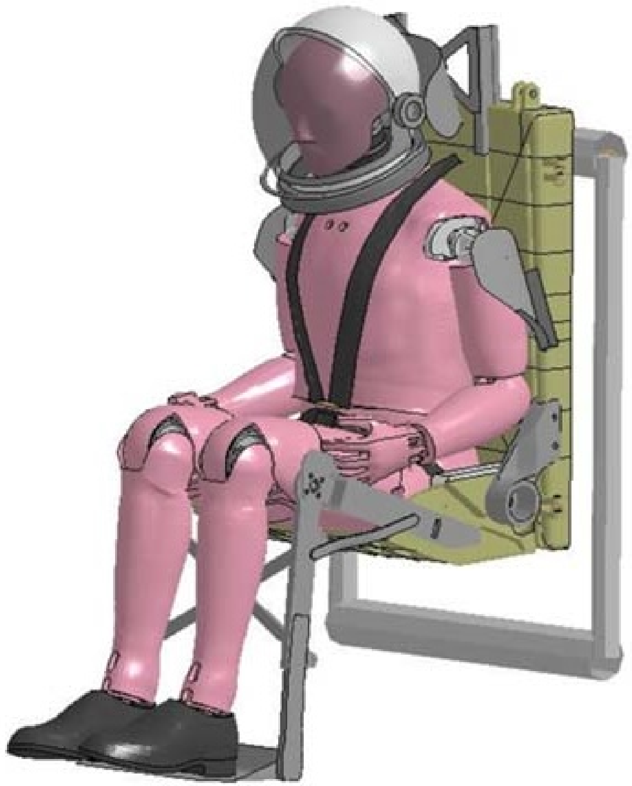
NASA harness and airbag testing in the event of an emergency landing on land.

Learning Lessons From the Past

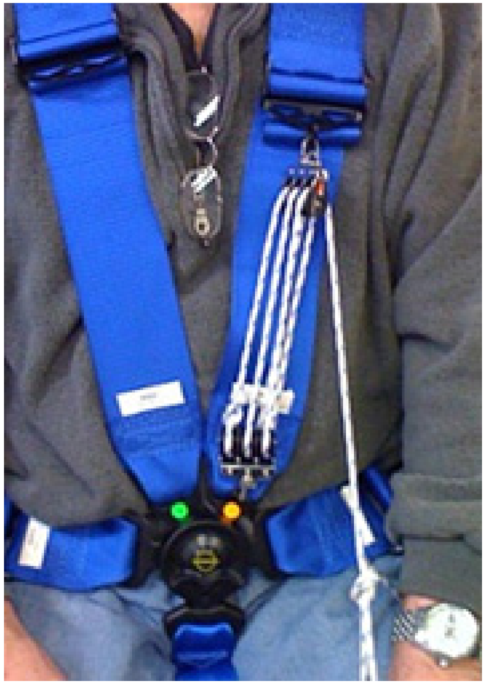
NASA Engineering and Safety Center team members (left) performing a fit check in an Orion seat mockup and (right) inspecting the Apollo capsule at Johnson Space Center for lessons learned related to how Apollo landed. Engineers continually try to make improvements on previous efforts.

Measuring Forces on Test Dummies

- A five-point harness system is tested in a simulated capsule using test dummies. Engineers use sensors to measure the strain from the harness before it is tested on live subjects.



Measuring Seat Belt Forces



- This harness tension mechanism mockup (lap strap, left, and shoulder strap, right) doubles the possible tension in the harness strap from previous systems to better protect the crewmembers and can be self-operated.

Hatch Design

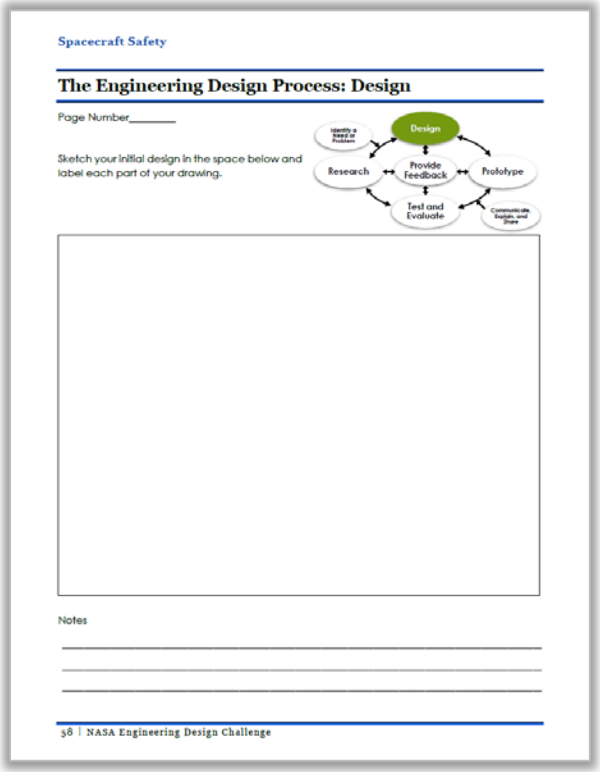
- Hatch design is difficult because the hatch must seal the capsule in the near-vacuum environment of space and yet be fairly easy to open in the event of an emergency by an astronaut in a pressure suit.

