Space as the Foundation of a Curriculum for Grades 4-12

First Draft

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Contents

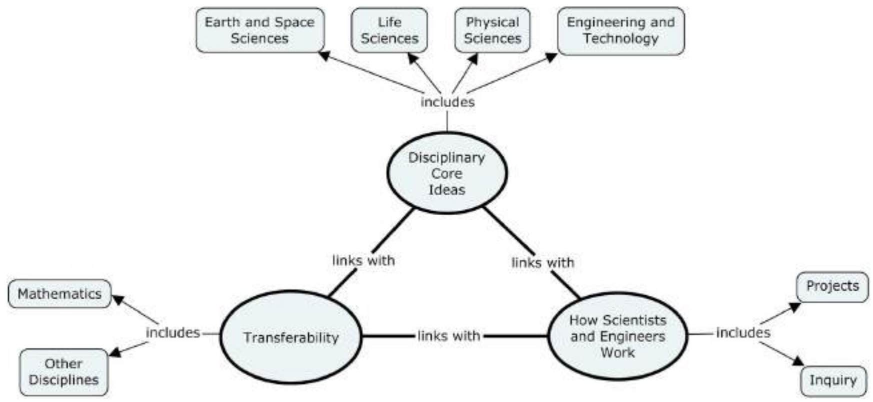
Introduction

In 2019 we celebrated the 50th anniversary of the date men walked on the moon for the first time. This historic event, watched by millions worldwide, was the culmination of explorations that started on October 4, 1957 when the Russians launched Sputnik, the first man-made satellite to orbit the Earth. Even though Sputnik was (by today's standards) a primitive device, it captured the imagination of people all over the world. Ever since, we have come to view Space and the next frontier, ripe for exploration.

I was a child when Sputnik was launched, and this event changed my life forever, heightening my interest in math and science, and leading me toward my PhD and a long career in the sciences and engineering. Decades ago, I shifted my focus to education with the goal of promoting the development of skills in the next generations of people who might also be engaged in one of the great adventures of our time.

The reason for this book

In 2013, the national Next Generation Science Standards were released. Since that time, twenty states have adopted the standards and numerous other states have written their own standards based on them. If you want, you can learn all about them here: https://www.nextgenscience.org/.



From my perspective, these standards had a lot of positive ideas, including the definition of four disciplinary core ideas: Earth and Space Sciences, Life Sciences, Physical Sciences, and Engineering and Technology.

This set of topics gave me an idea: Rather than think of these as separate topics, suppose all of them could be explored through the lens of Earth and Space Sciences! While this might not make sense in the primary grades, it surely would work from grades four through twelve. And, the topics that could be covered include language arts, math, and everything else we expect students to learn in school, not just traditional STEM topics.

To give one extreme example, let's look at language arts. Research using tools like the Kepler Space Telescope have shown the presence of quite a few "Goldilocks" planets — planets of the right size, temperature and atmosphere to support carbon-based life forms. Assuming that some of these life forms are intelligent, it is safe to speculate that they could communicate with us. Of course this leads to questions about language and methods of communication. One might argue that, right here on Earth, interspecies communication exists when we teach dogs to respond to verbal commands. This leads to an amazingly wide spectrum of potential educational projects for kids — projects that can encompass virtually all of the activities we explore when kids study communication in the classroom — reading, writing, presentation skills, etc.

While this topic has long been a topic in science fiction, it is now in the realm of reality. This was brought home in 2020 when the International Space Development Conference devoted an entire strand to Messaging Extra Terrestrial Intelligence. Again, we're talking science, not science fiction.

When looked at against the backdrop of K-12 education, the challenge is tremendous. We still talk about generating an educational model for the 21st century. The problem is that we are already 20% of the way through the 21st century, and our curriculum and pedagogy remain largely as they've been for generations.

This book is a modest attempt to trigger a new way to think about the curriculum in ways that foster enthusiasm and deep involvement from students and teachers alike.

How this book is structured

The bulk of this book consists of projects organized around themes. Each project is independent, freeing you to pick and choose activities at will.

Each project consists of a starting tidbit to pique interest, background information, the activity itself, the duration, a list of resources to get you started, a list of benchmark areas, and a description of the desired student outcome.

You may find that an activity may require more or less time than we allotted, and you should feel free to modify activities as appropriate.

As for the scope of the projects, we've scarcely scratched the surface, and as you get started you will likely come up with new projects of your own. I would love to hear from you as you use this book, and my email address is included in the last chapter.

A bit more on standards and classroom ideas

This book contains curriculum projects across the bulk of school subjects through the theme of exploration of the region from the Earth to the Moon, ranging from the design and construction of rockets and other tools needed to explore space, conducting research on the International Space Station (ISS) to many other topics related to space exploration.

This curriculum is designed around multiple topics, each of which has several projects. It is anticipated that groups of students will work on a single project per theme and then share their results with all the other students to ensure that every student is exposed to the ideas developed by everyone else.

Every group will produce final project reports in any of several appropriate media ranging from written reports to videos and interactive web sites. These presentations can be supplemented four times a year with formal presentations to the rest of the class, emulating the process used in traditional conferences on these topics. In addition to these formal presentations, student groups are also encouraged to give 5-minute pop-up presentations/poster sessions to the school at large, perhaps with an exhibit space outside the school cafeteria or library. School science fairs become a place for students to submit their best work, as well as a place to attract more students to the program in following years. Student work will also be shared with the public at large through the Thornburg Center for Space Exploration's own website.

These themes are chosen to provide a deep exploration of STEM topics and support student creativity, invention, and speculation designed to build an appreciation for the topics that might lead to students deciding to pursue careers in the STEM fields. We go beyond STEM subjects to include language, history, art and other subjects studied in school.

About the curriculum:

- The activities are all standards based, but not standards driven. We have elected to use the NGSS and AAAS benchmarks on STEM, along with Common Core math and language arts. We've also touched on the subjects of history and the fine arts.
- Students should be encouraged to understand the power of concept mapping to find relevant strands of inquiry, and evaluate their progress on a project.
- All students should be provided with all the software needed for the year in formats suitable for their computers at home (Mac, Windows, Linux), and every computer in the classroom needs to have this software installed as well. Because every title we have chosen is free (and largely open source) software, this incurs no financial burden on the site. Those with Chromebooks will find many resources open to them as well.
- Students need to know how to conduct research using both online and other resources, as well as how to tell if a question might require some experiments on their part to find the answers.
- To provide consistency (and meet international expectations), all units of measure will be metric. Conversion tables should be provided to every student.
- At the very start, the whole class will choose a name for their class (e.g., Hyperdrive Space Exploration League) and design a patch or logo that can be used as a classroom decoration, ironed on T-shirts, etc.
- As students are likely to encounter new words in the course of their study, they need to be shown how to use online dictionaries and encyclopedias, or use materials

available to them in the school or public library.

- At least four times per year, students will be giving formal presentations of their work to others. This means they should be taught presentation skills ranging from the mechanics of presentations creation, to the aesthetics and techniques of effective communication.

