From Looking at Stars to Living on Mars

Session Time: One, 50-minute session

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The rapid pace of innovation in computer and information technology, materials science, engineering, and communication is driving advancements in the aerospace industry that are changing the way humans interact with and explore their world and the universe.

The teams that will design, build, fly, and maintain the aerospace fleets of the future will require the collaborative efforts of professionals from disciplines spread across the entire spectrum of STEM careers.

ESSENTIAL QUESTIONS

1. How are government and private corporations partnering to take the next steps in space exploration?
2. What are some of the design challenges that need to be overcome in order to achieve the goal of long-duration stays on the Moon and Mars?
3. What STEM careers could be in greatest demand in the aerospace industry in the next twenty years?

LEARNING GOALS

Students Will Know

- Emerging visions for space exploration and the effect those visions have had on the growth of collaborative efforts between government and corporate aerospace companies.
- Key careers from across all STEM disciplines that will form collaborative design, implementation, and maintenance teams in the aerospace industry.

Students Will Be Able To

- *Identify* emerging trends and directions in aerospace that will change the types of vehicles we fly into space and beyond Earth orbit. [DOK-L1]
- *Investigate* the STEM career fields that will play major roles in the design and implementation teams who will make the aerospace vehicles of tomorrow a reality. [DOK-L3]

ASSESSMENT EVIDENCE

Warm-up
Students will watch two videos: one explaining how the space race of the 1950s-70s came about, and one exploring the current space race. The class will then discuss the videos, comparing and contrasting the motives, opportunities, and challenges of the previous and current space races.

Formative Assessment
Working in small groups, students will brainstorm possible solutions for avoiding or mitigating specific hazards of deep space flight. The Formative Assessment will consist of the students submitting their notes for the teacher to review.

Summative Assessment
There is no Summative Assessment for this lesson.

LESSON PREPARATION

MATERIALS/RESOURCES

- From Looking at Stars to Living on Mars Presentation
- **From Looking at Stars to Living on Mars Student Activity (5 Hazard Notes sheets)**
  - Hazard 1: Radiation
  - Hazard 2: Isolation and Confinement
  - Hazard 3: Distance from Earth
  - Hazard 4: Lack of Gravity
  - Hazard 5: Hostile or Closed Environments
- **From Looking at Stars to Living on Mars Teacher Notes (5 Hazard Notes sheets)**
  - Hazard 1: Radiation
  - Hazard 2: Isolation and Confinement
  - Hazard 3: Distance from Earth
  - Hazard 4: Lack of Gravity
  - Hazard 5: Hostile or Closed Environments

LESSON SUMMARY

Lesson 1: Aviation Innovations Big and Small
Lesson 2: Astronautics for the 21st Century: From Looking at Stars to Living on Mars
Lesson 3: Science Fiction to Aerospace Reality

The lesson begins with a warm-up in which students watch videos about the past and future of space travel. Students will then discuss the videos, answering questions about motivations and hurdles faced by scientists in a space race.

The lesson then explores multiple emerging technologies in aerospace by leading students through a series of slides organized by categories such as manned spacecraft, launch systems, and missions to Mars.

Students end the lesson by participating in a jigsaw activity in which they learn about hazards of space travel that have been identified by NASA. The students brainstorm solutions to the hazards and discuss their solutions.

BACKGROUND

Prehistoric carvings on cave walls in Europe, Asia, and Africa indicate that humans have had a fascination with space and the stars since the very beginning of our history, but it is only in the past century that humans have been able to travel into the void and beyond, to touch and walk on the moon, and to send machines to other planets for exploration and scientific discovery.

The Space Race that began during the Cold War is used as a mechanism to present students with the idea that competition can accelerate innovation. New problems required creative solutions from those in STEM fields. Recent interest in space travel and exploration has reignited the need for students to enter STEM fields in order to generate the creative solutions to the many challenges of extended space flight.

The expense of space flight meant that, in the past, only governments of large countries could support the development of space programs. Advances in technology have made space flight accessible to a wider range of nations and corporations. The advent of companies such as Blue Origin and SpaceX evidence the commercial potential that is perceived by private organizations.

