National Aeronautics and Space Administration

# 21CCLC NASA STEM Challenge

# Exploration Design Challenge

## Facilitation Guide

EDC
Exploration Design Challenge

## Radiation Shield Exploration

# FACILITATOR'S WELCOME

Dear 21CCLC STEM Facilitators,

Welcome to this year's 2014-2015 STEM Engineering Design Challenge Team! As part of this team, you will play an integral part in helping today's students become tomorrow's scientists, technicians, engineers, and mathematicians. Engineering Design Challenges, like the one included in this Facilitator's Guide. Through the Engineering Design Challenge (EDC), students will participate in authentic learning experiences that allow them to develop valuable skills through rigorous and engaging science, technology, engineering, and mathematics (STEM) content.

As a 21CCLC STEM facilitator, you are helping your students use their creativity, curiosity, analytical thinking as they utilize the **Engineering Design Process (EDP)**. Solving problems utilizing the EDP will be a key to the success of NASA's future engineering workforce.

Through the design challenge, ***Exploration Design Challenge – Radiation Shielding***, students will work in small teams of no more than four students, to design a shielding device to solve the problem of how to protect our astronauts from space radiation.

The major real-world concepts of this challenge are:

1. **Radiation: Radiation Exposure on Earth**
2. **Solar Radiation**
3. **Protection from Space Radiation**
4. **Spacecraft materials and construction to shield against radiation**

This Facilitator's Guide is designed to provide the facilitator with important information to use in planning and conducting the challenge. It includes simple explanations of relevant background information; clear step-by-step instructions, reflective data sheets, and concise rubrics for student performance. You will be expected to use all of the included materials with your students. You can adapt the timeline to fit your classroom schedule.

NASA supports educators and facilitators, like you, who play a key role in preparing students for careers in STEM fields through engaging content. Thank you for helping us share this learning experience with your students.

Engineering Design Challenge Team

US Department of Education
NASA Office of Education

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This challenge was adapted and content modified from "Space Faring: The Radiation Challenge: An Interdisciplinary guide on Radiation and Human Space Flight" EP-2008-08-120-MSFC.

# INTRODUCTION

# FACILITATOR'S OVERVIEW

The US Department of Education and NASA's Office of Education have worked together to create an **Engineering Design Challenge (EDC)** that teaches students about the **Engineering Design Process (EDP).** This process will help students complete the Engineering Design Challenge.

The EDC serves as an authentic standards-based investigation. It allows students to engage in the process of solving problems in a manner that today's scientists and engineers are experiencing. This EDC provides students with opportunities to gain tangible skills that are essential in STEM careers.

This guide is organized as follows:

1. Introductory Materials – Establishes a common basic level of understanding about the Engineering Design Process and its relation to this challenge. The introductory materials also includes an alignment to Next Generation Science Standards and the Common Core State Standards for Mathematics, as well as background information highlighting NASA's science and research related to the effects of radiation on astronauts in space.
2. Facilitator Pages – Provides instructions for facilitators to use throughout the design challenge Also, included in this section are tools for you to use to assess student understanding throughout all steps of the challenge.
3. Student Challenge Journal – Contains prompts and tools to guide students through the cycle of steps in the Engineering Design Process, while documenting their work through each step.
4. Support Materials – Consists of information to supplement, enhance, and build on the EDC.

These user-friendly sections are provided to help you support your students as they work in teams to complete the EDC. At the conclusion of the EDC, your students will be required to articulate the steps taken in the Engineering Design Process in a video each team will create. Good luck as help create the next generation of STEM professionals!

For more information, and to access the Help Desk, visit the NASA STEM Challenges website at http://y4y.ed.gov/stemchallenge/nasa.

# THE BASICS OF ENGINEERING DESIGN

**What is an Engineer?** Engineers are at the heart of every Engineering Design Challenge. Engineers are people who design and build things that we use every day. The video at the link below will explain the role of an engineer and can be shared with your students: http://youtu.be/wE-z_TJyzil. After viewing the video ask the students as a class to describe what an engineer does.

*Figure 1: Aerospace Engineer Chris Randall tests rocket parts and life support systems to ensure they work as planned. (NASA)*

*Figure 2: Simulation System Engineer Debbie Martinez works on developing a general aviation flight simulation software. (NASA)*

**What is an Engineering Design Challenge?** An Engineering Design Challenge is developed to assist students to understand the Engineering Design Process. The students are presented with a challenge problem and, using the process, they participate in teams to complete activities and experiments to develop solutions to the original problem. These challenges facilitate teamwork, problem solving, and brainstorming ideas very similar to what real-world engineers encounter in their careers.

### Engineering Design Process

**What is the Engineering Design Process?** The engineering design process is a cycle of steps that lead to the development of a new product or system. The cycle is repeated to continuously refine and improve the product. In this design challenge, students are to complete each step and document their work as they develop and test their design. To accomplish this task, the students need to perform each of the steps in the Engineering Design Process and repeat the cycle, as many times as time and resources allow, to develop the best end product. Some steps (for example, Researching the Need or Problem) will only need to be briefly revisited as a checkup that teams are still on track. Some steps (for example, Test and Evaluate the Solution) will need to be completely redone.

# THE ENGINEERING DESIGN PROCESS

**STEP 1: Identify the Need or Problem** – Students, working in teams; state the challenge problem in their own words. Example: How can I design a __________ that will __________?

**STEP 2: Research the Need or Problem** – Teams use resources, from the Internet, the library, or discussions with experts, to examine the how this problem is currently being solved or how similar problems are being solved.

**STEP 3: Develop Possible Solutions** – Team members draw on their mathematic and scientific knowledge to brainstorm all the possible ways that they might solve the problem. Out of their ideas, they choose the most promising options, and refine their solution by quickly sketching in two or three dimensions. Labels and arrows should be included to identify parts.

**STEP 4: Select the Best Possible Solution(s)** – Team members share their ideas and answer questions from other team members. The team then discusses and records strengths and weaknesses from each design and determines which solution(s) best meet(s) the original need or solve(s) the original problem. This may include features from more than one design. The team writes a statement that describes why they chose the solution.