Structure of each unit:

Each unit has several projects or activities. The teacher will have divided the students into groups of four or five, and each group will be assigned a project from the pool associated with the theme. If appropriate, groups may trade their project with another group if mutually desired. Once assigned, the following activities will be done in sequence:

- Teacher introduction of each topic, including very brief presentation and discussion. The presentation should focus on just enough information to have the topic's questions make sense to the students, and not be a traditional lecture on the content.
- Individual "before" concept map showing prior knowledge and understandings (if any) of the theme
- Class shares "before" concept map
- Assignment of students to groups and group naming
- Activity
- Final individual concept map
- Final Group concept map
- Project product given to every student (paper, multimedia, web site, video, etc.)
- Self-assessment for the activity

The final project of the year will be based on a question asked by each student relating to the theme. This project will be done independently and will be related to the year's overall theme. In choosing this project, students will need to formulate a question, test it against an inquiry rubric provided by the Thornburg Center, for Space Education (tcse-k12.com/pages/inquiry.pdf) and pursue their independent research culminating in a final report and presentation. Students should probably start work on this project at the start of the second semester of the year.

The curious student

This program is designed to inspire students to develop a lifelong interest in the STEM subject areas. Some students may have a hard time in traditional science and math classes, questioning the relevance of their learning. Some may not feel appropriately challenged in traditional classes, or feel that the classes are otherwise "boring." It is important to know that other subjects (e.g., language arts, history) are encompassed as well.

The role of faculty members

Faculty members need to keep in mind that the task is not to just learn about STEM subjects in the context of space exploration, but to help students understand why there are people who devote their lives to working in these fields, and to help them experience the kinds of questioning processes used by professionals. The temptation to provide direct answers to student questions should be redirected in ways that promote more student inquiry and independent problem solving. For example, if a student asks: "Why is some astronaut food freeze-dried?" the teacher might respond: "How would you find the answer to that question?" instead of providing the answer directly.

A few words about standards

As mentioned above, our curriculum is aligned with educational standards in the fields of science, technology, engineering and mathematics, but it is not driven by them. The projects speak for themselves, and are designed for maximum student benefit and interest with the goal of having students explore these subjects in similar manner to those who work in the fields professionally. Our overall topics have been selected in ways that make it likely that standards will be addressed even in projects completely designed by students themselves.

After a careful review of several standards, we have chosen the benchmarks in the relevant fields (and grade levels from middle- to high-school) developed by the AAAS. These thoughtfully designed benchmarks reflect best professional practices. Similarly, the NGSS (Next Generation Science Standards) and Common Core Math and Language Arts standards are incorporated as appropriate.

Each project in the curriculum indicates whether it encompasses language (L), history (H), fine arts (A), science (S), technology (T), engineering (E) and/or mathematics (M). These designations make it easy for you to see which sets of standards may apply to each activity.

The AAAS benchmarks can be found here. AAAS Benchmarks (from http://www.project2061.org/publications/bsl/)

We hope you find these activities stimulating!

Name your class

Did you know? Names convey more than identification. They often suggest an affiliation with the strength of the group being named.

Background Create a name for your space exploration class

Activity Names are important. You will be making this class your own. Even when this class is offered again, it will not be the same.

What unique name do you think characterizes your classmates in terms of common interests?

When you think of names (For example, the Chicago High School Space Exploration League) you will have a way to express your membership in this program with pride. Also, the conversation you have with your classmates to choose a name allows you to express your hopes for the class this year.

Duration 1 week

Resources Class conversation

Benchmarks L

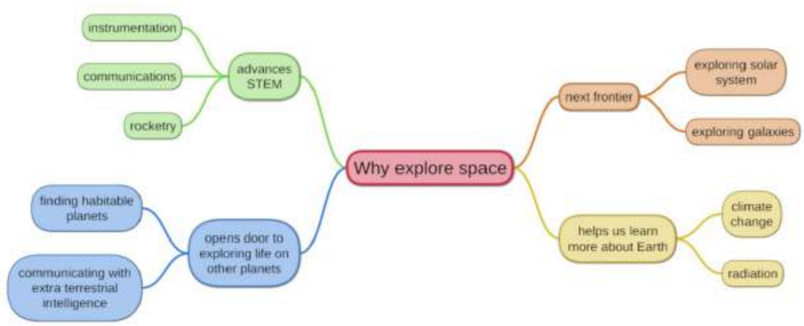
Desired Student Outcome Students agree on a special name for their space exploration class

Concept and idea mapping

Did you know? Maps of ideas and understandings can be powerful tools for use in navigating to new levels of knowledge.

Background Concept mapping is a powerful tool for quickly representing your knowledge of a topic. It can also lead to the identification of areas where you may need to find more information. An excellent article for teachers on concept mapping can be found here: cmap.ihmc.us/docs/theory-of-concept-maps

For example here is a simple idea map based on the question "Why explore space?"



This map was created on my Chromebook using the miMind app.

Activity Here are some topics you might want to address: Where do you live? Do you have any pets? What are your hobbies? What kinds of music do you like? What are your favorite foods?

You can add to this list of topics as you build your map using the Cmap software provided to you as part of this program. Keep your map handy because you will use it in the next activity.

Duration 1 week

Resources Cmap (cmap.ihmc.us) or other concept mapping software on the user's computer, or use of a flipchart or whiteboard that can be photographed for archival purposes. On Chromebooks, you might use the miMind app.

Benchmarks TL

Desired Student Outcome Students learn how to build and evaluate concept maps and how to use specialized software to facilitate this process.

Design a mission patch

Did you know? One of the first things astronauts do each time they are assigned a mission is to collaboratively design a “mission patch” that embodies the spirit, purpose, and vision of their mission. Designing the patch is not merely a "feel-good" exercise for the astronauts - it's a vital part of creating each mission's focus and sense of team identity. Each patch also plays an important role in internal NASA culture and builds the historical record.

Background Patches play an important symbolic role on space projects, and encapsulate, graphically, the unique qualities of the mission. You can get a sense of this by looking at existing mission patches used for NASA projects.

Apollo patch (NASA)

Activity To start your activity, design a personal patch that represents you! Based on the concept map of yourself you did in the previous activity, explore the images that best represent your interests and identity, and incorporate these into a patch design. As you design your own patch, consider: How will the patch be used? What colors should you use? What symbols on your patch best convey the ideas behind your class mission? If your patch will be embroidered, how many colors will be required?

Once you have completed this activity, design a mission patch that reflects the mission of this year's Space Exploration activity. Your focus will be on the Earth, Moon, and everything in between. What symbols do you think best represent the ideas of what you would like to explore this year in this program? How should these symbols be balanced to create an attractive patch?

When your patch is completed, print it on thermal transfer paper and iron it onto a T-shirt you can wear in class. Be prepared to explain what every element of your patch conveys.

Duration 1 week

Resources https://history.nasa.gov/mission_patches.html

Benchmarks TAHL

Desired Student Outcome Students will design a patch reflective of their class's name that embodies the values, hopes and expectations of the students for the year's activities.

Software for this curriculum

Did you know? Your home computer is probably more powerful than the computers used on the initial missions to the Moon.

