



FUTURE U.

Deep Space Gateway

Objectives

Students will be able to:

- **Summarize** and **discuss** the obstacles of creating a research base on the Moon.
- **Evaluate** how to design a sustainable lunar research base that overcomes the Moon's obstacles.
- **Analyze** various lunar base models in order to **develop** their own opinion about the most effective lunar base design.

Lesson Overview

As planetary research scientists with NASA's Solar System Exploration Research Virtual Institute (SSERVI), students will analyze why we should pursue the building of a lunar research base, explore obstacles to creating such a base, and describe the resources that can be used to our advantage as we build one. To accomplish this, students will first receive a short briefing about the changing attitudes toward lunar exploration and learn about recent discoveries that may prove beneficial for the creation of a lunar outpost. They will then uncover the obstacles to creating a lunar base, including the need to minimize the impact of the Moon's dusty soil. Next, they will gather data through internet research about strategies that could be used to overcome these obstacles and they will create a model of a possible solution. Once their research is complete, they will view possible designs for a lunar base and discuss the pros and cons of various designs. Finally, students will draft an opinion essay to defend their choice of a solution that will best overcome the Moon's obstacles.

This lesson focuses on

Engineering Design Process

- Defining the Problem
- Designing Solutions
- Refine or Improve
- Communicating Results

21st Century Skills

- Communication
- Critical thinking
- Creativity

Timing

Three 45–60 minute class periods

Materials

- Masking tape
- Lunar Rover Simulation handout, one per every three students
- Fabric or material to be used as a blindfold, one per every three students
- Computer or device with the ability to project
- Starliner [video](#): to project
- Cave Discovery [video](#): to project
- Ice Discovery [video](#): to project
- Lunar Obstacles articles, enough of each for one-quarter of the class:
 - [Lunar Dust article](#)
 - [Radiation article](#)
 - [Food Source article](#) (page 2 only)
 - [Oxygen article](#)
- Lunar Base Design Notes Pages 1 and 2, one per student
- Computers or devices with internet access, enough for at least half the class
- Model materials: can include (but is not limited to): aluminum foil, plastic wrap, paper towel rolls, cardboard, paper, string, glue, etc.
- Lunar Base Design Images, to project
- Lunar Base Recommendation handout, one per student

Have you ever wondered...

If the Moon isn't a planet, what is it?

One criteria of a planet is that it must orbit around the Sun. The Moon is not a planet because it does not rotate around the Sun...but it does orbit around the Earth! The Moon is therefore a satellite, and it is Earth's only natural satellite. It takes 27 days for the Moon to orbit once around the Earth. As it orbits, it stays about 239,000 miles away. It is the fifth largest moon in our solar system, and it is the only place beyond Earth where humans have walked!¹

Does the Moon affect Earth?

The Moon has a few large effects on the Earth. First, ocean tides are formed by the Moon as its gravity pulls on the Earth. These tides help bring heat from the equator out to the Earth's poles. The Moon also helps stabilize the Earth's tilt and keep it from wobbling. This stabilization helps maintain a more consistent climate on our planet. We also can't forget that the Moon is the brightest and biggest object in the night's sky! Without it, nighttime would be much darker.¹

MAKE CONNECTIONS!

How does this connect to students?

Twenty-four humans have traveled to the Moon. Of these 24 astronauts, 12 have walked on its surface. The last human mission to land on the Moon was Apollo 17... but that was in 1972! A large reason why manned exploration has not occurred in so many years is because of funding: Taking humans to space is the most expensive type of space exploration. However, an emphasis on human space travel (to the Moon and beyond!) has returned, and there are growing funds and resources being dedicated to human exploration.¹ Humans are likely to have the chance to travel to the Moon, Mars, and perhaps even further in students' lifetime!

How does this connect to careers?

Space Software Engineers

Space software engineers research, design, and develop computer programs that are used to measure and control activity in outer space on everything from satellites to human missions.