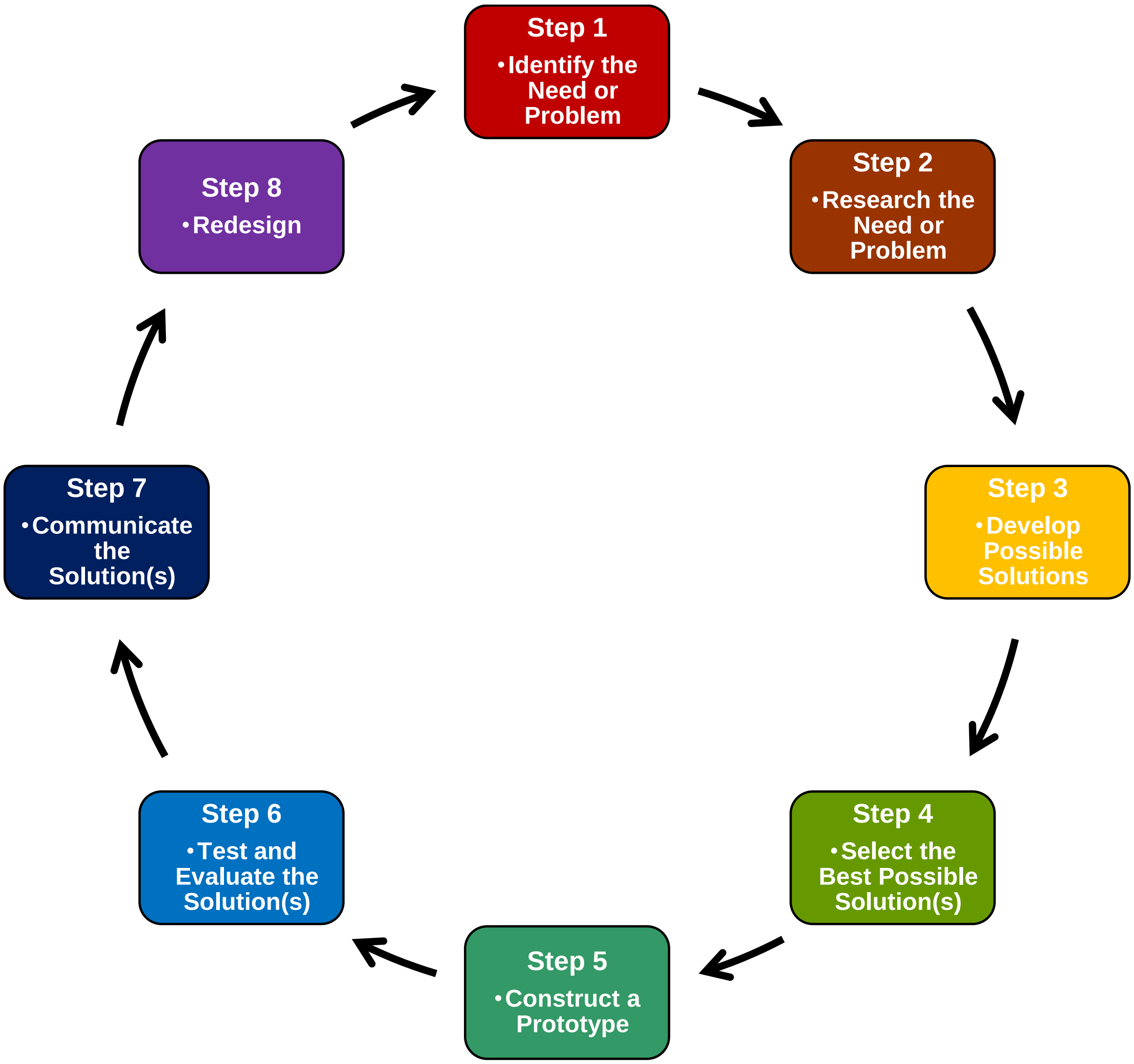
**STEP 5: Construct a Prototype** – Team members construct a full-size or scale model of the selected solution(s) in two or three dimensions. The facilitator helps to identify and acquire appropriate modeling materials and tools.

**STEP 6: Test and Evaluate the Solution(s)** – Team members test their model to determine how effective it was in solving the need or problem. Data is collected to serve as evidence of their success or need for improvement.

**STEP 7: Communicate the Solution(s)** – Team members record and share what was learned about their design based on testing. They make a presentation that includes how the solution(s) best solved the need or problem and any improvements that could be made. They may enlist students from other groups to review the solution and help identify changes.

**STEP 8: Redesign** – Team members consider modifications to their solution(s) based on the information gathered during the tests and presentation. Teams revisit the original need or problem to ensure their modifications still meet the necessary criteria and constraints, restarting the cycle of the Engineering Design Process.

# THE ENGINEERING DESIGN PROCESS




*This Engineering Design Process model was adapted from the Massachusetts Science and Technology/Engineering Curriculum Framework (published October 2006, http://www.doe.mass.edu/frameworks/scitech/1006.pdf).*

# STANDARDS ADDRESSED

| Next Generation Science Standards | Common Core State Standards Mathematics |
|---|---|
| Practices<br>1. Asking questions, defining problems<br>2. Developing and using models<br>3. Planning and carrying out investigations<br>4. Analyzing and interpreting data<br>5. Using math and computational thinking<br>6. Constructing explanations and designing solutions<br>7. Engaging in argument from evidence<br>8. Obtaining, evaluating, and communicating information<br><br>*Cross-Cutting Concepts*<br>1. Patterns<br>2. Cause and effect<br>3. Scale<br>4. Systems and system models<br>5. Energy and matter<br>6. Structure and function<br><br>*Core and Component Ideas*<br><br>*Physical Science*<br>PS1.A Structure of matter<br>PS4.B Electromagnetic radiation | *Standards for Mathematical Practice*<br>Measurement and Data<br>Describe and compare measurable attributes<br>Represent and interpret data<br>Measure and estimate lengths in standard units<br><br>Statistics and Probability<br>Summarize and describe distribution |

# BACKGROUND INFORMATION: RADIATION SHIELD

### What Is Radiation?

Radiation is a form of energy that is emitted or transmitted in the form of rays, electromagnetic waves, and/or particles. In some cases, radiation can be seen (visible light) or felt (infrared radiation), while other forms like x-rays and gamma rays are not visible and can only be observed directly or indirectly with special equipment. Although radiation can have negative effects both on biological and mechanical systems, it can also be carefully used to learn more about each of those systems.

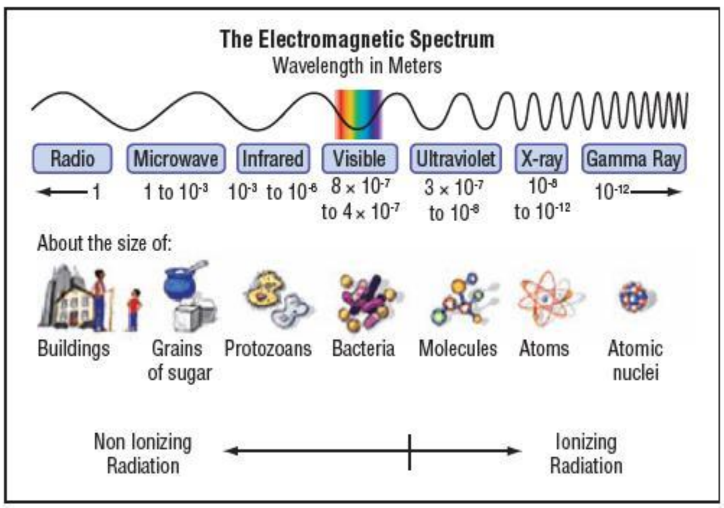



*Figure 3: The electromagnetic spectrum and comparative sizes of waves.*

The motion of electrically charged particles produces electromagnetic waves. These waves are also called “electromagnetic radiation” because they radiate from the electrically charged particles. They travel through empty space, as well as through air and other substances. Scientists have observed that electromagnetic radiation has a dual “personality.” Besides acting like waves, it acts like a massless stream of particles, called photons. The photons with the highest energy correspond to the shortest wavelengths and vice versa. The full range of wavelengths and photon energies is called the electromagnetic spectrum (*see Figure 3 above).* The shorter the wavelength, the more energetic the radiation and the greater the potential for biological harm.

## How does the Radiation Environment on Earth Compare to the Radiation Environment Elsewhere?

NASA has collected a variety of radiation and environmental data from the Moon and Mars. During the Lunar Prospector mission, NASA scientists discovered that some areas on both the Moon and Mars have a weak magnetic field. Magnetic fields have the ability to deflect radiation. Locations with these fields are slightly more protected and might be candidate sites for a lunar outpost. The strongest magnetic fields on the Moon are located near 20˚S, 170˚E and 43˚S, 170˚E (*as shown in figure 4*).

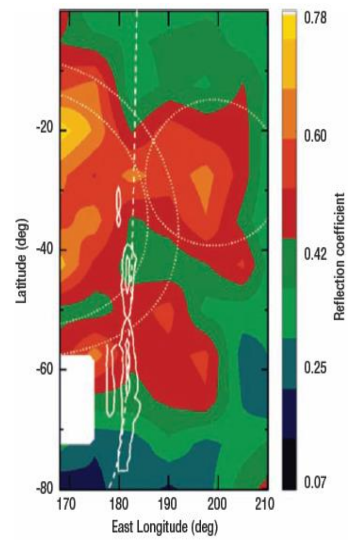



*Figure 4: Magnetic fields on the moon. (NASA)*

The Moon and Mars are vulnerable to the effects of space radiation despite these localized magnetic fields. They do not have global magnetic fields like Earth. As a result, their surfaces are not naturally shielded from solar radiation. Also, the Moon and Mars lack dense atmospheres which offer additional protection. The atmosphere of Mars is extremely thin, and the Moon essentially has no atmosphere. People living on the Moon or Mars will need to limit time spent outside of their shielded habitats.