Background Students can find the software they need online. Chromebook users have an increasing number of options. For those using laptops, the software we've chosen is free and they all have versions that work with whichever computer platforms students have (Mac, Windows, Linux) so there is no incompatibilities between projects started on one system and completed on another.

Activity The goal is to install the software and learn enough about it to use it as needed on a variety of projects throughout the year. Some titles you might find interesting include:

- Concept or idea mapping tool: Cmap (cmap.ihmc.us)
  the miMind app for Chromebooks
- Office Suite: LibreOffice (www.libreoffice.org/discover/libreoffice/) Google Docs
- Image editor: GIMP (www.gimp.org/)
- Image analyzer: ImageJ (imagej.nih.gov/ij/)
- Earth map: GoogleEarth (www.google.com/earth/)
- Orbit and other simulators: PhET (phet.colorado.edu/)
- Mathematical modeling and plotting software: MathTrax (prime.jsc.nasa.gov/mathtrax/)
- Space exploration tool: Celestia (celestia.space)

Download and experiment with the various software packages. If you like other tools better, feel free to use them. If a particular piece of software is needed for a project, it will be referenced in the project.

Duration 1 week

Resources Downloaded software

Benchmarks T

Desired Student Outcome Students will be comfortable with the software tools used in these activities.

How is information found?

Did you know? Some people still believe that, if something is published, it must be true.

Background The Internet is a popular tool for finding information. It has become so popular that some people think that it is the only place to look for material, and, if it can't be found there, it must not exist. This is dangerous thinking. There is a lot of valuable information in print resources that will likely never make it to the Internet. Also, sometimes talking with experts can be the fastest and most reliable way to gather some information. If you are trying to find something that no one else seems to know, then you may have uncovered a question that requires original research on your part. This kind of research is what STEM experts do all the time.

Activity What are your favorite sources of information? How do you verify that what you have found is reliable? What would you do if you found conflicting information on a topic you are exploring? What strategies can you use to see which references are more accurate?

In doing a research project, have you ever encountered interesting information that has nothing to do with your original research question? If so, how do you keep track of what you found in case you need it later?

The topic of this program is space exploration. What websites are likely to have good information in this area? Do you know any people who you could contact to get information as you need it?

Many of the projects in this program include reference materials as a starting guide. Are you comfortable moving beyond the listed references to see what else you can find? If not, what do you need to do in order to improve your own research skills?

Duration 1 week

Resources "The Right Stuff" document on information gathering strategies found on the student page at www.tcse-k12.com

Benchmarks STEMLA

Desired Student Outcome Students learn that the Internet is just one of many powerful research tools, that some information sources may be incorrect, and that some research questions require original research or experiments in order to find answers.

Units of measure

Did you know? The United States is the last major country to still use the "English" measuring system. Most countries have switched to the Metric system, including the United Kingdom, where our system of measurement was developed. U.S. Scientists, however, use the Metric system to comply with international standards.

Background The metric system has been adopted worldwide for scientific measurement. Residents of the United States are generally more familiar with the English system of measurement (inches, pounds, etc.) which are cumbersome to use. For example, there are 12 inches in a foot and three feet in a yard. In the metric system, length is measured in meters. There are 100 centimeters in a meter, ten millimeters in a centimeter and 1000 meters in a kilometer. Once the core units are established, Greek prefixes generally are used to define measurements larger than the basic measurement (*e.g.*, kilo, mega), and Latin prefixes are used to define measurements smaller than the basic measurement (*e.g.*, centi, milli).

You can make a conversion table that lets you convert English units of measure to metric, and also find the value to some important physical constants used during the year. This sheet also shows scientific representation of large and small numbers using powers of ten (*e.g.*, 1000 is 10^3, .0000001 is 10^{-6}). This notation system makes it easy to work with numbers without making decimal errors.

Activity Why did the metric system become popular? What challenges do you face in learning how to use this system of measurement?

Watch the Powers of Ten video at the site listed below. Which part seemed most compelling to you (the region larger than human scale, or the region smaller than human scale)? Using a digital camera, how many powers of ten (in size) can you photograph? Can you create a slideshow that shows your own powers of ten pictures?

Duration 2 weeks

Resources
https://www.eamesoffice.com/the-work/powers-of-ten/

Benchmarks SM

Desired Student Outcome Students develop a familiarity with the metric system of measurement, and are provided with a table of constants and other data they will use during this year.

Creating presentations

Did you know? It is reported that many people fear public speaking more than death.

Background Scientists and engineers need to present their ideas clearly to others. These presentations not only inform, they inspire. This activity will prepare you to create and give dynamic presentations to groups of any size.

Activity How can you hold your audience's attention? What role do photographic images play in your presentation? How much (or little) text do you think is appropriate? Should your presentation be different for small audiences than it is for larger groups? Are there presentations that are best given without any visual aids? Can you express the main points of your presentation in a minute?

On the technical side, what tools or props can make your presentation even more compelling?

Duration 1 week

Resources LibreOffice software on a user's computer or Google Docs on Chromebooks.

Benchmarks TLA

Desired Student Outcome Students learn how to prepare and give concise and engaging presentations of their own work using a variety of tools and props.

Why explore space?

The ancient Greeks told the story of Icarus who glued wings to his arms with wax so he could escape from Crete by flying. He flew near the Sun, but the heat soon melted the wax and he fell into the sea. This ancient story was one of the early tales of space travel, a topic that has captured the interest of people since they first gazed at the stars.

By the 1800's, authors were writing science fiction stories about space travel, capturing the imagination of some who went on to create inventions that ultimately led to our ability to launch ourselves into space.

The activities in this theme let students explore the history of space exploration through the eyes of science fiction authors and others who wrote about this topic many years before our first rockets were sent skyward. The goal is to develop an understanding of the motivation underpinning space exploration, the topic of the entire course.

Mythology and science fiction

Did you know? Several pioneers of rocketry and space travel were inspired to pursue their interests in these areas by an early interest in science fiction.

Background Fascination with space travel has been a driving force for fiction authors all over the world. Well over a century ago, in 1865, French author Jules Verne wrote a story of an American flight to the Moon (From the Earth to the Moon). (This story and its companion, 'Round the Moon, can be downloaded from the Project Gutenberg website.)

An early science fiction movie on this topic was created by George Méliès (A Trip to the Moon, 1902,), starting the tradition of science fiction movies that continues to the present time.

Activity Greek mythology tells of Icarus' flight to the Sun. This story is thousands of years old. What other myths can you find that relate to travel away from our planet? Why do you suppose ancient people thought about traveling away from our planet?

Watch the Trip to the Moon film and/or read Jules Verne's novels on the topic. What parts of the stories made sense? What parts were wrong? Why do you think the stories had errors? If you were making a film on the topic of travel to the Moon today, how would it be different from what you read/saw in the materials mentioned above? Can you create an outline for your own production? Can you make a short film based on your story?

If you have seen any recent science fiction films based on space exploration, how accurately do you think they represent space travel? What films or stories about space are your favorites? Why do you like them?