MISCONCEPTIONS

Specific to this lesson, there is a common misconception that all vehicles designed to take humans to space, regardless of the destination, have essentially the same design parameters (i.e., "Space is space no matter where you go"). In fact, there are substantial differences between the risks associated with long-duration space travel across vast distances and those associated with relatively short-duration trips (for example, to the International Space Station) in low-Earth orbit. The differences in risks require differences in spacecraft design, and different STEM career fields are necessary to meet different design criteria. Students will explore these differences in the **EXTEND** part of this lesson.

While we often herald individual inventors, no innovation sees the light of day without a dedicated team working to bring an idea to fruition. Students should recognize that within an innovative STEM team, there is likely a career for them.

DIFFERENTIATION

To support student comprehension in the **EXTEND** section of the course, review some examples and descriptions of STEM skill sets. Allow students to brainstorm a description of how a STEM skill set can be applied to the field to further enhance their ability to apply it correctly to the hazards outlined in the formative assessment.

LEARNING PLAN

ENGAGE

Teacher Material: From Looking at Stars to Living on Mars Presentation

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4-5: Conduct the **Warm-Up**. Students will work to *identify* emerging trends and directions in aerospace that will change the types of vehicles we fly into space and beyond Earth orbit. [DOK-L1]

Warm-Up

Begin the **Warm-Up** by having students watch the following video. As students watch, they should reflect on the motivations for and technologies used in the Space Race of the 1950s-70s.

- "How The Cold War Launched The Space Race" (Length 2:50)
  https://safeYouTube.net/w/fyVO
  For teachers unable to view Safe Youtube files, the video may also be seen here:
  https://www.youtube.com/embed/i5ROHWSFqfQ?start=00&end=170

Then have students watch the video below, which chronicles key moments and visions for the new generation of space travel.

- "A Timeline of the New Space Race" (Length 3:50)
  https://safeYouTube.net/w/CYoQ

For teachers unable to view Safe YouTube files, the video may also been seen here: https://www.youtube.com/watch?v=f7qfbktd4SI

EXPLORE

Teacher Material: From Looking at Stars to Living on Mars Presentation

Slide 5: In a brief class discussion, have students compare the reasons behind the Space Race of the 1950s-70s and the reasons for the emerging space race of today. Use the following reflection questions to structure the discussion:

Questions

- What do you think were some of the major motivations for the original Space Race?

Possible responses: national pride; desire to be "the first"; desire to defeat communism by demonstrating superior scientific and technological abilities; the projection of U.S. power into space

- Based on the video and what you know about history, what were some of the hurdles (scientific, political, economic, etc.) faced by NASA?

Students should understand that the goal of the original Space Race was quite specific: to land a person on the Moon. Scientific challenges included the physics and manufacturing skills required for space flight; political challenges included convincing politicians and the public that the goals of the space program were valuable; and economic challenges included not only finding the money to fund the Space Race but also convincing the public and politicians that diverting money from social programs to the space program was worthwhile.

- What do you think are some of the major motivations for the new space race?

Students should understand that space is now seen as a business where lots of money can be made. Private companies bring capital (money and resources)—which governments may not have—to fund research in the hopes of making a profit. Resources available on asteroids and other planets may be new and profitable sources of resources that are dwindling on Earth. Colonizing the Moon and Mars would give humanity new places to move to and live should we exhaust Earth's resources.

- What are some of the hurdles today's astronautics innovators face?

Possible responses: Advancing technology to a point where access to space is inexpensive enough to be profitable; overcoming safety concerns related to living for extended periods in space; managing public opinion both positive and negative—environmental concerns about more rocket launches, encouraging interest in space tourism, promoting jobs and careers in space, supporting efforts to educate more STEM professionals, etc.

Slide 6: The key takeaway from the **Warm-Up** is that humanity is on the verge of a new space race, or at least a new era in space exploration. Recent innovations point to fundamentally new ways of how we get into space, what we do in space, and how we return from space. These innovations have put permanent moon bases and the human exploration of Mars within our reach. These goals present certain challenges and scientists, mathematicians, engineers, and others in

STEM fields are working hard to overcome hurdles from protecting space travelers from excessive radiation to avoiding space debris. The following slides present some astronautic challenges and current solutions to them.