### Harmful Radiation in Space

NASA is working to make long-duration human exploration of space a possibility without exceeding an acceptable level of risk from exposure to space radiation. Space radiation consists of heavy charged particles. High-energy protons and charged particles can damage both shielding materials and biological systems. Baseline levels of space radiation are typically low, but the effects are cumulative. Since solar activity fluctuates, the risk of exposure increases with the amount of time spent in space. Possible health risks include cancer, damage to the central nervous system, cataracts, risk of acute radiation sickness, and hereditary effects.

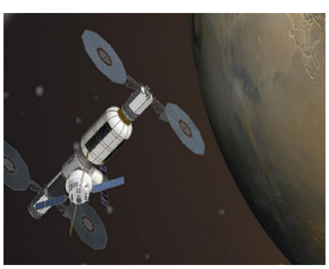


*Figure 5: Artist's depiction of a long-duration spacecraft mission to Mars. (NASA)*

For more than 35 years, NASA has been collecting and monitoring the radiation doses received by all NASA astronauts in space. While uncertainties still remain in predicting space radiation's biological risks, research is helping to quantify and reduce those risks. If long-duration space missions are to become reality, mission planners must have a thorough understanding the biological limitations of the human body in space and how to reduce the effects of space radiation through manufactured shielding on spacecraft and habitats.

For more information, visit:

- http://www.nasa.gov/sites/default/files/np-2014-03-001-jsc-orion_radiation_handout.pdf.

# SAMPLE TIMELINE

The EDC must be completed within the eight-week challenge period. The following timeline serves as a suggestion for the eight-week implementation. You may structure the sessions to fit your needs.

| EDC Weeks | EDP | Actions |
|---|---|---|
| Pre-EDC | Pre-EDP | Attend Training and Order Materials |
| Week 1 | Step 1<br>Step 2<br>Step 3 | Identify the Need or Problem<br>Research the Need or Problem<br>Develop Possible Solution(s) |
| Week 2 | Step 4<br>Step 5 | Select the Best Solution<br>Construct a Prototype |
| Week 3 | Step 6<br>Step 7 | Test and Evaluate Solution<br>Communicate Solution |
| Week 4 | Step 8<br>Step 1<br>Step 2 | Redesign the Model<br>Identify the Need or Problem<br>Research the Need or Problem |
| Week 5 | Step 3<br>Step 4 | Develop Possible Solutions<br>Select the Best Solution |
| Week 6 | Step 5<br>Step 6 | Construct a Prototype<br>Test and Evaluate Solution |
| Week 7 | Step 7<br>Step 8 | Communicate Solutions (Compare Iterations)<br>Recommend future Redesign |
| Week 8 | Post-EDP | Create and Upload Student Videos |

# SAFETY

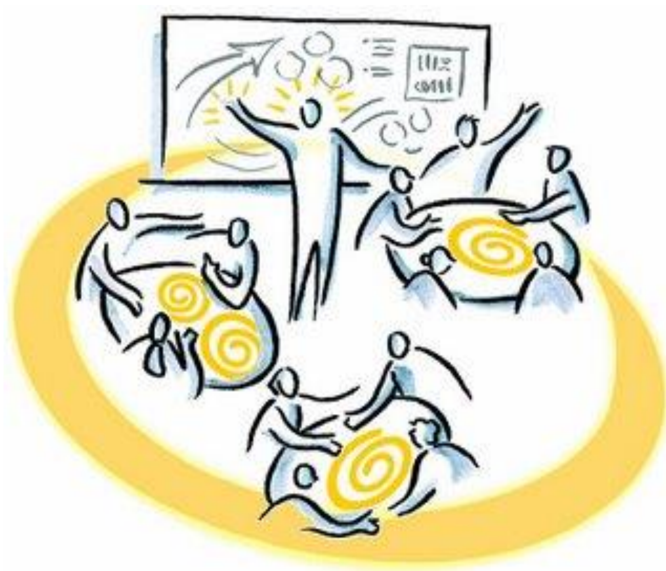
Safety is an important goal for all curricular areas of education. Safety issues are a special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote student development of knowledge and abilities in a safe learning environment.

It is the responsibility of the school's administration, teachers, and facilitators to provide a learning environment that is safe, up-to-date, and supportive of learning. Additionally, facilitators are responsible for their students' welfare in the classroom and laboratory.

Facilitators must be knowledgeable and diligent in providing a safe learning environment. Students should receive safety instructions relevant to the topics being taught. Assessments must accompany the lessons on safety, and records must be kept on student results. The facilitator must properly supervise students while they are working. The facilitator must inspect and maintain equipment and tools to ensure they are in proper working condition. Parents should be informed that a safe environment exists during the program. The facilitator should keep all students safe and assure that a safe environment exists and that proper procedures are being followed in the classroom and laboratory.

1. Students should demonstrate respect and courtesy for the ideas expressed by others in the group.
2. Students should use tools and equipment in a safe manner and assume responsibility for their safety, as well as for the safety of others.
3. Students should make safety a priority during all activities.
4. Students should wear safety goggles when conducting the EDC.
5. Facilitators should approve all drawings before students start building their designs.
6. Facilitators should look for potentially hazardous combinations of materials and flimsy designs of structures.
7. Facilitators should be sure resources are clean and dry with no sharp edges.
8. Facilitators should be the only ones using hot-glue guns and sharp instruments.
9. Facilitators should not allow students to bring additional materials for their designs without prior approval.
10. Facilitators should make sure all materials are not damaged or in disrepair.

# FACILITATOR PAGES



# USING A KLEW CHART

**FACILITATOR DIRECTIONS**: This KLEW chart can be used as a starting point for science investigation. Before you start the challenge, students should complete the **KNOW** section of this chart. It will allow students to share their prior knowledge and experiences (whether accurate or inaccurate). The **LEARN** section is after students are given background information about radiation shielding. This background information may come from videos, articles, and other supplemental information. The **EVIDENCE** section helps students to reinforce concepts that they learned using the background information and during the challenge by providing supporting information to validate what they stated in the LEARN column. In the **WONDER** section, students share any new questions they may still want to explore.

Please allow students to have flexibility in their answers. There are no right or wrong answers as long as the students answer the questions. Questions can be modified at the discretion of the Facilitator.

| KNOW | LEARN | EVIDENCE | WONDER |
|---|---|---|---|
| **What do I know about radiation and space travel?** | **What did I learn about radiation and traveling into space based on my research?** | **What evidence do I have that supports what I learned about radiation and space travel?** | **What am I still wondering about radiation and space travel?** |
| NOTE: Have students complete this column before researching about radiation and space travel. | NOTE: Have students complete this column after researching about radiation and space travel. | NOTE: Have students complete this column using supporting information from articles, background information research, direct observation, and SME connections. | NOTE: Have students complete this column as they move through the process as a way of documenting ongoing questions. |

# THE ENGINEERING DESIGN CHALLENGE

You will be using the Engineering Design Process (EDP) to solve the challenge. The following pages will help you guide the students through the Challenge. You will break the students into teams of up to four students and follow each step of the EDP. Please note that both the Facilitator Pages and the Student Journal section are organized to align with the each step of the EDP.

**THE CHALLENGE:**

NASA is working on a new vehicle to take astronauts beyond Low Earth Orbit and on long-term duration human space exploration such as to Mars and other destinations the solar system. However, many dangers to the human body, such as solar radiation, exist as humans travel away from Earth. To ensure the safety of the astronauts this new vehicle will need protective shielding that offers similar protection to Earth's atmosphere and magnetic fields. This shielding needs to be durable and safe, while having as little mass as possible for launch.