Duration 2 weeks

Resources http://www.gutenberg.org/wiki/Main_Page, for books by Jules Verne

https://www.youtube.com/watch?v=xLVChRVfZ74 (A Trip to the Moon)

Benchmarks STEML

Desired Student Outcome Students learn about science fiction as a motivator for science exploration and will find errors in early science fiction and create their own story about travel from the Earth to the Moon and evaluate the accuracy and subject of two pioneering films on the subject.

Why do humans explore new territories?

Did you know? Some researchers think people explore the unknown because they enjoy pushing themselves to their limits.

Background It seems that we have always had people among us who have a quest to explore the unknown, even if the dangers are great. Early explorers of the seas were afraid of falling off the edge of the Earth. And yet, the quest for exploration continues. Now that adventure has moved us into space.

Activity This quest to explore the unknown has driven us for thousands of years. Why do you suppose that is? If you could explore anything or anywhere, what would you choose? How concerned are you for your own safety in your quest? How about the safety of others you might encourage to come with you? What would you hope to find or do if your quest is successful?

Every area has some resources that make it unique. Few nations seem to be completely self-sufficient today. For example, oil is found in some parts of the world, but not in others.

What kinds of resources (food, minerals, medicines, etc.) drive exploration of new territories? Since all resources are finite, what impact does this have on exploration? What kinds of relationships are built between the explorers and the people who live in the region being explored? Have these relationships changed over time? Why or why not?

What are some of the resources we are searching for today? Can space exploration assist in these searches? Why or why not?

Duration 2 weeks

Resources General resources both on- and off-line

Benchmarks SH

Desired Student Outcome Students find that natural resources are unequally distributed, and examine how best to look for these resources, taking into consideration the needs and desires of the people who live in the areas being explored.

Why explore space?

Did you know? Columbus apparently had no idea he had found a new continent. He was trying to find an alternate route to India, and had miscalculated the size of the Earth.

Background Compare and contrast the mission of Christopher Columbus with that of one of the first astronauts in space.

Build a timeline of each journey, information about the provisions for each mission, and the mission itself. Write a summary of each exploration.

Activity Which of the two journeys was most successful? Which was the most dangerous? Why? What were the challenges faced by Columbus? How were they overcome? What challenges were faced by Yuri Gagarin, the first Russian cosmonaut? How were these challenges addressed?

Duration 2 weeks

Resources https://www.nasa.gov/stem/foreducators

Benchmarks SEM

Desired Student Outcome Students will develop an understanding and appreciation for the challenge of facing the unknown.

Defining space

Did you know? We are continuing to develop our understanding of space every day through international research projects.

Our universe is filled with myriad galaxies (NASA)

Background Think about the definitions of space and outer space you find in dictionaries and in Wikipedia. Read, review and think about these definitions. Create a presentation to share either these definitions or your own definition.

Activity Have our definitions of "space" changed since the launch of the first satellite, Sputnik? How do we distinguish between the domain of space near the Earth and what we might call "deep space"?

Duration 1 week

Resources www.wikipedia.org

Benchmarks STM

Desired Student Outcome Students will look for evidence , models, explorations of the topics of space and outer space and then construct one's own definition of space and outer space.

Why is space exploration an international topic?

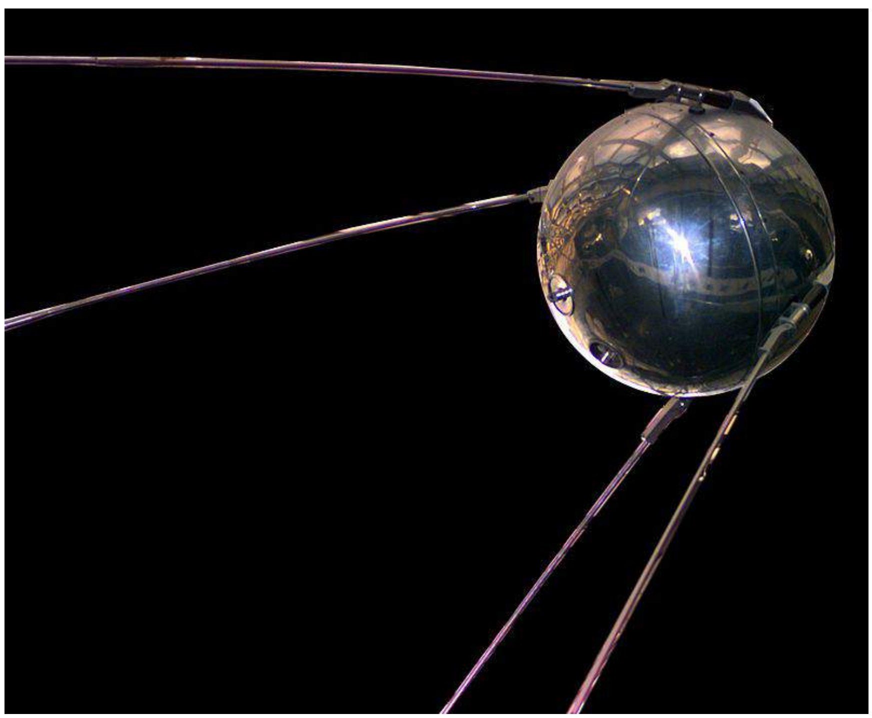
The former Soviet Union was the first nation to launch a satellite into orbit, followed by the United States. For many years, the rivalry between the US and the Soviet Union resulted in both nations expanding their space programs to include manned flight, travel to the Moon, etc. If those early ventures were driven by an adversarial relationship between the two nations, today's international efforts are far more collaborative. As a result, today space exploration is a truly international endeavor. The International Space Station (ISS), for example, has components built or designed by seventeen countries, and research facilities have been manned by people from sixteen nations since it was first assembled.

This topic examines the international aspect of space exploration. Is this international endeavor designed to demonstrate that, no matter what countries we are from, we are all "Earthlings"? Is the international focus collaborative, competitive, or a combination of both? Has international space exploration been viewed differently at different times? How can the peaceful exploration of space by Earthlings be insured?

What are the different motivations for space exploration?

Did you know? In the 1950's, many were fearful that the United States and Soviet Union would launch rockets with nuclear warheads at each other from space.

Background This activity examines multiple motivations for national space exploration efforts over time and region, starting with Sputnik in 1957, and reaching to the rich international efforts of today.



Sputnik: the first satellite in orbit (NASA)

Activity Why do you think the United States wanted to explore space in the 1950's? Have those reasons changed over time? If so, how?

What about other countries? How many countries have active space exploration programs today? Many programs today are shared efforts among several countries. Why do you think this is? What are the benefits and challenges of shared space projects?

