Discussion Guide

Slide 1 Download in advance or stream the *Welcome to the Challenge* video from Astronaut Sunita Williams on the home page of the NASA Exploration Design Challenge: www.nasa.gov/education/edc

Additional introductory videos from NASA's Associate Administrator for Education, Leland Melvin or Heather McKay, Orion Propulsion Engineer, can also be downloaded from the main page.

Show the short video(s) to the students.

Slide 2 Welcome to NASA's Exploration Design Challenge!

When astronauts are traveling through space, the space vehicle provides protection from many dangers. Space radiation is one of those dangers.

Space radiation comes from the sun and sources outside the solar system. Space radiation is difficult to block and can damage human tissue.

Spacecraft for long space exploration missions must be built with materials that give the space explorer more protection from space radiation than what is currently provided.

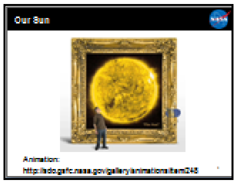
NASA and Lockheed Martin are currently developing the Orion Multi-Purpose Crew Vehicle. Orion will carry the crew to space and protect them during space travel. But first, we have to solve the problem of how to protect our astronauts from space radiation.

So NASA is looking for your help.

Slide 3 Throughout this challenge you are going to be asked to think and act like scientists and engineers. Working in teams, you will create a video to share your solutions. Evaluators will use the Video Rubric to review and score your videos. Be sure to document all of your work so the reviewers can see what you did and what you learned through each step of the challenge. You may want to record information on paper or take digital photos and video that you can later edit.

For participating in this challenge, NASA and Lockheed Martin will fly your name on Orion's first Exploration Flight Test (EFT-1) in September 2014. You will serve as the honorary virtual crew for that flight!
Are you ready to chart your path to Mars and become a part of space exploration history?

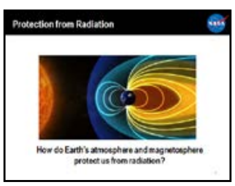
Let's get started.



Slide 4 Tell students that the greatest source of radiation here on Earth is something they know well – our sun! Ask what they know about the sun:

- The sun is a star – a very big ball of hot gases
- Seems small when we look at it in the sky because it is so far away
- 93 million miles from Earth (equal to one astronomical unit or AU)
- If you could fly an airplane to the sun, it would take you 26 years to arrive
- The sun gives us heat and light necessary for life – without it Earth would be a frozen ball of ice
- Our sun is very dynamic; it changes constantly
- As the gases of the sun move and flow, they form darker and lighter spots
- The dark spots are called sunspots and may be as large as the Earth or bigger
- Huge explosions called solar flares also occur when the hot gases are spit away from the sun
- These great storms blast material out of the sun and into space
- Sunspots, solar flares, and coronal mass ejections are all part of what scientists call space weather.
- The high energy material blasted out from the sun can cause damage to humans and to machines
- Earth's atmosphere and a special magnetic field around Earth called the magnetosphere protect us from this harmful radiation

To see some of the features of the sun, like sunspots or solar flares, visit NASA's Solar Dynamics Observatory web site and view the sun in real-time through different types of filters:
http://sunearthday.gsfc.nasa.gov/spaceweather/#



Slide 5 Most radiation does not reach the surface of Earth because of the magnetic field that surrounds Earth. Earth's magnetosphere and our atmosphere protect us from high energy radiation, including the giant explosions that sometimes happen on the surface of the sun.

(To learn more about Earth's magnetosphere, you may wish to watch the NASA eClips video segment, *Our World: The Sun – A Real Star*, which can be found at www.nasa.gov/nasaeclips)
But some of the radiation from the sun still reaches Earth and we have to protect ourselves. Ask students ways that they protect themselves from the sun.

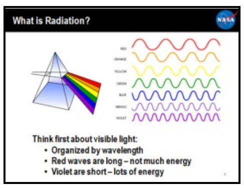
- Wear sun screen/sun block – even on a cloudy day
- Wear a hat or long sleeves
- Wear sunglasses
- Never look at the sun directly

Slide 6 Now imagine getting off the planet and going somewhere that has no atmosphere to shield you from the powerful radiation of the sun.

Special instruments taken by NASA's Mars Science Laboratory mission as it delivered the Curiosity rover to Mars have shown that radiation exposure for human explorers could exceed the radiation limit set for astronauts.

To learn more about the radiation on a trip to Mars, read:
http://www.nasa.gov/mission_pages/msl/news/msl20130530.html

To learn more about acceptable limits of radiation, view *Brad Gersey's Ask the Experts* video, *What are Acceptable Limits of Radiation?*
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=86141

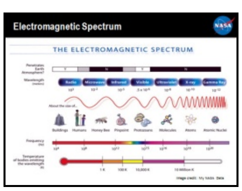


Slide 7 Ask the students to think back to what Astronaut Williams is suggesting they do. *(May show the introductory video a second time.)* Tell the students that NASA is looking for their help to solve this important challenge – the problems with space radiation on long-duration missions.