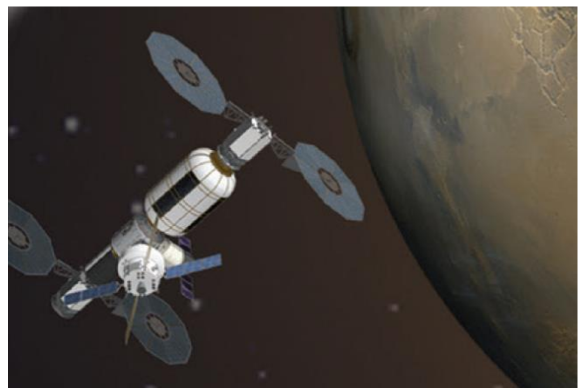


*Figure 6: Artist's depiction of a long-duration spacecraft mission to Mars. (NASA)*

You will work in a team to design and build a radiation shield with the following criteria and constraints:

1. The shield must be designed to absorb or reflect as much visible and ultraviolet light as possible. The shield must also be able to withstand a simulated water landing.

2. The mass of the shield may not exceed 300 g, but should be as light as possible. The thickness of the shielding may not exceed 2 cm, but should be as thin as possible. Total materials for the final shield design may not exceed $10.00, but should be as cost effective as possible.

3. The shield must completely cover the entire opening of the "test chamber" (oatmeal canister).

4. The shield must be able to perform under both wet and dry conditions.

5. Your shield must survive the following tests: radiation tests (above), flexibility test, ballistic impact test, load bearing test.

# MATERIALS

The following is a suggested list of materials needed to complete this challenge. The quantity will depend on the number of students participating. Alternatives can be used if necessary.

- Digital scale or balance (1)
- Measuring tape (1)
- Rulers (1 per team)
- Ream of paper
- Oatmeal canister (used as a test chamber)
- Flashlight
- Ultraviolet reactive ("solar") beads
- General building supplies for teams to assemble their radiation shields. These could include:

aluminum foil
balloons
skewers or stirrers
binder clips
bubble wrap
buttons or beads
cardboard or cardstock
clothespins
cloth
coffee filters
cotton balls
empty paper towel/toilet paper tubes
glue sticks
mini foil pie plates
modeling clay
paper bags
paper clips
pennies
pipe cleaners
plastic cups
plastic eggs
plastic wrap
craft sticks or tongue depressors
rubber bands
scissors
staplers and staples
straws
string
masking, electrical, transparent and duct tapes

**Pre-Activity Set-Up:**

- To construct a test chamber, cut a quarter size hole in the center of the base of the oatmeal canister opposite the open end. This will be used to test the amount of visible light shining through the students' designs.
- Determine a unit cost for each of the materials available. These values can be raised or lowered to adjust the level of challenge difficulty. Teams should itemize their budget using the Budget Planning Worksheet on page 39.

# STEP-BY-STEP FACILITATION INSTRUCTIONS

**Introduce the Challenge**

Provide students the information covered in the challenge description found on page 15. Use the Challenge Rubric on page 26 in the Student Journal section to show students how their work during this challenge will be evaluated.

**The Engineering Design Process Steps with Guiding Questions**

**STEP 1: Identify the Need or Problem**

- Help facilitate learning by asking Guided Questions:
    - How can our team design a _____ that will _____?
    - What needs to be solved/improved?
    - What are we trying to accomplish?
- Review the Engineering Design Process with the students.
- Show the NASA BEST video titled "Repeatability" found at https://www.youtube.com/watch?v=-2Az1KDn-YM.
- Ask the team members why it is important to test their own designs.
- Team members should identify the specific criteria and constraints of the design challenge. The shield must be designed to absorb or reflect as much visible and ultraviolet light as possible. The shield must also be able to withstand a simulated water landing. The mass of the shield may not exceed 300 g, but should be as light as possible. The thickness of the shielding may not exceed 2 cm, but should be as thin as possible. Total materials for the final shield design may not exceed $10.00, but should be as cost-effective as possible. The shield must completely cover the entire opening of the "test chamber" (oatmeal canister). The shield must be able to perform under both wet and dry conditions. The shield must survive the following tests: radiation test, flexibility test, ballistic impact test, load bearing test.
- Have team members fill out *Step 1: Identify the Need or Problem Worksheet* on page 29 in the Student Journal section.

**STEP 2: Research the Need or Problem**

- Help facilitate learning by asking Guided Questions:
    - Where can you find more information about the topic?
    - What questions could you ask an expert?
- Help team members answer any questions they have about the challenge. Use the Internet or school library to research answers. Sample resources have been provided in the NASA Resources section on page 41. Any unanswered questions should be written down and saved to ask during the NASA Subject Matter Expert connections.
- Have the team members fill out Step 2: Research the Need or Problem Worksheet page 30 in the Student Journal section.

**STEP 3: Develop Possible Solutions**

- Help facilitate learning by asking Guided Questions:
    - What are all the ways your team can imagine to solve this?
    - What do we need to do to add _____ to the design?
    - What might go wrong if we add _____ to the design?
- Each team member is to brainstorm and make sketches representing their ideas for a solution to the design challenge. The students will clearly label and identify each part of their drawing.
- Each team member should make sure that designs meet all constraints and criteria
- Have the team members complete Step 3: Develop Possible Solutions Worksheet, page 31 in the Student Journal section.

**STEP 4: Select the Best Possible Solution(s)**

- Help facilitate learning by asking Guided Questions:
    - Would it be better to _____ or _____?
    - Can we combine more than one plan?
    - Would a _____ fulfill the constraints of the challenge?
    - Do we have the resources to build a _____?
- Each team member is to discuss their ideas and drawings with the rest of the team.
- The students will record the strengths and weaknesses of each of the designs.
- Have the student fill out Step 4: Develop Possible Solutions Worksheet, page 32 in the Student Journal section.

**STEP 5: Construct a Prototype**

- Help facilitate learning by asking Guided Questions:
    - What resources do we need to gather?
    - What is the plan?
    - Who is doing what?
- Each team is to identify the design that appears to solve the problem that they identified.
- A final diagram of the design should be precisely drawn and labeled with a key.
- Each team is to determine what materials they will need to build their design and assign responsibilities for each team member for prototype completion.
- The final drawings should be approved by the facilitator before building begins.
- Students will receive the materials they will need to build their model and complete a budget sheet representing the cost of their model.
- Using the drawings, teams are to construct their prototypes.
- Have each team member complete Step 5: Construct a Prototype Worksheet, page 33 in the Student Journal section.

**STEP 6: Test and Evaluate the Solution(s)**

- Help facilitate learning by asking Guided Questions:
  - How did the prototype perform when tested?
  - Was the design successful?
- Students will affix their shield across the open end of the "test chamber" (oatmeal canister). Students will then conduct the following series of tests. In each test, they will rate and record their results on a scale of 0-5, "0" being "failure" and "5" being "total success."
  - Radiation tests: students will conduct a visible light test by shining a flashlight through the shield into the chamber and observing the remaining light, if any, through a quarter-sized viewing hole cut into the opposite side of the canister. Students will also conduct a UV test by placing three UV-reactive "solar" beads into the bottom of the canister, exposing the shield and chamber to sunlight for two minutes, and observing to what extent the UV beads have changed color.
  - Load-bearing test: students will place a small (5-gram) mass of paper clips on top of the shield and observe for signs of stress or damage for one minute. Students will repeat the test, gradually increasing mass up to at least 500 grams.
  - Ballistic impact test: students will drop a small (5-gram) mass of paper clips onto the shield from a height of one meter, observing for signs of stress or damage. Students will repeat the test, gradually increasing mass up to at least 100 grams.
  - Flexibility test: students will remove the shield from the canister and determine to what degree their shield can bend without breaking.
- If the design survives all dry tests above, have students immerse their design in water for ten seconds and repeat all tests. Ideal designs should survive all dry and wet tests; however, students are free to simply identify tests that their design will not pass.
- Have the students fill out pages 34-35 in the Student Journal section.

**STEP 7: Communicate the Solution(s)**

- Help facilitate learning by asking Guided Questions:
  - What did or did not work? Why?
  - What are the pros and cons of this solution?
- Students will document and report the results of their designs. They will identify what changes were made with each iteration of design and what the team believed caused the design to succeed or fail during the tests.
- Have the student fill out <u>one row</u> of page 36 in the Student Journal section.