Aerospace Engineer

Aerospace engineers design spacecraft, aircraft and satellites. The first step in their design process is the creation and testing of prototypes to make sure they function effectively!

Astronomers

Astronomers are scientists who collect and analyze data related to celestial bodies in our universe, such as galaxies, planets and stars. They use equipment on both Earth and in space to make their observations.

Avionics Technicians

Avionics technicians test, install and replace systems (such as communication and navigation systems) that are necessary to aircraft and spacecraft. Engineers then use their records of problems and repairs to improve future designs.

How does this connect to our world?

In December of 2017, President Trump signed Space Policy Directive 1, which called for a program that brings humans back to the Moon and later to Mars. Unlike the 20th century space race in which countries competed against each other, this directive calls for NASA to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." Therefore, there is hope that the U.S. government, countries around the world, and private sector companies will work together to make this exploration possible.³

Sources

¹ "Earth's Moon". NASA. solarsystem.nasa.gov/moons/earths-moon/overview/.

² Mosher, Dave and Brueck, Hilary. "Astronauts explain why nobody has visited the moon in more than 45 years—and the reasons are depressing." *Business Insider*. businessinsider.com/moon-missions-why-astronauts-have-not-returned-2018-7.

³ "New Space Policy Directive Calls for Human Expansion Across Solar System". NASA. nasa.gov/press-release/new-space-policy-directive-calls-for-human-expansion-across-solar-system.

Blueprint for Discovery

DAY 1

Preparation Note: Before the beginning of class, use masking tape to place between 10 and 20 Xs on the classroom floor. Students will be giving each other instructions on how to navigate around these Xs with their eyes closed—so there should be enough markings to make this challenging!

1. Begin class with a quick simulation. Tell students that a system restart at NASA's Mission Satellites Operation and Control Center has resulted in several confused lunar robots. These robotic vehicles need help in order to avoid being damaged by the moon's many obstacles, which are marked with Xs on the classroom floor. The students will therefore participate in a simulation in which they take over the teleoperation of these vehicles.

Divide the class into groups of three or four students and distribute a Lunar Rover Simulation handout and blindfold to each group. Explain that one student in each group will need to take on each of the following roles:

- Lunar Rover: One student will be blindfolded and pretend to be a robotic lunar vehicle. This robot can only move when it is directed to do so and must follow instructions precisely.
- Programmer(s): One or two students will record quick and careful instructions on the Lunar Rover handout in real time. These directions will tell the robot where and how it should move in order to avoid all lunar obstacles.
- Transmitter: One student will read these instructions as they are written and share them with the robotic vehicle.

Tell students that the lunar robots should be able to move continuously around the moon, so the team should work together to ensure that the rover is moving with as few interruptions as possible. Every time any portion of an X is stepped on, students should mark an X in the handout's bottom box.

Once the directions are clear, instruct each group to begin in a different area of the classroom, select their group roles, and begin!

2. After about five minutes have passed, bring the class back together and discuss the experience. Ask: What aspects made it difficult to control the movements of a lunar vehicle from "afar"?
3. Tell students that the United States is working hard to bring humans back to space. As a result, this issue of controlling robots from afar should become less of an issue because humans will be on the moon to do their own exploring! Elaborate on this topic by showing this video.
4. Then read the following aloud to students:

As of this moment, you are no longer middle school students. You are planetary research scientists with NASA's Solar System Exploration Research Virtual Institute (SSERVI). In other words, you now work for a NASA research center that seeks to better understand the moon and its surroundings.

Though humans have not set foot on the Moon since Apollo 17's mission in 1972, a new era of space exploration has begun! Last year, the President signed a directive instructing NASA to send astronauts back to the Moon. The video you just watched about the Starliner CST-100 is an important step towards achieving this. This spacecraft is being designed to carry humans to the International Space Station, which will serve as a stepping stone for lunar exploration.