Duration 2 weeks

Resources Sputnik Mania film (listed on Amazon Prime), General internet resources

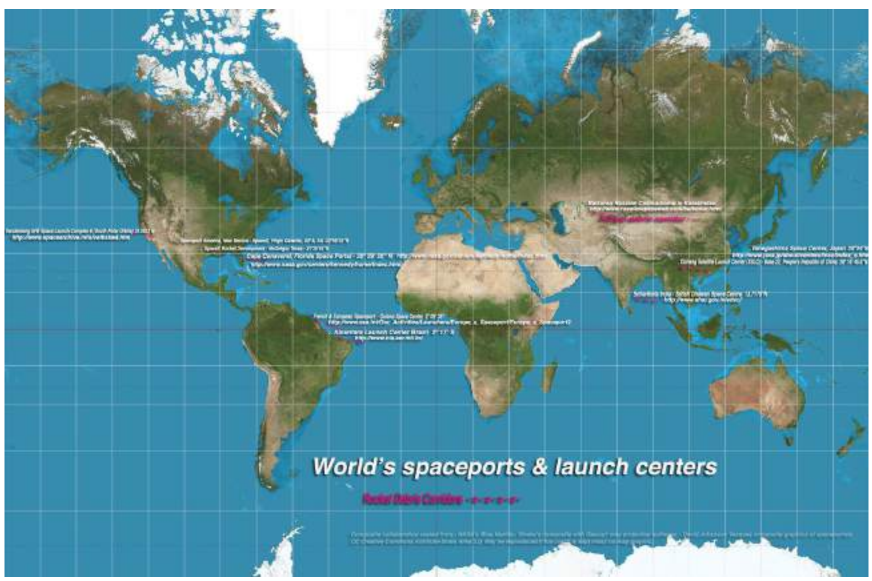
Benchmarks STEMH

Desired Student Outcome Students demonstrate knowledge that, at different times in history, and in different countries, there have been several motivations for exploring space based on national interest.

Where are the best rocket launch sites located?

Did you know? Brazil lies on both sides of the equator, making it easy to have a launch site for rockets right on the equator itself.

Background This activity explores existing and ideal launch sites for rockets of various types. The choice of launch site has to be based on several criteria. Not every country is able to launch their rockets from their own land, so they arrange for their projects to be launched from other countries.



Spaceports (NASA)

Activity What are the factors that make a location perfect for launching rockets into space? (Consider weather, safety, nature of the mission, etc.) What types of space projects benefit from having rockets launched from the equator? When rockets are launched, what direction do they travel? Is there a reason for sending rockets in one direction around the Earth?

Duration 1 week

Resources Internet research

Benchmarks STEM

Desired Student Outcome Students know that rocket launch sites are determined by several factors ranging from safety to the nature of the mission itself.

What is the impact of space exploration?

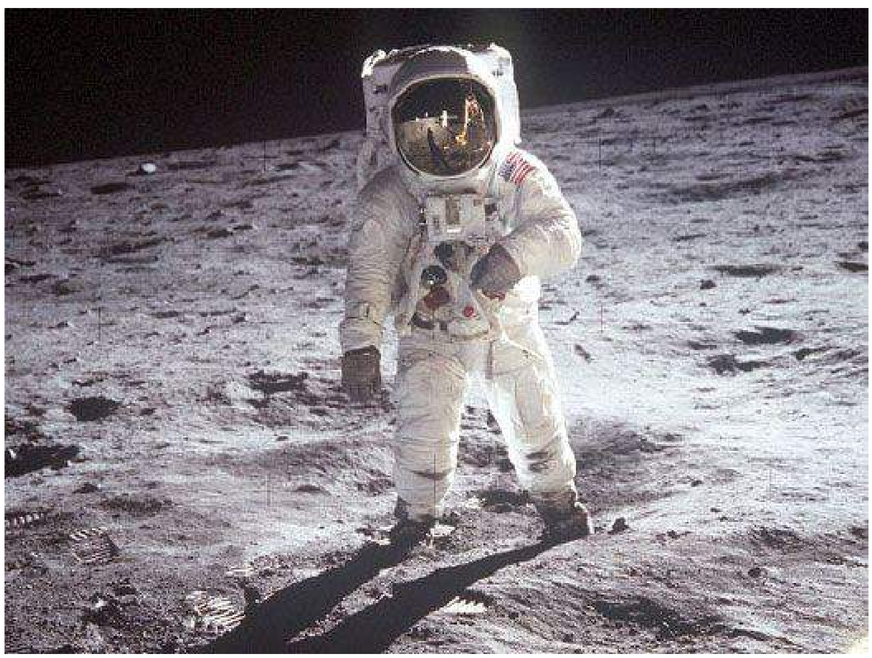
The exploration of space has an impact on many areas ranging from pure science to practical engineering. In addition to building an understanding of the worlds apart from our own, space exploration has helped us develop greater knowledge and understanding of our own planet.

This topic explores these impacts in a variety of projects related to "big picture" areas that can affect policy decisions for continued explorations.

What is the impact of space exploration on society?

Did you know? When Sputnik was launched, some leaders in the United States felt we had lost the race to excellence to the Soviet Union.

Background Pioneering achievements in space exploration have always brought positive international attention to the countries that achieved them. This was true for the Soviet Union with the launch of Sputnik, and for the US when Neil Armstrong and Buzz Aldrin took the first steps on the Moon.



Buzz Aldrin on the moon (NASA)

Activity Now that more nations have launched satellites and other objects into space, is national pride much of a factor today? How aware are you of innovations or achievements in space exploration that come from other nations?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students know the societal impact of space exploration based on case studies.

What is the environmental impact of space exploration?

Did you know? Much of what we now know about global climate change comes from measurements made from Earth-orbiting satellites.

Background Spacecraft require a lot of fuel to be launched from the Earth. There are clearly some environmental issues associated with space exploration. At the same time, we can study environmental challenges on our planet in unique ways from space to increase our understanding of planetary changes, and these observations can be used to reinforce decisions to protect our environment.

Activity What kinds of environmental information can we gather from space that would have the greatest impact in getting people to be more aware of the challenges we face? What information can be measured over a period of years to see progress or continued challenges to our environment? How compelling do you find some of the information you have found?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students know how space exploration both impacts the environment, and provides us with information that helps us monitor and preserve the environment.

What is the impact of space exploration on history?

Did you know? History has always been shaped by discoveries of new lands and territories.

Background Humans have long been curious about lands beyond their own. Tales of early exploration to new areas go back thousands of years. The conquests of new lands has long been a force shaping history, especially in the times of empire building and the colonization of the western hemisphere by Europe. Now that we are landing craft on "new" lands (such as the Phoenix mission to Mars), we might well think about how these explorations may shape the history of the future.

Activity What are the historical consequences of space exploration? Is it possible that, as we explore worlds beyond our own, we will develop a better understanding of our own planet? What kinds of things might we discover that would have a lasting impact on our own lives, governments, and relationships with people around the world?

Duration 1 week

Resources General internet research

Benchmarks STEHL

Desired Student Outcome Students will develop an understanding that our exploration of new worlds can shape our relationships with the people of our own world, and that these insights can shape the course of history.

What is the impact of space exploration on the economy?

Did you know? The U.S spends about 22.6 billion dollars a year on space exploration and that amount increases every year.

Background Without doubt, there are a lot of challenges facing us right on our own planet, and not enough money to address many of these challenges in the manner we might like. Even so, we are choosing to spend some money on our space program, and other countries are doing the same. While the benefits that come from scientific knowledge are important, it is worth exploring what impact (positive or negative) space exploration has on our economy.