**STEP 8: Redesign**

- Help facilitate learning by asking Guided Questions:
  - How did the prototype perform when tested?
  - What did and didn't work?
  - What could be improved in the next iteration of this design?
- Student teams will identify the cause(s) of any problems that were observed during testing. They will consider possible modifications to solve these problems.
- Have students check that their redesigned model still meets all the criteria to solve the problem.
- Have the student fill out page 37 in the Student Journal section.

From here, the cycle repeats with redefined problems and redesigned solutions as often as time and resources allow. With each additional iteration, and depending on the amount of redesign students put into one iteration, some steps may only need a quick revisit to be sure students are on track, while some steps will need to be completely redone**. <u>In those cases, additional copies of cycle step pages should be made and added into the Student Journal section.</u>**

**Submit Final Design**

On the last design iteration, the documentation from Step 7 will be used to create a video of the design development and final design solution according to the Video Criteria and Video Rubric found on pages 27-28. Also at this time, use the Engineering Design Process worksheet on page 24 to test student knowledge of the entire design cycle.

# STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What was the greatest challenge or challenges for your team through this process?

2. What strategy or strategies did your team prove effective in overcoming your greatest challenge?

3. How did you use the Engineering Design Process to help you with your design?

4. What changes, or compromises, in your design (if any) had to be made due to constraints?

5. Are the materials used to build the radiation shield strong and reliable? If not, what materials might work better? Would there be limitations to these new materials?

6. Will your final design protect the astronauts from radiation? Why or why not?

# CHALLENGE CHECKLIST

**Prior to the Challenge**

Things to download, print, review, and copy:

- ❑ 1. Download and review the Presentation Slides for Students.
- ❑ 2. Download, print, and review the Video Criteria and Rubric. Make a copy for each team of students.
- ❑ 3. Download, print, and review the Educator Guide, Exploration Design Challenge – Radiation Shield. Print the Student Journal pages for each team of students.
- ❑ 4. Download or bookmark the Introductory Video, Telling Our Story with Video, and any other videos needed for your presentation.
- ❑ 5. Download and review the Technical Requirements for the Video.
- ❑ 6. Download, review, and print the Media Release Form. Make one copy for each student.

Things to schedule, set up, or test:

- ❑ 1. Review the online Event Schedule and select at least one live event for students to interact with a NASA Subject Matter Expert.
- ❑ 2. Gather and organize materials from the Materials List for each activity.
- ❑ 3. Test your technology set up to make sure students can see and hear videos, slides, etc.
- ❑ 4. Select a suitable and safe area to conduct UV test (access to direct sunlight), as well as ballistic test (1-meter drop height and safe perimeter).
- ❑ 5. Check your video or digital cameras to ensure they are fully charged and have enough memory or tape for recording challenge activities.

**During the Challenge**

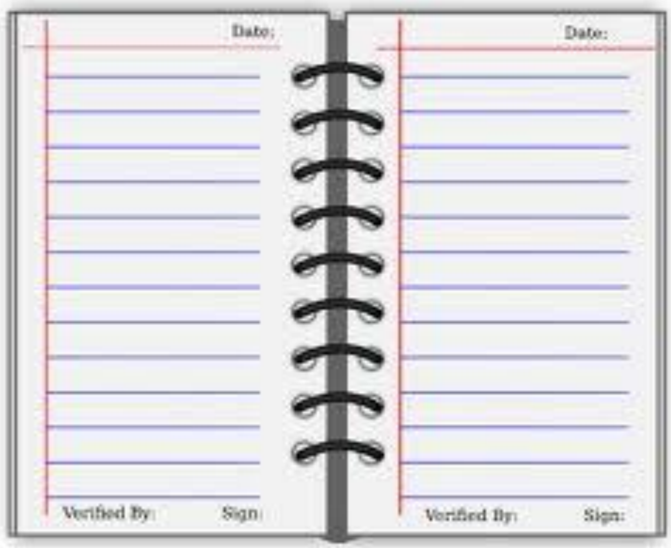
- ❑ 1. Distribute Media Release Form to each participating student and set a due date for return.
- ❑ 2. Ask each group of students to come up with a unique team name.
- ❑ 3. Use the Presentation Slides for Students to lead the students through the challenge.
- ❑ 4. Encourage each group to take pictures and video throughout the challenge to use in their final video.
- ❑ 5. Help students prepare questions and information to share with the NASA Subject Matter Expert for the live event for students.
- ❑ 6. Participate in one or more live events for students.

**After the Challenge**

- ❑ 1. Review Video Criteria and Rubric and Telling Our Story with Video with students.
- ❑ 2. Assist students as they plan and create their final video.
- ❑ 3. Upload student video submissions.
- ❑ 4. Allow enough time to send a separate email with entry information and media release forms for each video by April 16, 2015.
- ❑ 5. Participate in evaluation of the 21CCLC pilot program.