Testing Hatch Opening

- NASA astronaut Stan Love practices exiting the Orion side hatch while observers check hatch hardware performance while in moderate ocean conditions. Note the simple mechanism to open the hatch.

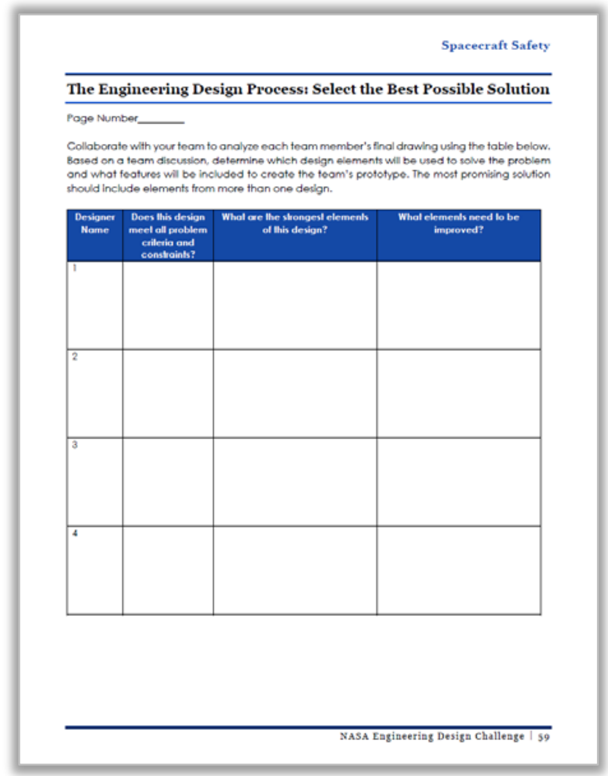
Design

- Use your research and scientific knowledge to brainstorm all the possible ways you can think of to improve the capsule, hatch, and harnesses.
- Quickly sketch your design, using labels and arrows to identify parts.



Design

- Share your ideas with your team.
- Discuss strengths and weaknesses from each design.
- Which design best solves the challenge? Are there parts from other designs that could improve that idea?



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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			

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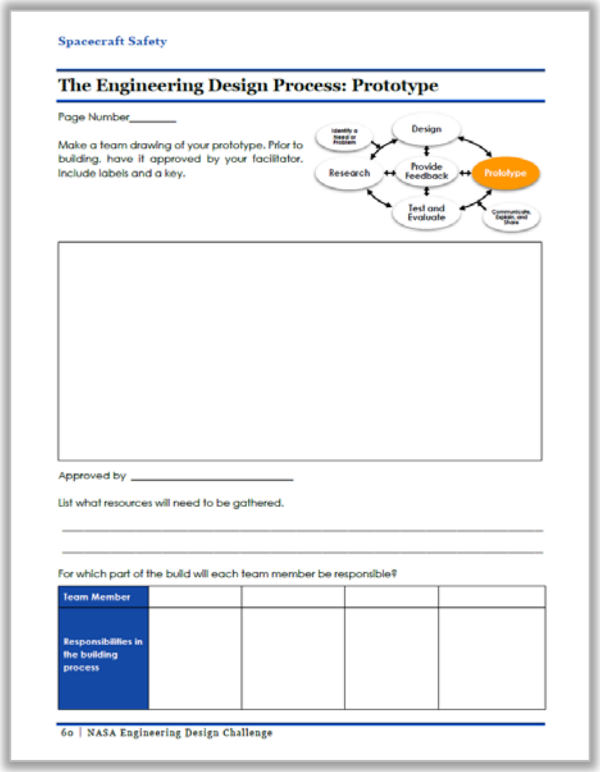
Prototype

- Construct a model of the selected solution.
- What materials will be needed for each part of the assembly?
- Who will build each part?