Activity Weather forecasts are aided by satellite imagery. What are the potential economic benefits of accurate weather forecasts? Do these benefits exceed the costs?

Can measurements of the Earth's conditions from space be used to identify sources of valuable natural resources? What kinds of resources can be found through this method?

Many health and technology techniques are a byproduct of space exploration programs. What impact do these developments have on our economy?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students are able to balance the cost of space programs against the benefits of these programs to our economy.

What are the benefits of space exploration?

The television weatherman may not always be accurate in predicting the next-day's weather, but the use of numerous weather satellites has provided us with far better information than was available to our grandparents. This is especially true when exploring the path of hurricanes and other major storms.

Beyond these mundane topics, the benefits of space exploration are numerous. In addition to scientific discoveries that help us understand the universe of which we all a part, space exploration also results in breakthroughs in engineering that impact everything from medical equipment, exercise machines, and numerous other things we take for granted on Earth.

The projects in this topic explore these and other benefits of space exploration.

What are the benefits of space exploration in science?

Did you know? Many scientists devote their careers to exploring subjects that are so difficult, that they may never find an ultimate answer to the questions they are asking.

Background Since 1957, we on Earth have made tremendous advances in the development and understanding of science as a result of space exploration. Areas as diverse as astronomy, quantum physics, and medicine have all benefited from this work.

Activity Using information found on the internet and elsewhere, make a timeline of significant scientific discoveries that have come about because of our explorations of space. What areas of study have benefited the most? Which ones do you find most interesting, personally? What questions do you think scientists should try to answer next through their research? If you were to design an experiment to study one of the areas you found, what would you measure?

Is there something you found that scientists once believed was true, but that current research has cast into doubt? Are there scientific questions that seem to still be too complex to answer?

Duration 1 week

Resources General internet research

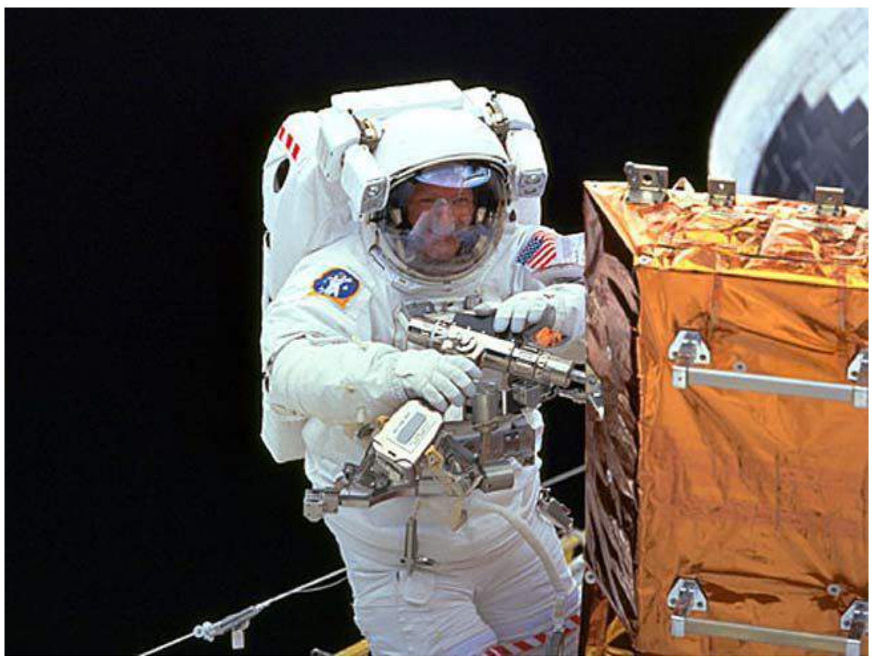
Benchmarks S

Desired Student Outcome Students will find some of the benefits of space exploration in the continued advancements of science. They will see that some old beliefs are wrong, some are right, and that many unexpected discoveries have been made in the past 50 years.

What are the benefits of space exploration in engineering?

Did you know? The ability to cover thin plastic sheeting with a reflective metal layer was essential for the space program, and also has tremendous applications here on Earth.

Background A wide variety of low and high technology structures and tools are needed in any exploration of space. Some of these constructions are based on very simple concepts (springs, levers, etc.) and some have resulted in the advancement of technology beyond anything we might have thought of from the perspective of Earth.



Astronaut using tools during spacewalk (NASA)

Activity Make a list of a variety of engineering challenges that face the launch of a satellite into orbit around the Earth. What new tools have been invented? What new materials have been designed? What overall design ideas are important once we have launched something out of our atmosphere?

Of the many inventions required for the space program, what inventions are now in common use on Earth?

Duration 1 week

Resources General internet research

Benchmarks E

Desired Student Outcome Students will see that simple machines have tremendous application in space, along with cutting edge breakthroughs in engineering. They will also see how technologies developed originally for the space program have great value here on Earth as well.

Who should own scientific knowledge?

Did you know? Most scientific research is published internationally so other scientists can build on the work of others as they expand our understanding of the Universe.

Background Space exploration is expensive. It might make sense that the country that pays for the research retains all the discoveries for their own benefit. At the same time, scientists generally share the results of their work internationally with peers. While designed objects (the result of engineering) are generally owned by the inventors (or licensed to others), scientific knowledge is discovered. Breakthroughs in science largely consist of decoding information relating to processes that occur naturally. In this case the concept of "ownership" becomes clouded. As a result, many scientists are content to have their names associated with their discoveries, but the discoveries are seen as belonging to everyone.

Activity The ownership of scientific knowledge is a topic of heated debate. Research this topic yourself and then form your own opinions illustrated with examples from your research. Should discoverers "own" the rights to their discoveries? If so, how can commercial value be assigned to the discovery? What is being exchanged that has monetary value?

Look at this topic from both sides. There is no question that some scientific knowledge can have great commercial value. If this knowledge should be sold, how would prices be set? Would ownership go to the first people to make the discovery? What if several people make the same discovery at the same time? What do you think is the most fair way to treat the ownership of scientific knowledge?

Duration 1 week

Resources General internet research

Benchmarks S

Desired Student Outcome Students will learn that the topic of the ownership of scientific breakthroughs is a hotly contested subject, with staunch advocates on both sides of the question. They will also formulate their own opinions on this topic.

What spinoffs has the space exploration program produced?

Did you know? Since 1958, Congress has asked NASA to provide reports on technologies developed as a result of the program. Every year, numerous developments created in support of the space exploration program find commercial application in everyday life.

Background Whether it is a tool for cleaning up oil spills, a device to remove acne, a new surgical procedure, "spinoffs" from NASA and other space agencies are impacting life right here on Earth. Each year, NASA publishes a report listing the products, processes, and techniques that were originally developed by them, but have found practical application in contemporary life.

Activity Using the site listed below, download and read the summaries of breakthrough spinoffs developed as a result of NASA work for the previous few years. Did you come across anything that has already had an impact on your life? Are you surprised by the wide range of application areas for some of these developments? Do you think some of these spinoffs are important enough to justify the space exploration program itself?