**Student Name:** ___________________ **Team Name**___________________

# STUDENT TEAM CHALLENGE JOURNAL

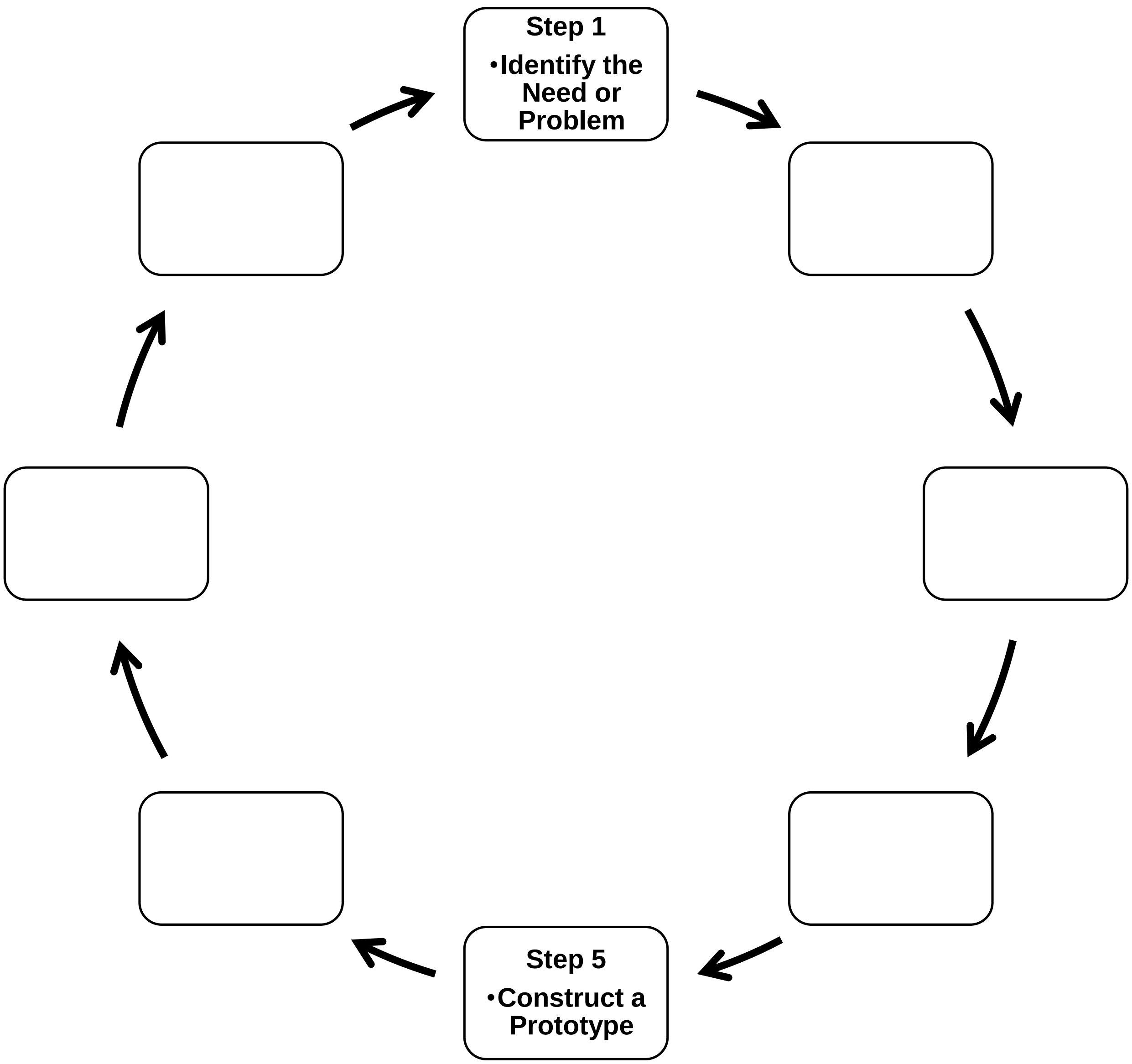


# ENGINEERING DESIGN PROCESS

**<u>Directions for the Students:</u>** Can you determine the sequence that engineers take to make a completed design? On your own, try to label the steps of the Engineering Design Process. Put the rest of the steps below in order based on the two that have already been filled in for you.

~~Identify the Need or Problem~~
~~Construct a Prototype~~
Research the Need or Problem
Test and Evaluate the Solution(s)

Select the Best Possible Solution(s)
Communicate the Solution(s)
Develop Possible Solution(s)
Redesign



# KLEW CHART FOR STUDENTS

**Student Name:** ___________________ **Team Name**___________________

**This Challenge is:** ______________________________

| KNOW | LEARN | EVIDENCE | WONDER |
|---|---|---|---|
| What do I know about radiation and space travel? | What did I learn about radiation and traveling into space based on my research? | What evidence do I have that supports what I learned about radiation and space travel? | What am I still wondering about radiation and space travel? |
| | | | |

# CHALLENGE RUBRIC

Use the Challenge Rubric below to assess each team's final design. It may be helpful to have each group explain how they use the Engineering Design Process, Steps 1-8, to create their designs.

| Category | Below Target (1) | At Target (2) | Above Target (3) |
|---|---|---|---|
| **1. Identifying the Need or Problem** | Rephrases the problem with limited clarity and fails to identify criteria or constraints | Rephrases the problem clearly and identifies most criteria and constraints | Rephrases the problem precisely and identifies all criteria and constraints |
| **2. Research the Need or Problem** | Need or problem is not well researched and will not be helpful in development of solutions | Need or problem is adequately researched and may assist in development of solutions | Need or problem is thoroughly researched and can easily direct development of solutions |
| **3. Develop Possible Solutions** | Contributes implausible ideas or no ideas. Produces incomplete sketches. Does not present a concept | Contributes a plausible idea. Produces marginally accurate sketches of design concepts | Contributes multiple, plausible ideas. Produces accurate sketches of design concepts |
| **4. Selecting the Best Possible Solution(s)** | Inadequately analyzes strengths/weaknesses of possible solutions. Does not select a solution based on criteria and constraints of the need or problem | Satisfactorily analyzes strengths/weaknesses of possible solutions. Selects a solution based on some but not all criteria and constraints of the need or problem | Thoroughly analyzes strengths/weaknesses of possible solutions. Selects a promising solution based on thorough analysis of all criteria and constraints of the need or problem |
| **5. Construct a Prototype** | Prototype meets the task criteria to a limited extent | Prototype meets the task criteria | Prototype meets the task criteria in insightful ways |
| 6. **Test and Evaluate the Solution(s)** | Data is inaccurately taken or does not reflect performance of the prototype | Data is taken accurately that reflects the performance of the prototype | Accurate data is taken that reflects the performance of the prototype and will clearly aid in redesign |
| 7. **Communicate the Solution(s)** | Both the results of testing are not accurately reported and there is no sharing of areas of improvement | Either results of testing are not accurately reported or there is no sharing of areas of improvement | Results of testing are accurately reported and shares insightful areas for improvement |
| **8. Redesign** | Refinement based on testing and evaluation is not evident | Refinements made based on testing and evaluation results | Significant improvement in the design is made based on prototype testing and evaluation |

**Total Score:** ______________________

**Team Name:** ______________________

# VIDEO CRITERIA AND VIDEO RUBRIC

**Video Criteria**

Video submissions showcase your prototype and the process it took to go from initial design to final solution and should include the following information.

1. Teams MUST use the following script to introduce their video:
    a. "This is team (team name) and we did the 'Radiation Shield' challenge. The title of our video is ____________________."
    b. Do not identify the name of any student, teacher, school, group, or city/region in your video. Submissions that do not follow these directions will be disqualified.
1. Introduce special features and unique qualities of your design.
2. Discuss the results of tests from Step 6 and modifications made to improve the device from Step 8 for each design iteration.
3. Based on your results and modifications, explain your best design solution from Step 4. Be sure to give reasons for your choice.
4. Include photos or video of a summary of your work including drawings of your design, key measurements, and how the prototype was built and tested.
5. Identify any information provided by NASA Subject Matter Experts (SMEs) that helped you in your design or testing.
6. Explain which characteristics of your design provided the most reliable results and why?
7. Based on your results and the modifications you recorded in Step 7, include advice for the engineers working on this project in the future.
8. Total length of video should be three to five minutes.

The following Video Rubric will be used by evaluators to review and score each submitted video based on the above criteria and presentation style.

## Video Rubric

**Student Name:** ___________________ **Team Name**___________________

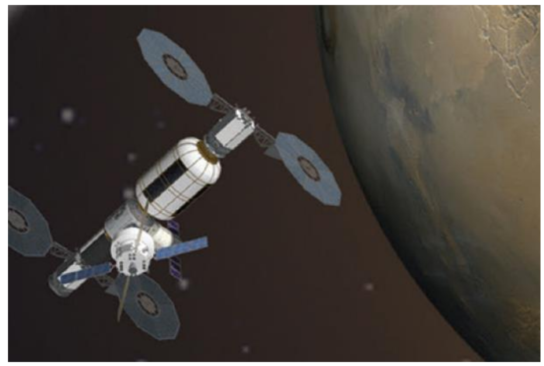
This rubric can be used to review and assess the quality of each video. Each category will be scored 0-3 points. Totals for each column will be added for a final score.

| Rubric Category | Best 3 points | Better 2 points | Good 1 point | Missing 0 points |
|---|---|---|---|---|
| **Introduction Statement** | Special features are stated clearly with additional words and/or images. | Special features are stated but no additional images are included. | Special feature statement is incomplete. | No statement is included. |
| **Drawings** | A detailed drawing of the final design, as well as detailed drawings of each iteration are included. | A detailed drawing of the final design is included, but no other iterations. | Rough drawings of the final designs or other iterations are included. | No drawings are included. |
| **Engineering Design Process** | All of the phases of the Engineering Design Process are mentioned. | More than four elements of the Engineering Design Process are mentioned. | At least one element of the Engineering Design Process is mentioned. | No mention of the engineering design process is included. |
| **NASA Subject Matter Expert (SME) Comments** | Interactions with NASA SMEs are discussed and show how the feedback was incorporated into design or testing. | Interactions with NASA SMEs are discussed and gives details about the feedback they provided. | Interactions with NASA SMEs are discussed in only general terms. | No mention of NASA SME interactions are included. |
| **Video Criteria** | All criteria are addressed thoroughly and thoughtfully. | Criteria are addressed. | Some criteria are addressed. | No criteria are addressed. |
| **Photos or Video** | Video of the build and test phases are included with additional still shots added. | The build and test phases are included in the photos/video. | Only the build *or* only the test phase is included in the photos/video. | No photos or video showing the build or test phases are included. |
| **COLUMN SCORE** | | | | |

**Total Score:** ______________________

# STEP 1: IDENTIFY THE NEED OR PROBLEM

**The Challenge:**



NASA is working on a new vehicle to take astronauts beyond Low Earth Orbit and on long-term duration human space exploration such as to Mars and other destinations the solar system. However, many dangers to the human body, such as solar radiation, exist as humans travel away from Earth. To ensure the safety of the astronauts this new vehicle will need protective shielding that offers similar protection to Earth's atmosphere and magnetic fields. This shielding needs to be durable and safe, while having as little mass as possible for launch.