Why is protecting astronauts from radiation important*? (Radiation damages human cells and can even cause death.)*

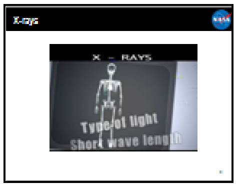
The students will need to understand more about radiation. Remember that we talked about radiation from the sun. Ask students, "What is radiation?"

- Form of energy
- Travels in waves
- Some radiation can be seen: visible light
- Some radiation can be felt: (as heat) infrared
- Other types of radiation cannot be seen, but can be observed either directly or indirectly with special equipment
- Different kinds of energy are organized by wavelength



Slide 8 Motion of electrically charged particles produces electromagnetic waves. Different kinds of energy have different wavelengths. The full range of these wavelengths is called the electromagnetic spectrum.

- Energy on the spectrum acts both like a wave and like a stream of particles
- Charged particles of energy are called photons
- Photons travel through empty space, air and other substances (called mediums)
- Photons with the highest energy correspond to the shortest wavelength
- The shorter the wavelength, the greater the potential for harm to both humans and mechanical systems



Slide 9 Ask if any of the students have ever broken a bone or been to the dentist. Did the doctor or dentist take an x-ray image? How did the technician taking the x-ray protect you? *(Put a lead apron over the child.)* How did the technician protect himself or herself? *(Went into another room or a separate area behind a special wall to operate the x-ray camera. Technicians also wear special badges that record the amount of radiation they are exposed to. Badges are checked periodically to make sure the technician is protected.)*

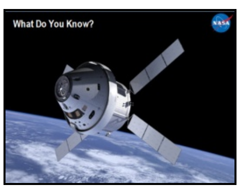
X-rays are examples of high energy radiation that can be harmful over time. If you look at the Electromagnetic Spectrum chart, where do you find x-rays in comparison to visible light? How do the wavelengths of x-rays compare to the wavelengths of visible radiation? *(shorter wavelength – higher energy)*

Slide 10 Looking at this chart, where are humans in space now? *(On the International Space Station which is found in Low-Earth Orbit, or LEO).* What is the farthest that humans have traveled in the past? *(To the moon – humans have not been beyond LEO since the last moon mission in 1972).*

NASA is currently preparing to take humans to deep space, where only robotic missions like the Curiosity rover have gone.

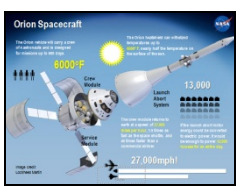
(Optional) Use a basketball and softball to create a model of the relative distance between Earth and the moon. See how close to Earth low-Earth orbit actually is. (*NASA eClips Distance to the Moon Guide Lite:*

http://www.nasa.gov/pdf/438170main_GLDistancetotheMoon.pdf)



Slide 11 Ask students what they know about Orion, NASA's next human spacecraft.

- Will provide the capability for us to travel to deep space
- Will eventually take humans to Mars



Slide 12 The spacecraft will be made up of 4 parts: the Crew Module, the Launch Abort System, the Service Module, and the Spacecraft Adapter.

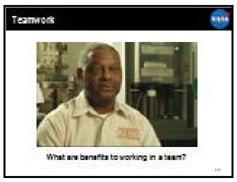
- The Crew Module is designed to carry a crew of 4 astronauts for missions up to 600 days
- The heat shield can withstand temperatures up to 6,000 degrees Fahrenheit.
- The Crew Module will return to Earth at a speed of 27,000 miles per hour, or 45 times faster than a commercial plane.
- The first flight test of the Orion vehicle is scheduled for September, 2014.

(Optional) To learn more about Orion, including up-to-date flight information, an animation of EFT-1, and information about the spacecraft itself, visit: www.nasa.gov/orion

(Optional) You may download a paper model of Orion that you can construct from: http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Orion_Model.html

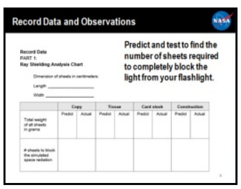
Slide 13 As we saw in an earlier slide, NASA has plans to send astronauts to new destinations like asteroids or Mars. Before we can do that, scientists must solve the challenge of radiation. NASA is currently testing new materials that might be used as radiation shielding for Orion to protect our astronauts.

Today you are going to think like scientists and conduct some tests on different kinds of materials. Be sure to record your findings.