It is this lunar exploration that SSERVI needs you for! You are being tasked with investigating how to best build a lunar research base, which is a semi-permanent structure that would allow humans to explore, live, and research on the Moon.

5. Explain that you will first be showing quick clips about two recent discoveries that may prove beneficial for the creation of a lunar base. Distribute one Lunar Base Design Notes handout to each student and quickly review the Opportunities chart. After you show each video, lead the class in a think/pair/share to facilitate discussion about how each discovery may help make a lunar base more possible. Students should fill out the first chart on their Lunar Base Design Notes handout accordingly.
 - a. Cave Discovery: [Video Link](#) (Show to 1:07)
 - b. Ice Discovery: [Video Link](#) (Show to 1:36)
6. Divide the class into groups of two or three, and distribute copies of one of the Lunar Obstacles articles to each group. (Try to ensure that approximately one-quarter of the class is reading each article.) Instruct students to read the article with their group, and annotate for problems and solutions. When they are done reading, students should fill out the first two columns of the Lunar Obstacles grid. Tell students that not all articles will present solutions, and they may leave the Solutions column blank if a solution is not presented.
7. When the majority of students have finished, instruct groups who have read the same article to find each other and discuss their notes. Each group should then appoint one or two spokespeople who will share their notes with the rest of the class.
8. Allow each spokesperson a couple minutes to present their group's findings. As these students share, the rest of the class should continue to fill out their grid with these other obstacles and potential solutions. At the end of each presentation, allow students a couple minutes to ask questions and clarify as needed.

DAY 2

1. Direct students to review their Lunar Base Design Notes. Ask student pairs to consider: Based on their research, what one obstacle seems to most stand in the way of a lunar base? Answers may vary.
2. For the first part of class today, explain that each pair will perform additional research on the obstacle they selected. They will then use this research to select one solution that they think will work best, and they will create a simple model of this solution so the class can better understand it. They will then apply what they have learned as they provide recommendations for a lunar base.
3. Take a quick poll to ensure that at least one group is performing research on each of the topics listed in the Obstacles graphic organizer. Then direct students to turn their Lunar Base Design Notes sheet to page two, and read the directions provided.
4. If needed, review the importance of reputable sources and provide a quick list of websites where students can begin their research, including:

- a. NASA.gov
 - b. PopSci.com
 - c. HowStuffWorks.com
 - d. Space.com
5. Allow students to get to work! As they research, be available for questions as needed.
6. Once the class has performed research for about 20 minutes, suggest that they move on to building a rough prototype of their solution, and show students where they can find materials for building this model.
7. When there are about 15 minutes left in class, call on each pair to: 1) Explain their obstacle, and 2) Use their model to demonstrate how their solution would help combat this issue. If time allows, encourage students to ask clarifying questions following the mini-presentations.

DAY 3

1. Begin by telling the class that you have just received several proposed lunar base designs from different companies and government agencies. Based on the research that the students have performed and the solutions they have already developed, they will review the designs and discuss the pros and cons of each. Encourage students to look especially critically at the images from the lens of the specific obstacle that they researched.
2. Draw a T-chart on the board titled “Pros” and “Cons”.
3. One by one, project the four lunar base design images. As students evaluate the images, add their thoughts to the chart. Prompt students to consider the potential pros and cons of each design in terms of the recent cave and water discoveries, as well as lunar dust, radiation, food sources, and oxygen. As a challenge, also encourage students to consider which designs seem to protect the Moon’s environment and make the best use of its natural resources. Students may have to infer some of the pros and cons!
4. Next, distribute one Lunar Base Recommendation handout to each student. Read the directions on the top of the sheet together, and remind students to use their notes as well as the Pro/Con list to begin planning.
5. Students should use the duration of the class period to begin a draft of their essay. You may choose to either allow students to finish their essays during the next class period, or have students take their planning sheet home and complete their essay after school.