Spacecraft Safety

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				

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Safety Considerations

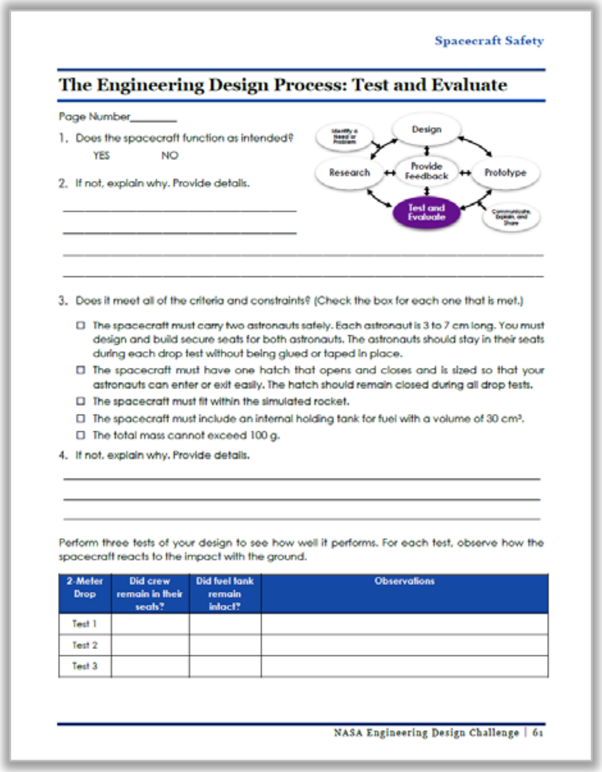
Safety is Priority #1.

- Make sure students understand the safety precautions necessary for all activities.
  - Make sure the drop area is clear before dropping capsules.
  - Have your facilitator assist with dropping your capsules from heights above your reach.
- Designs should be approved by a facilitator to prevent sharp or dangerous models.

A NASA researcher wearing personal protective equipment (PPE) appropriate for his work in this lab at Kennedy Space Center. PPE should be selected to match the potential risks of the work to be done.

Test and Evaluate

- Test your team’s model.
  - Check that the spacecraft fits within the simulated rocket.
  - Check that your spacecraft does not exceed 100 g.
  - Test three times and record data.
  - Make modifications and test again.



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The Engineering Design Process: Test and Evaluate

Page Number________

1. Does the spacecraft 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 spacecraft must carry two astronauts safely. Each astronaut is 3 to 7 cm long. You must design and build secure seats for both astronauts. The astronauts should stay in their seats during each drop test without being glued or taped in place.
   - ☐ The spacecraft must have one hatch that opens and closes and is sized so that your astronauts can enter or exit easily. The hatch should remain closed during all drop tests.
   - ☐ The spacecraft must fit within the simulated rocket.
   - ☐ The spacecraft must include an internal holding tank for fuel with a volume of 30 cm^3.
   - ☐ The total mass cannot exceed 100 g.
4. If not, explain why. Provide details.

Perform three tests of your design to see how well it performs. For each test, observe how the spacecraft reacts to the impact with the ground.

2-Meter Drop	Did crew remain in their seats?	Did fuel tank remain intact?	Observations
Test 1			
Test 2			
Test 3			

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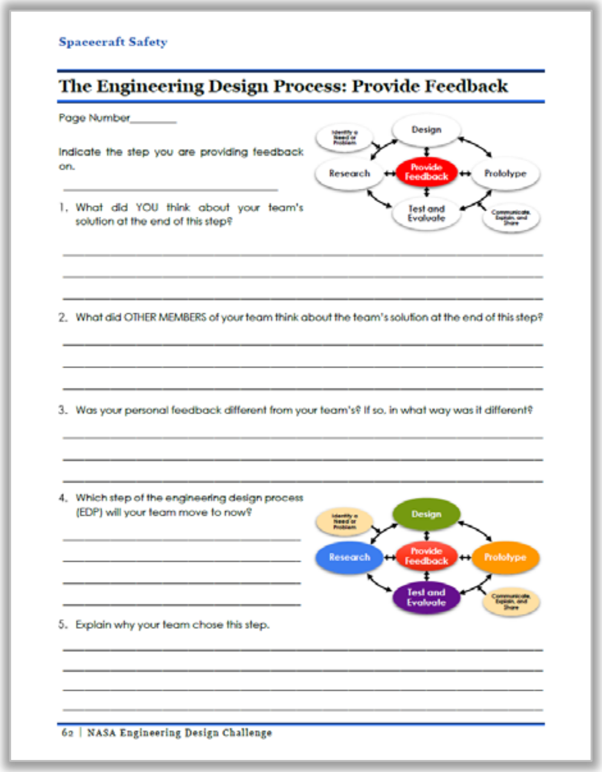
Provide Feedback

- Use this sheet to collaborate with your team as you progress through the challenge.
  - What worked?
  - What needs improvement?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The Engineering Design Process: Provide Feedback

Page Number______

Indicate the step you are providing feedback on.