Duration 1 week

Resources https://spinoff.nasa.gov/

Benchmarks STEM

Desired Student Outcome Students will find that there are many products in common use today that came about as a result of a development needed for the space exploration program.

How and why do we live and work in space?

Just as the early sea-faring explorers established colonies in new lands, space explorers are living and working in space. This topic explores how and why we choose to work far away from our home planet, along with the benefits and challenges of this work.

Instead of encountering foreign people's, today's space explorers are encountering environmental challenges of great magnitude, including the apparent loss of gravitational attraction, harsh working conditions, strange foods, and other challenges that are offset by the amazing opportunity to explore topics that can not be explored on the Earth.

What is the nature of gravity?

Did you know? The metric unit of force is named after the man who did the most to help us understand gravity, Sir Isaac Newton. One Newton of force happens to be roughly equal to the force exerted by gravity on a small apple at sea level.

Background Just as we live with the consequences every day, gravity applies universally, and had to be well understood before we could travel to space.

The force of gravity between one object and another depends on the mass of the two objects (usually measured in grams) and the distance between the centers of these objects (usually measured in meters). The force (measured in Newtons) is reflected in the equation:

$$F = \frac{Gm_1 m_2}{r^2}$$

where G is the universal gravitational constant (6.637300 x 10^{-11} m^3 kg^{-1} sec^{-2}, m_1 and m_2 are the masses of the two objects (in kilograms), and r is the distance between the centers of these two masses measured in meters.

Activity Look up the mass and radius of the Earth and use this equation to find the force your body exerts on the Earth at sea level. Build a spreadsheet to do this calculation and find the force exerted on the Earth by the students in your class. If you have measured your weight in pounds (w), the conversion to kilograms is: $m = 0.45359237w$.

While we know a lot about how the force of gravity affects us, and complicates space travel, the origins of gravitational force are fairly complex.

What would your life be like if you were not held down by the force of gravity? What things would be easier? What things would be more difficult? If there was a "gravity" switch you could use to turn gravity on and off, when would you use it?

Duration 1 week

Resources http://sten.astronomycafe.net/gravity/, Wikipedia, www.wikipedia.org

Benchmarks SM

Desired Student Outcome Students will calculate the force of gravity on their bodies, and also speculate on what life would be like if gravity could be switched on and off.

How do we balance out the force of gravity?

Did you know? Many people who experience weightlessness in simulation flights experience nausea, probably due to anxiety.

Background A characteristic of space flight is weightlessness. While we are still subject to the force of gravity, our spacecraft experiences the same force, and people inside the craft "float" from place to place, instead of being held in place by the force of our bodies against the floor or walls of the spacecraft. This is sometimes called a "zero-g" environment since it appears that the body does not experience any gravitational force.

NASA Trainees riding the "vomit comet" aircraft

Obviously, it is important for astronauts to learn how to live and work in this environment before they are launched into space. Special airplane flights allow people to experience short periods (about 30 seconds) of weightlessness. This is accomplished by flying the plane upwards at a 45 degree angle, and then entering a parabolic flight path that simulates free-fall. During this portion of the flight, everyone and anything on board that is not strapped down floats. Before the plane loses too much altitude, the pilot pulls the plane out of the falling path and can repeat the process several times before landing.

Activity Have you ever taken an amusement park ride where you felt like you were falling? What did that feel like to you? Can you imagine working for long periods of time inside a spacecraft where you did not experience the familiar pull of gravity on your body?

What would be the most interesting thing to you in experiencing weightlessness? What would be the most challenging?

You can build a device that lets you experiment with microgravity for short periods of time to see its effect on fluid drops, magnets, etc. These experiments are done with a drop tower. If you have the resources, build one of these towers and try some experiments.

What experiments can you design that could be conducted in the drop tower? Your experiments will be pretty short – less than a second. Still that may be enough time for you to see just how strangely some things behave when gravity is not holding them in place.

Duration 1 week

Resources General internet research

Benchmarks SEM

Desired Student Outcome Students will learn how gravitational forces are balanced out in simulations of space flight, and some of the effects of weightlessness on the human body.

What is the impact of microgravity on our bodies?

Did you know? Our bodies adapt to weightlessness in a variety of ways.

Background We are so used to feeling our bodies pressed down to the Earth we have a hard time thinking about what would happen if this force was not present. It turns out that our bodies adjust to gravitational forces in several ways, and this becomes an important consideration for people who are living and working in space for extended periods.

Activity What do you think happens to your body when it is no longer subjected to the gravitational pull of the Earth?

Do the experiment shown in the NASA resource listed below.

What results did you get? What do you think the long-term effects of reduced gravity might be on your body? How can space suit design and exercise compensate for the changes you body experiences?

Duration 1 week

Resources
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Get_a_Leg_Up_Activity.html

Benchmarks SEM

Desired Student Outcome Students simulate the effect of microgravity on their bodies and observe the results. They also develop ideas on how to balance out these effects during missions in space.

Space travel and nutrition

Did you know? When astronauts go into space, they have to bring all their food and water with them. The weight of all these supplies can be greater than the weight of the astronauts themselves.

Background Nutrition has played a critical role throughout the history of exploration, and space exploration is no exception. While a one- to two-week flight aboard the Space Shuttle might be analogous to a camping trip, adequate nutrition is absolutely critical when spending several months aboard the International Space Station or several years on a mission to another planet. To ensure adequate nutrition, space-nutrition specialists must know how much of various individual nutrients astronauts need, and these nutrients must be available in the spaceflight food system. To complicate matters, spaceflight nutritional requirements are influenced by many of the physiological changes that occur during spaceflight.

Activity What foods did the early astronauts get as a diet? Over time, how did NASA change the diets of the astronauts and why? How can food be cooked in space? Does the definition of a "balanced diet" change when living and working in space? Explore the food pyramid in the context of astronaut dietary needs. What foods make the most sense for use away from the Earth?

In the future, what kinds of foods should be sent to the space station? In a colony on the Moon, what foods could astronauts and colonists grow?