EXTEND: Funding Cut! As an extension, pretend that you heard a rumor that national space funding may be dramatically cut...which would affect any and all plans for their pending lunar base. Challenge students to perform research and develop an argument that explains why scientists are focusing on a lunar outpost as a foundation for deep space exploration and what such exploration has the potential to achieve. Students may choose how to present their argument: through a letter to Congress, editorial cartoon, protest poster, etc.

National Standards

Next Generation Science Standards

Engineering Design

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Common Core English Language Arts Standards

Science & Technical Subjects, Grades 6–8

- RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
- RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
- RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Group Roles:

- Lunar Rover: One student will be blindfolded and pretend to be a robotic lunar vehicle. This robot can only move when it is directed to do so and must follow instructions precisely.
- Programmer(s): One or two students will record quick and careful instructions below in real time. These directions will tell the robot where and how it should move in order to avoid all lunar obstacles.
- Transmitter: One student will read these instructions as they are written and share them with the robotic vehicle.

Rover Instructions:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____

Mark an X in the box below for each time the rover comes into contact with a lunar obstacle!

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Lunar Base Design Notes: Page 1

Opportunities

Lunar Discovery	How could this benefit a lunar base?

Obstacles

Brief obstacle overview	Details (What exactly is the obstacle? Why does it create problems? What are the problems it presents?)	Possible Solutions

Lunar Base Design Notes: Page 2

Directions: As you research, use the space below to take additional notes on the obstacle you selected. You will use these notes to: 1) Develop a model of a solution for this obstacle, and 2) Act as SSERVI's expert in this focus area when you evaluate different lunar base designs!

Focus Area for Lunar Base Research:

Additional notes about the obstacle:
Remember to cite your sources!

Additional Notes about possible solutions:
Remember to cite your sources!

Once your research is complete, work with your partner to narrow your possible solutions down to the one that you believe is best. Then use the materials provided to create a model of this solution. Be prepared to use this model to demonstrate *how* this solution will help overcome the obstacle!

Lunar Base Recommendation

As a key member of the Solar System Exploration Research Virtual Institute, your opinion is requested! Based on the in-depth research you have performed and the discussions in which you have participated with your colleagues, you are being asked to provide a recommendation for a lunar base design. SSERVI's Director and Chief Scientist will consult your recommendation as they work with NASA and other international organizations to develop a plan for the universe's first lunar base!

Your recommendation must take the form of an essay in which you address at least three obstacles facing the creation of lunar outposts, as well as design elements that could overcome these challenges. Within your essay, you must address the issue of lunar dust—but the other two obstacles are up to you. Make sure you explain not only how your design will help overcome each obstacle but also why this design would be the most effective. Cite findings from your research to support your opinion.

Use the space below to jot key points and ideas, and then complete your essay on a separate piece of paper.

