FUTURE U.

Innovating the Future VFT

Objectives

Students will:

- Identify key steps in the history of space exploration.
- Create a timeline to organize and illustrate key steps in the history of space exploration.
- Design and create a simple rocket from commonly available materials.
- Create models to demonstrate Newton's laws of motion.
- Identify STEM careers that match their skills, interests, and experiences.

Time Frame

Plan for two class periods (45 minutes)

Overview

Join us live at the historic Johnson Space Center in Houston, Texas! During this event, students will meet Boeing employees who are preparing to write the next chapter of space history.

During this VFT students will engage with innovative Boeing projects related to human exploration of space. In particular, students will be introduced to the back story of Boeing's two principal projects, the Starliner/CST-100 spacecraft and the Space Launch System (SLS). Currently under development, these vehicles are planned for use in orbital missions, and for human exploration of the moon and Mars. A key goal of the VFT is for students to relate elements of spacecraft construction and operations to the overall endeavor of putting people in space and exploring the universe beyond Earth. The "wow" factor is not so much the spacecraft as a fully-formed piece of technology as it is the thousands, if not millions, of smaller innovations that went into its development. Who hasn't dreamed of being an astronaut at some point in their lives? Middle school students are beginning to consider their career options. By connecting with real-life "rocket scientists," students will see the multitude of career paths and experiences through which Boeing's employees reached their current positions.

The pre-field trip activities in this companion guide are designed to introduce students to the topics they will learn about during the VFT. The activities designed for completion during and post viewership connect and extend student learning to classroom concepts.

National Standards

Next Generation Science Standards: Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. (MS-ETS1-4)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (MS-ETS1-3)

The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

Materials

- Careers in Aerospace capture sheet
- Space Exploration Technologies capture sheet
- Access to the Internet
- Graphic display materials (software or regular materials)

Pre-VFT Activity

Don't forget to also watch the Pre-VFT sneak peek to get your class excited for the live event!

4-Corners Question Boot up

Before you begin your journey, see what students already know about human exploration. Designate one corner of the room to represent each response. You might want to use small white boards or signs to label each corner. State the question and ask students to write their response on an index card or small piece of paper. Then, ask students to take their cards to the designated corner. Direct students to form groups of 2–3 and share why they selected this option. Repeat directions for each question and reveal correct answers.

1. Which of these is **NOT** an example of an Autonomous vehicle?

   Self-driving car

   remote-controlled robot

   remote-controlled drone

   bicycle (correct answer)

2. How many people typically **live** on the International Space Station at any one time?

   2

   6 (correct answer)

   12

   24

3. Worldwide, **approximately** how many rockets have been launched to date?5,000

   (correct answer)

   2,500

   500

   25

4. About how many Earth days does it take to go to Mars?

   15 days

   50 days

   100 days

   300 days (correct answer, but varies widely on fuel and positions of planets)

History of space timeline

To help prepare for the Virtual Field Trip, engage students in a discussion about the history of space. Clarify with students that the United States is one of several space-capable nations, but only one of three countries with human space exploration capability. (Russia and China are the other two.) Use images from NASA image library to illustrate the space race which the United States engaged in with the Soviet Union during the 1960s.

Share with students that during the space race different pieces of technologies used to build the spacecrafts expanded on or refined previous innovations and scientific advances.

Explain to students that they will create a graphic organizer in the form of a timeline to illustrate how each innovation relied on earlier advances. Ask students work in pairs or small groups. Ask students to brainstorm what kinds of information they should include in their time line. If needed, guide students to consider that their timelines should include:

- Date
- Title
- Short passage summary
- Image

For the title, students could research or imagine the headline that accompanied the event. The images for the timeline are optional but desirable, since students will observe the improvement in image quality corresponding to improvements. Students will be challenged to select the most relevant events to include in their timelines. Explain to students that to help them prioritize, they can sort events according to relative impact on the advancement of space exploration.

Suggested resources:
https://www.archives.gov/research/alic/reference/space-timeline.html
https://www.nasa.gov/centers/glenn/about/history/timeline.html
https://www.nasa.gov/centers/kennedy/about/history/spacehistory_toc.html
https://images.nasa.gov/

Students will collect their data and compile and organize it to create their timelines using the graphic display materials. Invite students to brainstorm ways they could create and share their timelines as a digital resource or in-person presentation.