____

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?

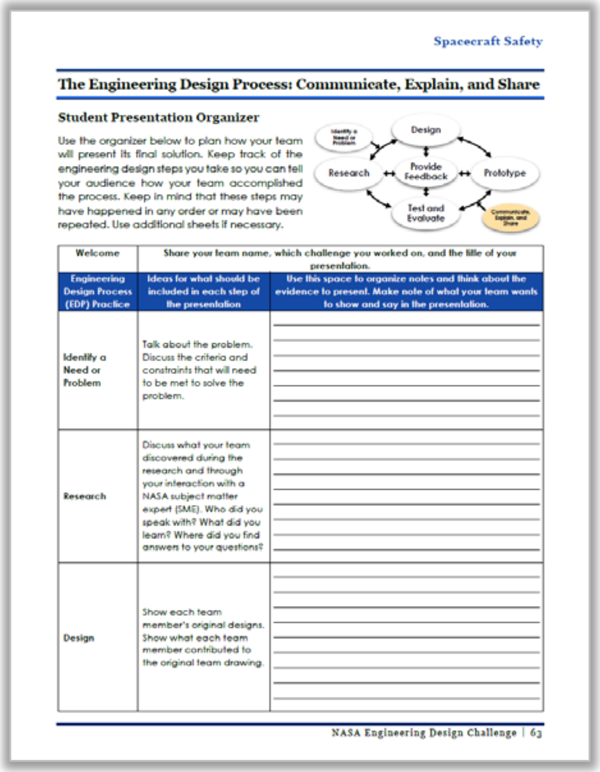
3. Was your personal feedback different from your team's? If so, in what way was it different?

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

5. Explain why your team chose this step.

Communicate, Explain, and Share

- Record and share what your team learned about your design based on testing.
  - What worked?
  - What needs improvement?
- Talk with other teams to get ideas.



The Engineering Design Process: Communicate, Explain, and Share

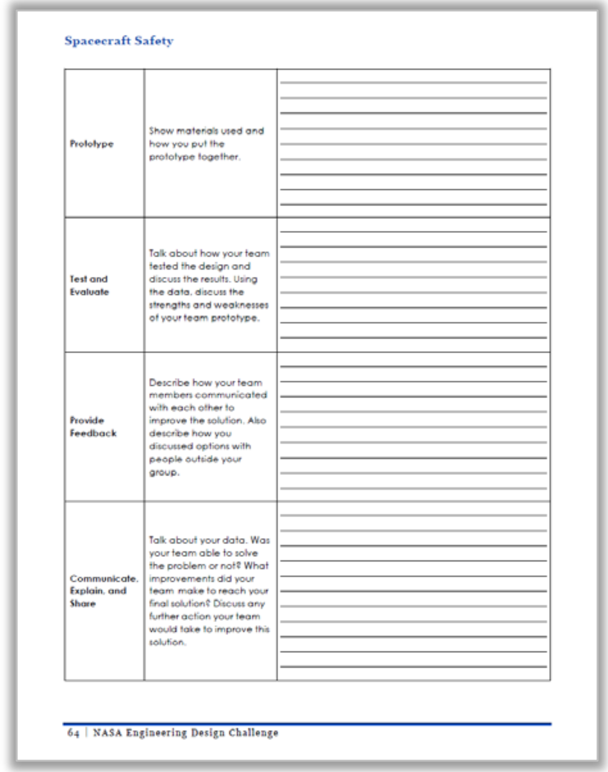
Student Presentation Organizer

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.	

Communicate, Explain, and Share

- Record and share what your team learned about your design based on testing.
  - What worked?
  - What needs improvement?
- Talk with other teams to get ideas.



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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.	
Provide Feedback	Describe how your team members communicated with each other to improve the solution. Also describe how you discussed options with people outside your group.	
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.	

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Debriefing Questions

1. Why did your team use this approach to solve the problem?
2. How did your research help you decide that this was the best solution?
3. What changes did you make to your design during your iterations of redesign?
4. How could you further improve on your design?
5. What were the greatest challenges for your team throughout this process?

Debriefing Questions

6. What strategies did your team use that proved effective in overcoming challenges?
7. How did you use the EDP to help with your design?
8. What concerns must be considered in constructing a safe spacecraft?
9. What specific problems did you need to address in designing the spacecraft?
10. If you were an astronaut heading to Mars, would you trust your team's spacecraft to bring you safely to the surface of the planet? Why or why not?