EXPLAIN

Teacher Material: From Looking at Stars to Landing on Mars Presentation

Slide 7: This section details a variety of astronautical innovations currently in use or under development. The objective is for students to see a problem and what the current solution is. The slides center around current interest in travel to Mars since this is an area of focus for the next lesson. This will help set up the **Student Activity** which is a jigsaw activity that will follow a similar format.

Slide 8: One of the prominent goals in astronomics today is sending humans to Mars. There are many questions scientists must answer as they prepare to send the first humans to Mars. The problem becomes: How do we learn about a distant planet?

Ask the students the following questions to reveal a few of the factors that scientists must consider as they develop plans for humans to visit Mars.

Questions

What do scientists, engineers, and astronauts need to know before traveling to Mars?

Answers may vary; plan to field a handful of responses from the students that address factors such as geology, meteorology, biology, etc.

What is the most effective way to learn about the planet before traveling there?

Answers may vary; however, the principal means of learning about a distant planet is to send a spacecraft to investigate the planet either with an orbiting probe or one that lands like the various rovers NASA has sent.

Slide 9: Since 1960, over 45 probes from a handful of nations have been sent to Mars in order to learn about the planet. Notable probes have included the Emirates Mars Mission Orbiter from the U.A.E., CNSA Tianwen 1 from the People's Republic of China, Perseverance and Ingenuity from the United States, and ExoMars 1 and 2 from the European Space Agency. These probes have provided a wide variety of information, including photographs, temperature and seismometer readings, geological samples, and more.

Slide 10: Once information has been gained from probes, the next step for countries will be to send manned spacecraft to the Red Planet. Again, there are a number of questions that scientists need to answer in preparation for this venture.

Questions

What are some qualities that need to be considered when designing a spacecraft to carry humans to Mars?

Answers may vary; considerations might include the specific missions that a spacecraft will need to be capable of, the necessity of a heat shield that can withstand high temperatures in space, the comfort of passengers aboard, the number of times that a vehicle can be reused, and more.

How might some of these issues be addressed?

Answers may vary; however, students might suggest that new spacecraft be multifunctional, capable of carrying a wide variety of cargo and people into space, thus allowing it to perform multiple missions. A large craft would allow more passenger comfort/mobility, and a large heat shield would be capable of protecting it. A reusable spacecraft would be ideal, allowing for more missions to be performed at a lower cost.

Slide 11: Much of the current astronautical research underway involves the development of the next generation of spacecraft that will carry humans and cargo deep into space. Examples of this new technology include the SpaceX Dragon, the Boeing CST-100 Starliner, and the Lockheed Martin Artemis III (the latter two projects are being developed in collaboration with NASA). A major advancement in all three spacecraft is that—unlike previous generations of vehicles—they will be reusable.

The Dragon and the Starliner will be capable of docking with the ISS, and will be used to carry people and cargo into orbit, serving as platforms from which experiments can be conducted and satellites can be launched. The Artemis III, a next-generation spacecraft featuring the world's largest heat shield and 33 engines, will be capable of transporting astronauts to the moon and back.

Teaching Tips

The information below supplements the brief descriptions of the missions on slide 11.

Much of the astronautical research currently underway involves the development of the next generation of spacecraft that will carry humans and cargo into space. The SpaceX Dragon is an example of this new technology. The Dragon has been designed to carry up to 7 people, plus cargo, into space, and has as a primary mission to dock with the International Space Station (ISS). The Dragon is the first privately built spacecraft capable of being used more than once. It can be used to orbit Earth, conduct experiments, launch satellites, and transport people and cargo to the ISS. In May, 2020, the Dragon successfully delivered two U.S. astronauts to the ISS for the first time.

The following video provides a closer look at the Dragon:

- "Crew Dragon: Interior" (Length 0:44)
  https://safeYouTube.net/w/7iCQ
  For teachers unable to view Safe Youtube files, the video may also be seen here:
  https://youtu.be/78ATfCaBn6E

Another example of a spacecraft designed to transport people and cargo into low Earth orbit, and then return to Earth to be reused, is the Boeing CST-100 Starliner. Boeing, a private company, is developing this spacecraft in collaboration with NASA. The Starliner is designed to carry up to seven passengers. It is completely autonomous (dramatically reducing crew training time), designed to dock with the ISS, and will be reusable up to 10 times.