During the Virtual Field Trip

Two activity options are available for students to obtain information as they watch the Virtual Field Trip.

During the Field Trip

Activity 1: Applying Your Knowledge and Skills to Careers in Space Science

Guide students to brainstorm their personal talents and interests and write them on the capture sheet. Then, direct students to watch the Virtual Field Trip. While they watch, they should look to match some of their talents and interests with the careers featured.

Activity 2: Aerospace Technologies

Students will use the capture sheet to analyze the technologies featured in the different career spotlights. Students will compare a technology they are familiar with to one they will observe during different segments of the VFT. After the VFT, students will use the second column sentence starters to evaluate and summarize the technologies they observed.

Post-VFT Activity

Be a Rocket Scientist

After the VFT, explain to students that they will create their own simple rockets to demonstrate key principles of rocket propulsion. In this activity students use readily-available, safe materials to test various designs for a baking soda rocket. The aim of the activity is to evaluate designs using the engineering design process to optimize the performance of their rocket. They will then use their rockets with different payload masses to investigate the effect of payload mass on performance.

Safety Note

Explain to students that although their rockets use safe, non-flammable materials, their rockets can travel several meters high at high speed. Students should be careful during preparation of their rockets and stay clear of the launch area just before launch. For the activity, find a suitable area outside away from buildings or vehicles.

Materials (for each group)

- large soda bottle (1 liter size)
- cork or rubber stopper for the soda bottle
- 3 pencils of equal size and length
- sticky tape
- cardstock

- scissors
- bathroom tissue
- set of measuring spoons
- baking soda
- white vinegar
- paper towels for clean up
- pennies

Procedure

1. Working in pairs or small groups, students create their rocket frame:
    a. Tape the three pencils equal distances around the top of the soda bottle.
    b. Ensure that half the length of the pencils is above the mouth of the bottle. The pencils serve as fins of the rocket, so that the base of the rocket rests on the three pencils, and the exhaust nozzle (mouth of the bottle) is a few inches above the ground.
2. Conduct an initial trial:
    a. Measure a teaspoon of baking soda and place it in a square of bathroom tissue.
    b. Fold the square to make a packet and push it through the mouth of the bottle.
    c. Measure a tablespoon of the vinegar and pour it into the bottle.
    d. Put the cork quickly into the mouth of the bottle. It shouldn't be pushed in too tightly but enough that it is sealed.
    e. Put the bottle upside down on a flat surface so that it is resting on the pencil "fins".
    f. Stand away from the bottle. Pressure in the bottle will build due to the carbon dioxide produced by the reaction of vinegar and baking soda. Wait for the cork to pop out and the rocket will fly upward.
3. Practice this procedure until a consistent performance is achieved.
4. Cut the cardstosck to create additional structures for the rocket as needed.

    To encourage students to experiment, set a design goal consistent with their ability and time available. Suggested enhancements:

    - Use the pennies as a payload taped to the bottom of the bottle (top of rocket) and compare rocket performance (height reached by rocket) with and without a fairing (made from the card).
    - Vary the number of pennies and compare rocket performance.

Materials

- Newton's cradle
- paperweight or similar small heavy object
- sheets of paper
- flour
- large dish or basin
- marble
- toy cars

Procedure

1. Engage students by asking them how a simple device such as Newton's cradle relates to such a complex machine as the SLS.
2. Explain that they will use the materials to investigate Newtons' laws of motion.
3. Students can work in pairs or small groups depending on the availability of materials.
4. Assign each group (or let them choose) to investigate one of the three laws using the available materials.
5. After students have completed their investigations, each group presents to the class how they used the materials to demonstrate their assigned law of motion.

Example Demonstrations

Example demonstrations that the students could present include:

First Law

1. Place a sheet of paper on a flat surface, so that a short portion of paper is protruding one or two centimeters over the edge of the surface.
2. Place a paperweight on the sheet of paper.
3. Quickly pull the piece of paper.
4. The paperweight will remain stationary due to its inertia, consistent with Newton's first law.
5. If the paperweight moves, encourage students to consider why. (Due to friction between the paperweight and the sheet of paper.)