Obstacle 1: Lunar Dust

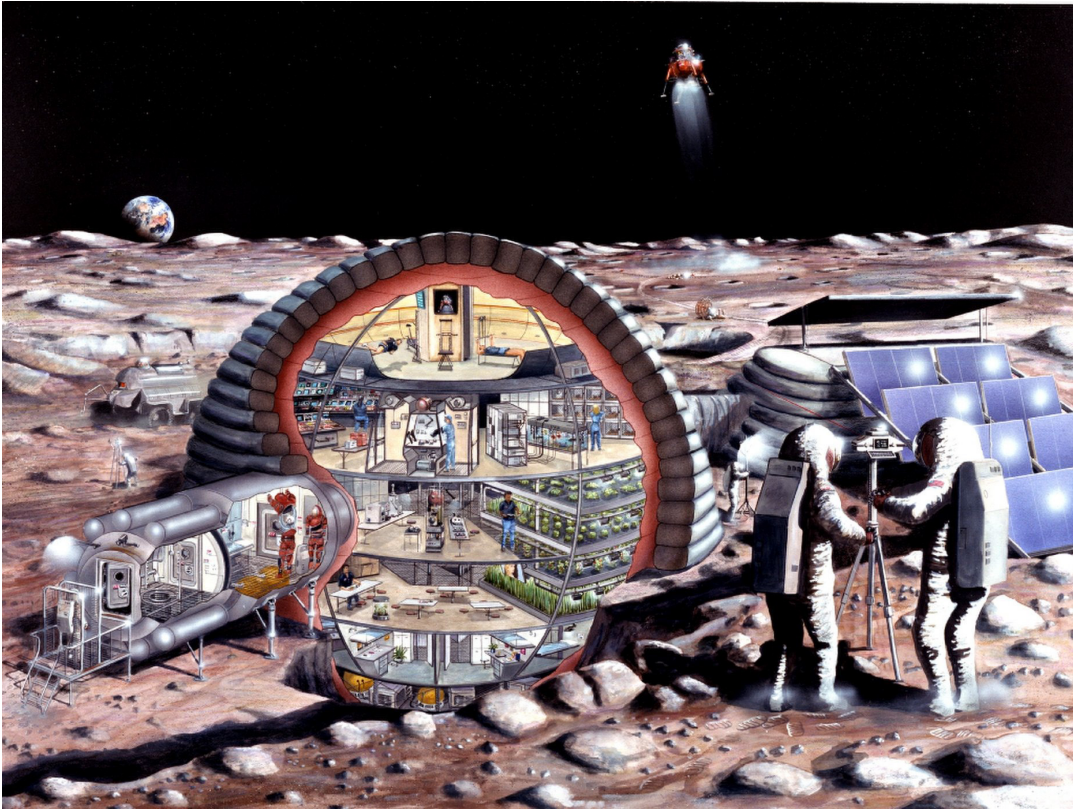
Design recommendation and justification:

Obstacle 2: _____

Design recommendation and justification:

Obstacle 2: _____

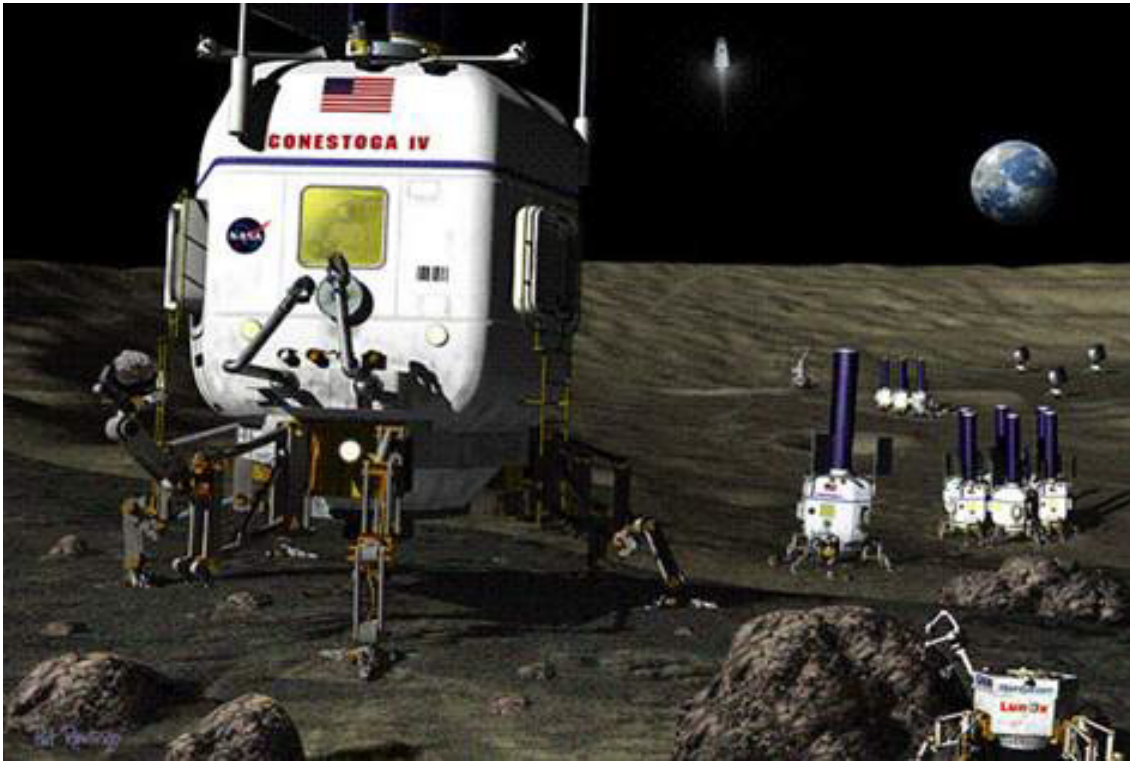
Design recommendation and justification:



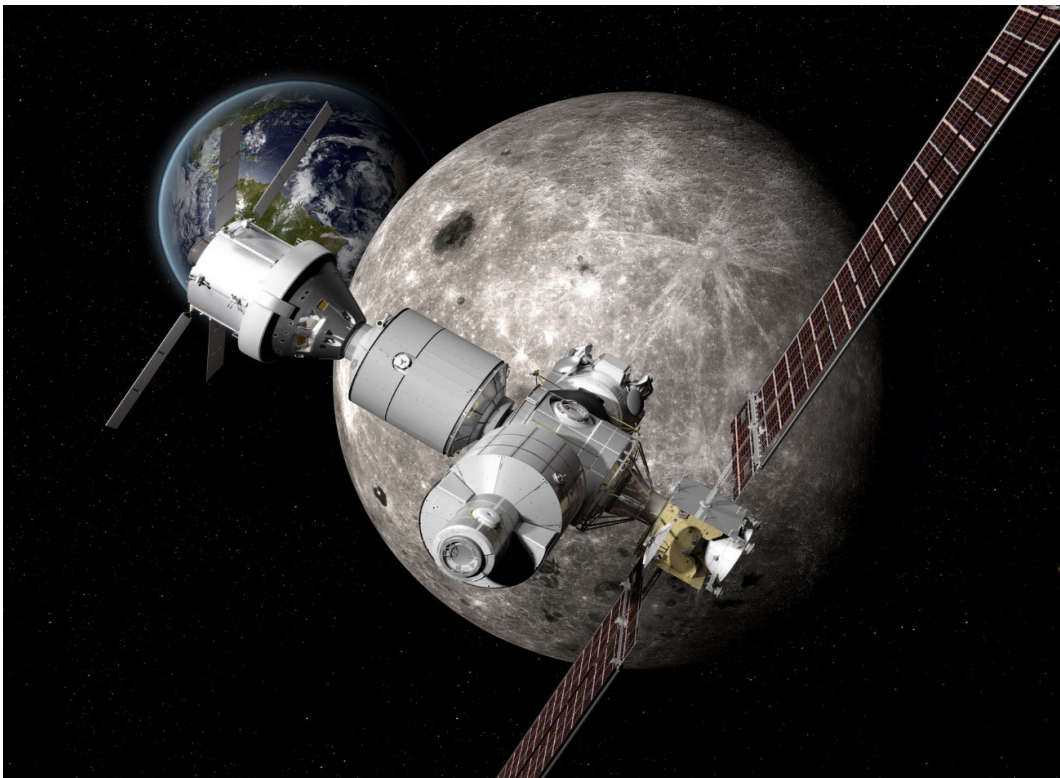
Lunar Base Design Image: space.com/21583-moon-base-lunar-colony-photos.html



Lunar Base Design Image: space.com/21583-moon-base-lunar-colony-photos.html



Lunar Base Design Image: nasa.gov/centers/ames/images/content/75977main_HABOT.jpg



Lunar Base Design Image: Boeing