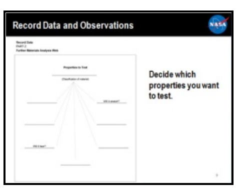
Slide 14 *(Group students into teams of 4-6.)*

(Optional) Being able to work with others on a team is an important skill. What role do you think teams play in a space mission? Let's hear what Kelvin Kirby in our *Ask the Experts* video, has to say about the importance of teams to Orion:
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=86141

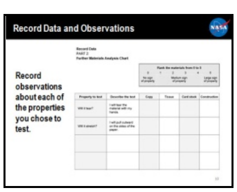


Slide 15 For our testing, we will use flashlights as our source of radiation. What kind of radiation comes from the flashlight? (*visible radiation or visible light*)

Our first step will be to look at the materials we are going to test and predict how much of each material it will take to completely block the light from your flashlight. Record your predictions. Then test the materials. Be sure to accurately count the pieces of each material it takes to block the light. Keep the stack of materials together and set it aside to use for the next part of the activity.
(Note: if you have access to a balance or gram scale, you may ask students to find the mass of the materials. In order to use the shielding in space, the radiation shield must also have less mass than other choices.)



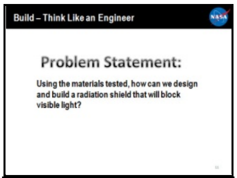
Slide 16 Next we need to decide what properties we are going to test. Properties are any characteristics we can observe. We might want to see if our material tears or stretches. What are some other properties we could test? (*Will it bounce? What is its hardness/strength? Is it breakable? Is it bendable? etc.*) Ask the students which properties they think would be important to travel into space. Be sure to ask for their reasons for selecting different properties.



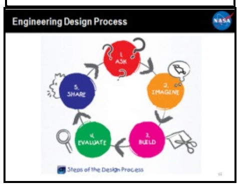
Slide 17 Design a test for each property. Use the stacks of materials you used to block the light and test for the specific property. Rank each stack of materials from 0 to 5:

- If the material shows no sign of that property, assign it a 0;
- If the material shows a small sign of that property, assign it a lower number;
- If the material shows a large sign of that property, assign it a larger number.

Once you have conducted your tests and assigned a rank to each material, add up the numbers in each column. This will be the total ranking for the material.



Slide 18 Using the materials you tested, what kind of radiation shield can you design that will block visible light?

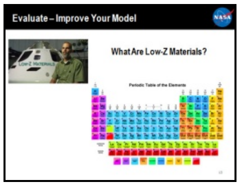


Slide 19 Let's use the Design Process to help us organize our thinking. The Design Process is what engineers use to help them solve problems. There is no right or wrong answer to the solutions – just designs that need to be tested and re-tested. There is also no one single Design Process. A design process simply asks us to consider the problem and create solutions. For our challenge, we are going to use this five step Design Process:

1. **Ask** is the first step of the process. What is the problem? *(How can we use the materials we have tested to design a radiation shield that will block visible light?)* What have others done to solve this problem? What are the limits? *(May talk about what NASA and Lockheed Martin are doing to test new materials; limits are that we can only use materials we currently have – just as the students can only use the materials they have been given.)*
2. **Imagine** is the next step of the process. Think about how you might solve this problem. What are some solutions? Brainstorm ideas. Choose the best one.
3. **Build** is the next step. You should draw a diagram of your plan. Engineers always draw their designs, either by hand or using computer programs, so they can make sure the parts will work together. Building every idea without considering which one is the best choice would cost too much money and waste materials. Once you have a design that works, make a list of the materials you will need. Follow your plan and build a model or prototype of your radiation shield.
4. Step 4 is **Evaluate**. Now that you have a model, you need to test it! Be sure to record your results. You will also want to take photos or draw pictures of what happened during your testing. Did your design work? Is there a better way to make your design? As you learn new information, you may need to make changes in your design to improve it. For example, if you just learned that many kinds of glue create a problem called "outgassing" when the glue is in space, you may need to find a different way to fasten the layers of your shield together.
5. Finally, **Share** your design. Explain your ideas to others. Is there a way to combine some of the ideas to make an even better design? What happens if new limits (criteria) are given to you? *(need to re-design)*

Now we're going to think like engineers. Let's begin our design. Once you have a design your team wants to test, begin your tests. Remember that you need to design a shield that will **completely** block the light from your flashlight.

Record your results. How effective is your design? Do you need to make changes? Be sure to document any changes you make in your design.



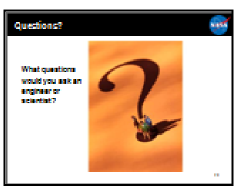
Slide 20 You were only allowed to use the materials we tested in your shield design. Would you like to use a different material? What kinds of materials do you think you would want to use? *(Allow students to brainstorm ideas.)*

Let's *Ask an Expert* about some of the properties that make good radiation shields. (Watch the *Ask the Expert* video, *What Is Radiation Shielding? Kerry Lee.* The 2-minute video may be streamed or downloaded in advance.)