In this Engineering Design Challenge, you must design and build a radiation shield to absorb or reflect as much visible and ultraviolet light as possible. The shield will also be subject to the following tests: flexibility test, ballistic impact test, and load bearing test. For testing, the shield must completely cover the entire opening of the "test chamber" (oatmeal canister). If the design survives all dry tests, immerse your design in water for ten seconds and repeat all tests. Ideal designs should survive all dry and wet tests; however, teams are free to identify tests that their designs will not pass. The mass of the shield may not exceed 300 g, but should be as light as possible. The thickness of the shielding may not exceed 2 cm, but should be as thin as possible. Total materials for the final shield design may not exceed $10.00.

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

1. Using your own words, restate the problem in the form of "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 to begin solving this need or problem?

_______________________________________________

_______________________________________________

# STEP 2: RESEARCH THE NEED OR PROBLEM

Conduct research to answer the following questions related to the challenge problem. Cite where you found your information on the line labeled “Source(s):”

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

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 uses in society?

Source(s):

4. What are some innovative options for using the materials that are available to solve this challenge?

Source(s):

# STEP 3: DEVELOP POSSIBLE SOLUTIONS

Sketch your radiation shield in the space below. Label each part of your drawing. Consider the following questions when brainstorming your ideas.

What features would your design have?
What materials could you use to design your radiation shield?
How will you design your shield to survive wet and dry conditions?
Are all the criteria and constraints being met by these ideas?

# STEP 4: SELECT THE BEST POSSIBLE SOLUTION(S)

Work with your team to analyze each person's final drawing using the table below. Based on the team's discussions, determine which design will be used to solve the problem, and what features will be included to create team's prototype.

| Design #<br><br>Designer Name | Does this design meet all criteria and constraints of the problem? | What are the strong elements of this design? | What elements need to be improved? |
|---|---|---|---|
| 1. | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

# STEP 5: CONSTRUCT A PROTOTYPE

1. Make a final drawing of your prototype. Have it approved by your facilitator.

Approved by: ______________________________

What are the resources that will need to be gathered?

______________________________

______________________________

______________________________

______________________________

Who in the group is doing what?

| **Team Member** | | | | |
|---|---|---|---|---|
| **Responsibilities in the building process?** | | | | |

# STEP 6: TEST AND EVALUATE THE SOLUTION(S)

Report the following information:

| Property | Constraint | Measured/Calculated |
|---|---|---|
| **Mass:** | Less than 300 g | |
| **Thickness:** | Less than 2 cm | |
| **Cost:** | Less than $10.00 | |

Determine the best way to attach your radiation shield to the open end of the test chamber. Be sure the shield completely covers the opening. Conduct the tests below in dry conditions. If the shield survives successfully, carefully remove the shield from the test chamber and immerse the shield in water for ten seconds. Reattach the wet shield to the test chamber and repeat all tests. Record general observation data, such as stress, damage, strengths, weaknesses, and maximum weight capacities in the table on the next page.

- **Radiation tests**: students will conduct a visible light test by shining a flashlight through the shield into the chamber and observing the remaining light, if any, through a quarter-sized viewing hole cut into the opposite side of the canister. Students will also conduct a UV test by placing three UV-reactive “solar” beads into the bottom of the canister, exposing the shield and chamber to sunlight for two minutes, and observing to what extent the UV beads have changed color.

- **Load-bearing test**: students will place a small (5-gram) mass of paper clips on top of the shield and observe for signs of stress or damage for one minute. Students will repeat the test, gradually increasing mass up to at least 500 grams.

- **Ballistic impact test**: students will drop a small (5-gram) mass of paper clips onto the shield from a height of one meter, observing for signs of stress or damage. Students will repeat the test, gradually increasing mass up to at least 100 grams.

- **Flexibility test**: students will remove the shield from the canister and determine to what degree their shield can bend without breaking.

Complete the table below to record the performance of the assembled shield design. Rank the materials according to the scale shown below.

| Rank the materials from 0 to 5 | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |
| No sign of property | | Medium Sign of property | | | Large sign of property |

| Property to Test | Description of the Test | Rank | Observations of Shield Design: |
|---|---|---|---|
| Radiation – Visible Light | Does it block the light from the flashlight? | Dry:<br>Wet: | Dry:<br>Wet: |
| Radiation – Ultraviolet Light | Does it prevent solar beads from changing color? | Dry:<br>Wet: | Dry:<br>Wet: |
| Flexibility | Does it stretch or bend? | Dry:<br>Wet: | Dry:<br>Wet: |
| Load-Bearing | Does it hold a mass on top? | Dry:<br>Wet: | Dry:<br>Wet: |
| Ballistic Impact | Does it stop a falling mass? | Dry:<br>Wet: | Dry:<br>Wet: |

# STEP 7: COMMUNICATE THE SOLUTION(S)

It is not enough to simply produce raw data. Scientists and engineers need to interpret the data so that they can convince others that their results are meaningful. This step will help you summarize how your design changed through multiple iterations of the engineering design process. Start by filling out the table about your initial prototype.

| Iteration # | What are the key components to your initial prototype? | What do you think caused the design to succeed or fail during testing and why do you think that? |
|---|---|---|
| 1 | | |

All modifications to your design, both major overhauls and minor tweaks, should be recorded below to track the changes made. After every phase of tests, complete the chart below by describing changes and summarizing what results the testing showed.

| Iteration # | What was added, removed, or changed in this iteration of your design? | What do you think caused the design to succeed or fail during testing and why do you think that? |
|---|---|---|
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

# STEP 8: REDESIGN

Did this iteration of your design meet all of the constraints of the original problem? ____________

What problem(s) did you discover while testing this iteration?

What will you do to try to improve your design based on this data?

How do you predict that these changes will improve over the iteration you just tested?

# STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What was the greatest challenge or challenges for your team today?

2. What strategy or strategies did your team prove effective in overcoming your greatest challenge?

3. How did you use the Engineering Design Process to help you with your design?

4. What changes, or compromises, in your design (if any) had to be made due to constraints?

5. Are the materials used to build the radiation shield strong and reliable? If not, what materials might work better? Would there be limitations to these new materials?

6. Will your final design protect the astronauts from radiation? Why or why not?

# BUDGET PLANNING WORKSHEET

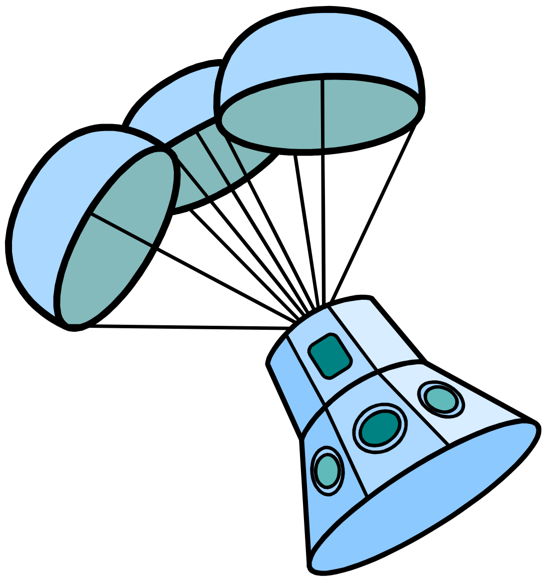
**Team Name:** ___________________

**Directions:** As a team, complete the cost sheet below. Be sure to include all of the materials that are needed, quantity, unit cost (determined by your facilitator), and the final total to complete your design. Try to use the least amount of materials to keep the cost of your design low.

| Line Item Number | Material | Unit Cost | Quantity | Item Total |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |

**TOTAL COST** ____________

# SUPPORT MATERIALS



# NASA RESOURCES

**Videos**

What is Radiation Shielding? - https://www.youtube.com/watch?v=SB_7b5sJJco
Radiation and Human Space Exploration -
https://www.youtube.com/watch?v=tBiuhOlgJsY
How Can We Protect Astronauts in Space? -
https://www.youtube.com/watch?v=5nSxFbDVlo8

**Websites**

Orion Radiation Handout - http://www.nasa.gov/sites/default/files/np-2014-03-001-jsc-orion_radiation_handout.pdf
NASA's Space Radiation Analysis Group - http://srag.jsc.nasa.gov/Index.cfm
How do we protect the astronauts from space radiation? -
http://srag.jsc.nasa.gov/SpaceRadiation/How/How.cfm
International Space Station Research and Technology -
http://www.nasa.gov/mission_pages/station/research/index.html
Human Research Program: Space Radiation Program Element -
http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-srpe.html
Fire Away, Sun and Stars! Shields to Protect Future Space Crews -
http://www.nasa.gov/vision/space/travelinginspace/radiation_shielding.html
Space Trash May Make Radiation Shields -
http://www.nasa.gov/centers/kennedy/exploration/researchtech/trashdiscs.html

For more information and to access the Help Desk, visit the 21CCLC NASA STEM Challenge website at http://y4y.ed.gov/stemchallenge/nasa.

# EXTENSION ACTIVITY

**Materials Analysis**

Engineers conduct tests of individual materials that they are considering to use in their engineering designs. In a similar fashion, the individual materials you plan to use to build your radiation shield must be individually tested based on the same properties you want your entire shield to exhibit.

Complete the table below to record the performance of each material you might use to construct your shield design. The first material, copy paper, has been provided. Choose four other materials for your tests. Rank the materials according to the same scale used for your full-shield testing, shown below. At the conclusion of your tests, report your results to your team.

| **Rank the materials from 0 to 5** | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |
| No sign of property | | Medium Sign of property | | | Large sign of property |

| **Property to Test** | **Description of the Test** | **Material 1:** Copy Paper | **Material 2:** | **Material 3:** | **Material 4:** | **Material 5:** |
|---|---|---|---|---|---|---|
| Radiation – Visible Light | Does it block the light from the flashlight? | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: |
| Radiation – Ultraviolet Light | Does it prevent solar beads from changing color? | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: |
| Flexibility | Does it stretch or bend? | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: |
| Load-Bearing | Does it hold a mass on top? | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: |
| Ballistic Impact | Does it stop a falling mass? | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: | Dry:<br>Wet: |

# GLOSSARY OF TERMS

**Acute exposure –** short-term, high-level exposure to radiation

**Central Nervous System (CNS) –** the brain and spinal cord; the CNS helps to coordinate muscle and organ activity and monitor input from your senses

**Chronic exposure –** long-term, low-level exposure to radiation

**Constraints –** the limits placed on the design due to available resources and environment

**Coronal Mass Ejections (CMEs) –** explosions that occur on the surface of the Sun; these eruptions release massive amounts of energy out into space in the form of X-rays, gamma rays, and streams of protons and electrons called solar particle events

**Criteria** – standards by which something may be judged or decided

**Deoxyribonucleic acid (DNA) –** the molecule that encodes genetic information in cells

**Electromagnetic spectrum –** the range of wavelengths or frequencies over which electromagnetic radiation extends

**Iteration –** one cycle of a repetitive process

**Mass** – a unified body of matter without any specific shape

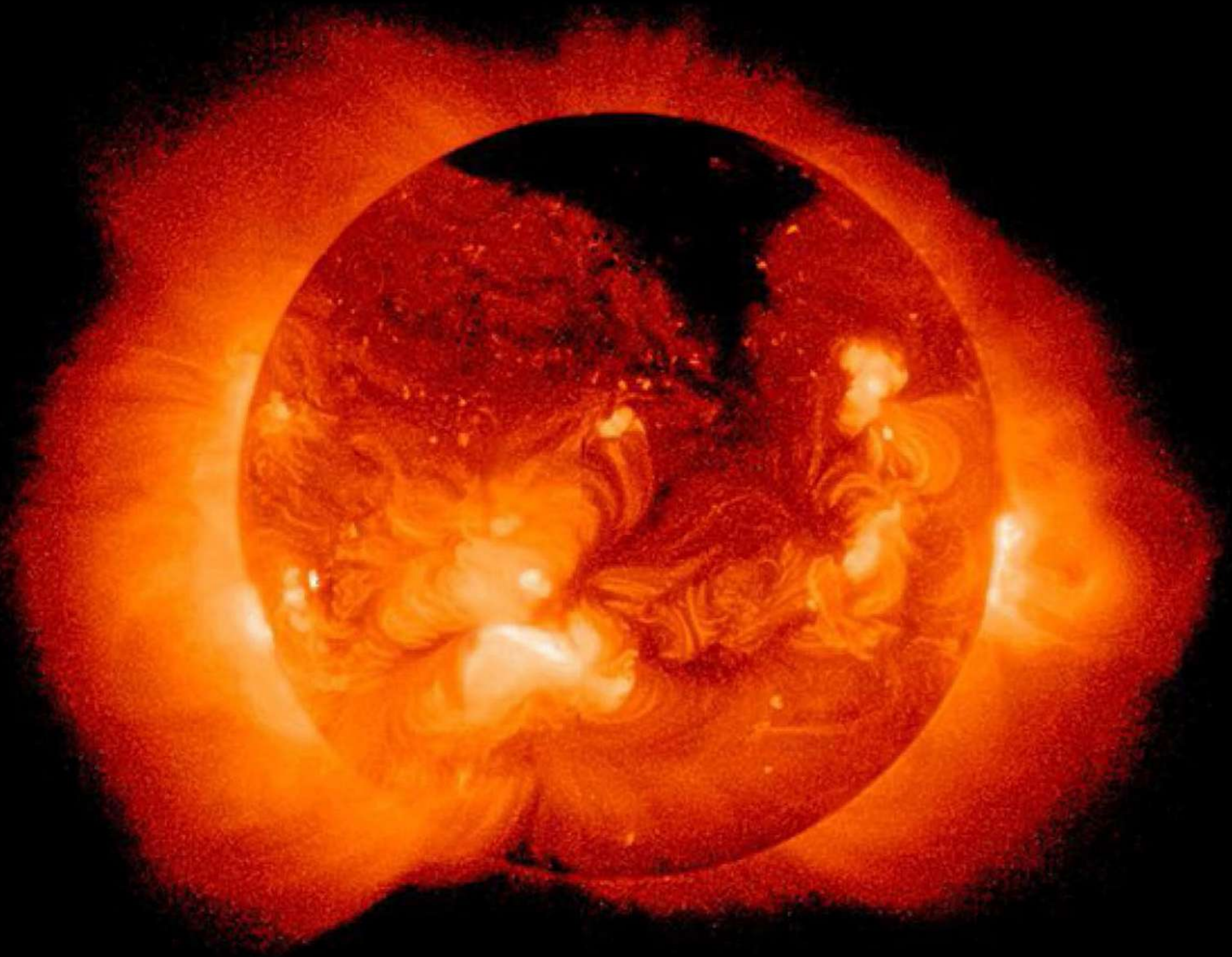
**Model** – a small object, usually built to scale, that represents another larger object

**Observation –** the act of noting and recording something with an instrument

**Prediction –** the act of attempting to tell beforehand what will happen

**Radiation –** the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles that cause ionization

**Solar Cycle –** the 11-year cycle of the Sun activity; during this period, the Sun cycles through producing large numbers of sunspots at solar maximum, and few during solar minimum



***"The most important thing we can do***
is inspire young minds and to advance the kind of science, math and technology education that will help youngsters take us to the next phase of space travel."

**Senator John H. Glenn, Jr.,**
**NASA Astronaut and United States Senator**

National Aeronautics and Space Administration

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