A major reason for developing both the Dragon and Starliner is to reduce U.S. dependence on Russia for transport to the ISS, a concern since 2011, when the U.S. retired its space shuttle fleet.

Carrying humans into deep space requires vehicles capable of reaching the Moon, Mars, and beyond. Lockheed Martin and NASA are developing just such a vehicle as part of their Orion project. The first spacecraft to launch will be called Artemis III, and it will take astronauts to the Moon and back. Artemis III will be a next-generation spacecraft, featuring the world's largest heat shield and 33 powerful engines.

Slide 12: As plans for the exploration of space become more ambitious, the size and complexity of spacecraft increases dramatically. Transporting humans and equipment to orbit, the Moon, Mars, or beyond requires enormous power. The problem faced by scientists is how to get massive payloads off Earth and into space.

Ask the students the following questions to uncover a few of the factors that scientists must consider as they develop plans for lifting larger and larger payloads into space.

Questions

What factors might scientists, engineers, and astronauts need to consider as they plan to launch larger payloads into space?

Answers may vary; students may note that large payloads require larger rockets; they may wonder if there is a practical limit to the size of a rocket, or if there is enough fuel available to power larger and larger rockets.

What is the most effective way to get materials and humans into space?

Answers may vary; however, at this stage in history, the only means of entering Earth orbit or traveling to any destination in space is with a rocket. Current plans for space exploration involve ambitious goals such as establishing a Moon base and traveling to Mars. Lifting large volumes of cargo into space requires powerful rockets.

Slide 13: NASA's Saturn V rocket has remained the most powerful rocket in history. After its role as the launch vehicle for the Apollo missions, the Saturn V was retired in 1973, and no rockets currently in use can match its 140 ton lifting capacity. The solution to lifting heavy payloads today is to create the next-generation of heavy-lift launch vehicles. At the time this lesson plan was written, Boeing/NASA, China, Russia, and SpaceX had plans for heavy-lift rockets that exceeded the lifting capacity of the Saturn V.

Teaching Tips

The information below supplements the brief descriptions of the missions on slide 11.

Boeing has produced the following short video, which provides a closer look at the SLS:

- "SLS Rocket Science in 60 Seconds" (Length 1:00) https://www.boeing.com/space/space-launch-system/#/videos/nasa-sls-rocket-science-in-60-seconds

The SpaceX Falcon Heavy launch system is currently the most powerful rocket in use, capable of producing five million pounds of thrust at liftoff. This is enough power to carry a fully loaded Boeing 747 into space. It is powered by 27 Merlin engines in 9 engine pods, and it is the first space vehicle of its type to land back on Earth under its own power for reuse. The Falcon Heavy was developed by SpaceX for launches into deep space, including missions to the moon and, perhaps later, Mars. Falcon Heavy is currently in use and has completed several successful missions.

The following video shows the launch of a rocket using the Falcon Heavy system. (The actual launch happens around 0:35.):

- "Falcon Heavy and Starman" (Length 1:52)
  https://safeYouTube.net/w/cOCQ
  For teachers unable to view Safe Youtube files, the video may also be seen here:
  https://youtu.be/A0FZIwabctw

The People's Republic of China is currently developing what may become the world's most powerful rocket, the Long March-9. This rocket is said to be capable of launching up to 140 metric tons into orbit; it will be used for moon launches as well as possible missions to Mars. The Long March-9 is expected to take its first flight sometime near 2030.

The following video is in Chinese, but it shows a variety of rocket prototypes. (The first minute is sufficient for students to see.)