Second Law

1. Add flour to the dish to create a layer 2–3 centimeters deep.
2. Wad up the paper as tightly as possible so that it is about the same size as the marble.
3. Drop the paper wad and marble at the same time from an equal height (e.g., 1 meter).
4. The paper wad and marble will hit the flour at the same time, but the marble will make a bigger crater because of its greater mass *(m)*, consistent with Newton's second law. Even though acceleration (a, due to gravity) was the same, the force *(F)* of the marble was greater due to its greater mass.
5. If the paper wad and marble do not hit the flour at the same time, encourage students to consider why. (Even if the paper is wadded up tightly, it will have a rougher surface area than the marble, so friction due to air resistance will be greater, causing it to fall more slowly.)
6. If time allows, encourage students to consider the problem algebraically:

   According to Newton's second law, $F = ma$

   Let:

   a = acceleration due to gravity

   m^m = mass of marble

   m^p = mass of paper wad

   F^m = force of falling marble

F^p = force of falling paper

Therefore, since a is the same for both objects, if $m^m > m^p$, then $F^m > F^p$, consistent with the observation that the marble makes a bigger impact crater.

Third Law

1. Using Newton's cradle, first pull one ball back.
2. Drop the ball.
3. The dropped ball hits the ball adjacent, but only last ball in the row moves, rising to about the same height from which the first ball was dropped.
4. Repeat with the first two balls in the row.
5. The middle ball remains stationary, but the last two balls in the row move.
6. These observations are consistent with Newton's third law as follows:
7. In the first case one ball hit the one adjacent (action), force was transferred through the balls in between because they're prevented from moving by adjacent balls. Only the last ball moves to the same height (equal and opposite reaction).
8. Encourage students to consider how they could demonstrate the third law using the toy cars. (e.g., students could cause two cars to collide and observe the motions before and after the collision.)

Engage students in a discussion around the following questions:

1. How do the demonstrations relate to the motion of the SLS:
    a. During launch?
    b. In orbit?
2. How do the demonstrations relate to the common misconception about rocket motion mentioned by Myron Fletcher?

Applying Your Knowledge and Skills to Careers in Aerospace

The competition for human exploration of space drives expansion and innovations resulting in growing and varied job opportunities in aerospace. People in these careers work together to develop aircraft, spacecraft, satellites, and missiles. Your interests, abilities, and goals will all influence your career choices.

Which of your talents and skills relate to a career in aerospace? Explain the connection.

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Which interests or hobbies you enjoy relate to a career in aerospace? Explain the connection.

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While watching the Virtual Field Trip, match some of your talents and interests related to each career highlighted.

	Tony Castilleja Jr., Mechanical Engineer	**Celena Dopart**, Human Factors Systems Engineer	**James Dickson**, ISS Mission Evaluation Room Manager	**Kavya Manyapu**, Flight Crew Operations and Test Engineer	**Jennifer Hammond**, ISS Mission Evaluation Room Manager	**Myron Fletcher**, Rocket Propulsion Engineer
List two skills the professional highlighted as being critical to their work.						
List two talents or interests that you have related to this job.						

Applying Your Knowledge and Skills to Careers in Aerospace

List two careers from the table that best match to your talents and/or interests.

Space Exploration Technologies

Complete the first column of the graphic organizer below as you watch the Virtual Field Trip. Complete the second column after the Virtual Field Trip to summarize your learning.

During the Virtual Field Trip	After the Virtual Field Trip
In what way is the technology of the CST-100 Starliner similar to that of a self-driving car?	Compare the Starliner to the shape of space capsules used in earlier space missions.
What is the role of the Human Factors System Engineer in the design of the spacecraft?	What design improvements does the CST-100 Starliner cockpit over older spacecraft, like the space shuttle?
What is the distance of Mars from Earth compared with the moon?	What factors must engineers take into account when planning a human mission to Mars compared with the moon?
What is XR?	How does XR relate to virtual reality and augmented reality?
What are some advantages of sleeping in a weight-less environment?	How are your personal habits for hygiene and exercising similar to astronauts?
Which high school classes would be useful for a career in XR?	What high school classes would be useful for a career in aerospace that interests you?