What are low-z materials? *(Materials that have a small atomic number.)* Let's look at the periodic table. Aluminum foil would probably block our light, but would it make a good shield? *(No, it has an atomic number of 13, so it would have 13 protons and 13 neutrons in the nucleus. That could create 26 particles that a high energy photon could bounce into, creating even more damage to the astronaut.)* Many planes and spacecraft are built of titanium. Is titanium a good shield? *(No, it has an even higher atomic number – 81.)*

Slide 21 So what kinds of materials might make good shields? Let's ask another expert, Dr. Richard Wilkins, to find out what kinds of materials NASA is testing to protect our astronauts in space: http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=86141

Using what you just learned, could you re-design your shield using a low-z material? What kind of material would you want to use? How would you use it? Do you need to know more about the kind of radiation found in space before you continue?

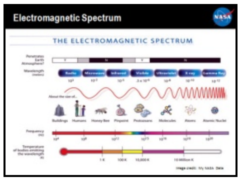


Slide 22 If you could actually speak with a scientist or engineer working on Orion or trying to solve the challenges of radiation in space, what kinds of questions would you want to ask?

(Brainstorm a list of questions that students could ask the subject matter experts during their virtual sessions with NASA experts. Prioritize the questions so the most important ones are asked first; if time permits additional questions could be asked.)

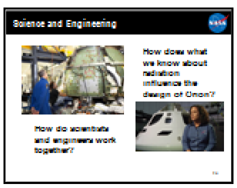
Slide 23 *(Slides 23 – 26 introduce an optional modification that can be used if you have access to UV beads. UV beads are small, inexpensive plastic beads that are sensitive to UV light. When they are protected or not exposed to UV light, the beads are white. When they are exposed to UV light, either artificial or from sunlight, the beads turn bright colors. UV beads can be purchased from science or teacher stores. Sources can easily be found online.)*

Let's *Ask an Expert* to see how radiation in space is different than radiation on Earth. (Download or stream Kerry Lee's video, *How Is Radiation in Space Different from Radiation on Earth?*)

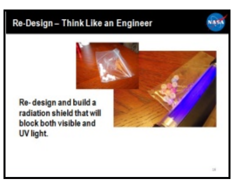


Slide 24 *(Use the image of the Electromagnetic Spectrum introduced in Slide 8 to help students review the different types of radiation.)* We already know that Earth's biggest source of radiation is the sun. The sun emits all wavelengths – the majority in the form of visible, Infrared, and ultraviolet (UV) radiation. Outside Earth's protective atmosphere and magnetosphere radiation from the sun can be harmful.

Galactic Cosmic Radiation, or GCR, comes from outside our solar system. Although it cannot pass through Earth's magnetosphere, these highly charged particles are dangerous to astronauts traveling in space. The particles, which move at a speed almost as fast as the speed of light, can pass through a typical spacecraft and the skin of an astronaut. The particles may damage equipment and damage human cells. Damaged cells usually die. (To print a comic book about Cosmic Galactic Radiation, go to: http://crater.sr.unh.edu/educ/extras_comic.html)



Slide 25 Let's *Ask an Expert* to find out how the design of Orion takes into consideration what we know about space radiation. (Download or stream the *Ask an Expert* video, "*How Does Space Radiation Influence the Design of Orion?* with Lara Kearney.)



Slide 26 Besides visible light, what other kinds of radiation make it through to Earth's surface? *(UV or Ultraviolet radiation)*

We tested our models for visible radiation. How can we re-design and test our radiation shield for not only visible light, but UV light?

We can use these UV beads as sensors to help us test the effectiveness of the shield. Indoors, the beads are white. As soon as they are exposed to UV radiation, like the UV light emitted from the sun, the beads turn color. It takes a few minutes for the beads to return to white. *(Note: you may wish to give the children a few minutes to experiment with the beads, watching them change color and recording the amount of time it takes for the beads to return to white after coming inside. Students may also want to test different materials to see how effectively they block the UV light prior to completing their re-design.)* We can test our new design outdoors, then bring the model back inside to check the color of the beads. If they are still white, your design effectively blocked UV radiation. Be sure to draw your design changes before you build. Record your results.

Slide 27 Edit and share your video. Once you have finished, each of you will get a certificate that shows you are now an official crew member of Orion's first flight test, EFT-1! Congratulations!

(For additional activities and updates about Orion and space radiation, please visit the NASA EDC web site: www.nasa.gov/education/edc)