- "China's New Rockets" (Length 0:52)
  https://safeYouTube.net/w/1l7R
  For teachers unable to view Safe Youtube files, the video may also be seen here:
  https://www.youtube.com/embed/G6y_vBaIALo?start=00&end=52

EXTEND

Teacher Materials: From Looking at Stars to Living on Mars Presentation, From Looking at Stars to Living on Mars Teacher Notes: Hazard Notes 1-5
Student Materials: From Looking at Stars to Living on Mars Student Activity: Hazard Notes 1-5

Slide 14: With the advent of new spacecraft capable of carrying humans and cargo on long space voyages, what hazards might they face in space? As a transition to the next activity, present the following question to the class. Record students' responses on a white board or poster board for reference.

Questions

- What hazards might be part of a multi-year exploration in deep space?

Possible answers: Astronauts on a multi-year mission in deep space might risk running out of air, unexpected illnesses or other changes to health, extreme loneliness or other psychological issues, mechanical failures that make return or rescue impossible, interpersonal conflicts with other crew members, etc.

Slide 15: In the previous section of the lesson, students learned mainly about technologies that are already in use or relatively close to implementation. Now, students will complete a jigsaw investigation in which they hypothesize solutions to avoid or mitigate the five main hazards that NASA has identified for deep space exploration. (Note that NASA has framed these hazards in the context of a manned mission to Mars.)

1. Radiation
2. Isolation and confinement
3. Distance from Earth
4. Lack of gravity

5. Hostile or closed environments

Teaching Tips

The hazard descriptions and solutions for this activity, as well as certain accompanying text, are copied from this NASA web page:

https://www.nasa.gov/hrp/5-hazards-of-human-spaceflight

The **Student Activity: Hazard Notes** sheets have links to individual videos produced by NASA that explain the five hazards with animations and text. A NASA playlist of the videos is available here: https://www.youtube.com/watch?v=3jRxgvwhGC0&list=PLiuUQ9asub3RRA-BMh7wLsU7V6gUUSRwH

The jigsaw activity should be performed with groups of five students each. Provide each group with a set of the five different **Student Activity: Hazard Notes** sheets. The sheets are numbered 1 through 5, and each focuses on one of the five main hazards identified by NASA. This is the "home" group for the students in this activity.

Tell all of the students holding **Student Activity: Hazard Notes Sheet 1: Radiation** to gather in what will be called an "expert" group. Continue in a similar fashion with the other four hazards to create five expert groups.

Each expert group will read about the hazard they hold and discuss ways that a spacecraft could be designed so that the hazard is mitigated. Scientists from a variety of STEM fields are likely to be working on solutions to mitigating these hazards. Students should discuss the types of scientists and engineers they believe would be involved in designing solutions to the hazard. Inform students that they are expected to write their notes in the appropriate columns of the activity sheet since the papers will be collected as the **Formative Assessment**.

After the expert groups have had enough time to discuss the hazards, all students should return to their home groups. In their home groups, students should share their particular hazard and the solutions that were discussed in their expert group.

You may choose to have students or groups share their responses with the entire class as part of a discussion to bring closure to the activity.

NASA's solutions for each hazard can be found in the five **Teacher Notes: Hazard Notes** sheets that accompany the student worksheets.

Tell the class that this activity provided a taste of things to come in the next lesson, when students will actually engage in the strategic planning necessary to realize an idea for a complex and multi-stage aerospace innovation.

EVALUATE

Teacher Material: From Looking at Stars to Living on Mars Presentation

Slide 16: Complete the **Formative Assessment**.

Formative Assessment

Each group should submit its completed Hazard Notes sheet. Use students' responses to evaluate their readiness to engage in the next lesson's in-depth strategic planning.

[DOK-L3; *investigate*]

Formative Assessment Scoring Rubric

- Follows assignment instructions
- Postings and in-class discussions show evidence of one or more of the following:
  - Ability to identify emerging trends in space vehicle development
  - Ability to suggest meaningful solutions to hazards of space flight
  - Ability to identify STEM skills sets necessary develop solutions to hazards
  - Ability to make thoughtful comments during class discussions
  - Ability to participate in a group activity and make meaningful contributions
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

STANDARDS ALIGNMENT

COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- **RST.11-12.7** - Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- **RST.11-12.9** - Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- **WHST.11-12.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures /experiments, or technical processes.
- **WHST.11-12.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research.
- **WHST.11-12.10** - Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

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