Duration 1 week

Resources Food pyramid information: https://en.wikipedia.org/wiki/Food_pyramid_(nutrition)

http://youtube.com/watch?v=zkdZb6K55-U

http://youtube.com/watch?v=9lMjY4RdSaw

http://youtube.com/watch?v=KPZ8HHRR1A0&feature=related

http://youtube.com/watch?v=Fg1RMEIP6i4&feature=related

http://youtube.com/watch?v=GK_hK2k4As0&feature=related

Benchmarks SM

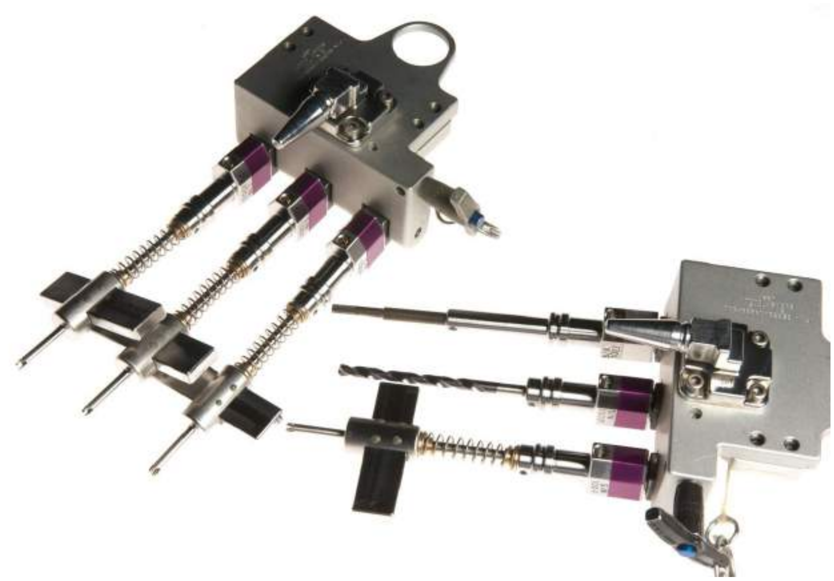
Desired Student Outcome Students will explore nutrition in the lives of astronauts who may be gone from the Earth for a long time.

Designing tools for use in microgravity

Did you know? Simple tools like screwdrivers and hammers may need to be redesigned for use in space.

Background You may be familiar with a variety of hand and power tools in your own home – screwdrivers, pliers, hammers, drills, saws, etc. Each of these tools is designed to be used easily and safely, but they all are designed on the assumption you will be using them right here on Earth. Once you no longer have a gravitational force holding you in place, you may find that, when turning a screwdriver, your body turns in the opposite direction as well. Hitting something with a hammer can cause your body to bounce away from the object you are hitting.

There are lots of challenges to designing tools that can be used in space.



Tools used in repairing the Hubble Space Telescope (NASA)

Activity Most hand tools are based on the simple machines you may have studied in physics classes: especially levers and inclined planes. Power tools are based on the same ideas, with electric motors providing more force that you can easily provide yourself.

Think about what forces act on a screwdriver when it is used. Remember that any force you apply is returned to you as well. Is it possible to design a screwdriver that works better in a microgravity environment than the tools we use here on Earth?

How about other tools (drills, etc.)? How might these be designed to be most useful in space?

Because of the vacuum of space, electron beam welding is a very good option for joining metal parts together permanently. The reference below describes the process. What kinds of materials can be welded? Why is welding a good option for assembling structures in space?

Duration 1 week

Resources
https://spaceplace.nasa.gov/story-space-tools/en/

Benchmarks STEM

Desired Student Outcome Students will learn about a variety of tools that are uniquely suited for use in space.

Building items in a spacecraft

Did you know? The International Space Station (ISS) has a 3D printer on board to let astronauts build parts they need to make minor repairs or modifications during a mission. This capability will be even more important as we send people to other planets.

Background A trip to Mars will take at least six months each way. During a voyage of this length, it is possible that some parts of the craft will require some minor repairs. For example, a small piece of space debris might poke a hole in the craft housing that will require some patching in order to complete the mission. Because it is impossible to know what specific parts may need repair, NASA is planning to use an on-board 3D printer on which small parts can be fabricated.

3D printer on the ISS (NASA)

Activity Imagine a part of a spacecraft that might need to be repaired in flight and design a replacement part that you can make on the 3D printer at school. This can be something as simple as a plug for a hole, to a bracket that holds a piece of equipment in place. In your design, take into consideration the various forces your part may need to withstand, understanding that some of these forces may be different than those experienced by the same parts if they were used on Earth.

Duration 1-2 weeks

Resources 3D design tools like Tinkercad and BlocksCAD. These tools run on any browser-based computer, including Chromebooks.

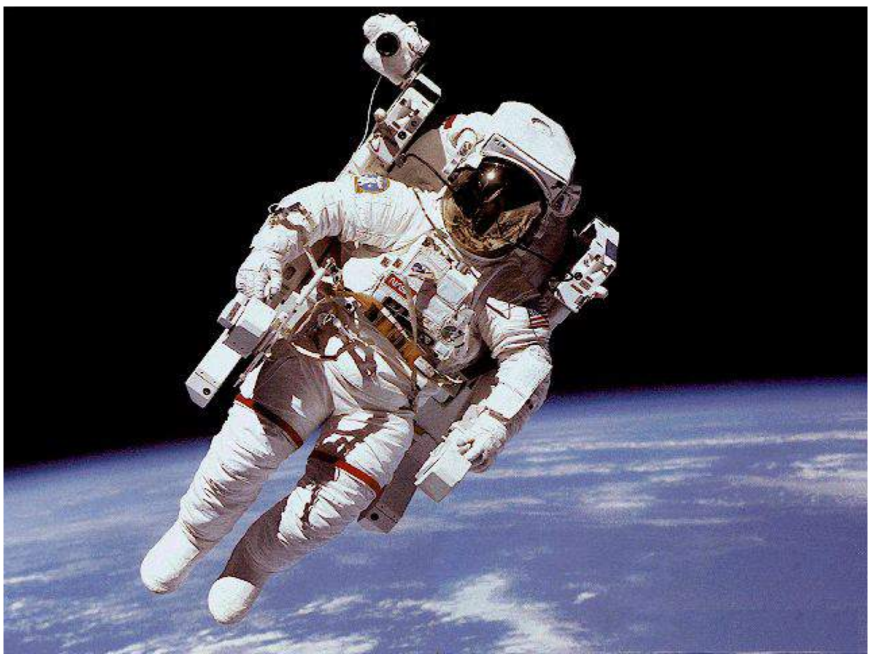
Benchmarks STEM

Desired Student Outcome Students will gain problem-solving and design skills they can apply in many areas.

Space suit design

Did you know? Space suits provide a personal environment that is comfortable and safe for astronauts working outside their spacecraft.

Background Space suits protect the body from the vacuum and radiation found in space, but can also inhibit motion.



Suited astronaut during a spacewalk (NASA)

Activity What are some of the protections that all space suits need to provide? Think about everything you can imagine experiencing in space – vacuum, temperature extremes, etc. Once you have a list of protections, how can these be achieved while still allowing the astronaut to move freely?

During extravehicular activities (EVA's) astronauts need mobility to perform repairs.

To see what challenges they might face, build a model airplane using Lego blocks while wearing quilted oven mitts. What made this task challenging? Based on your observations, can you design better gloves that meet the requirements of use in the vacuum of space. What other parts of the suit might you design?

Duration 1 week

Resources Pair of quilted fabric oven mitts, Lego blocks

Benchmarks SE

Desired Student Outcome Students will develop an appreciation for the difficulty of doing precise work while wearing a spacesuit, and will explore the challenges of designing a space suit design that overcomes some of these challenges.

Why space telescopes make sense

Did you know? One of the great challenges faced by many Earth-based telescopes is "light pollution," atmospheric scattering of light from nearby cities.

Background Spaced-based telescopes are amazingly expensive to launch and repair. They are also limited in size, and have to be capable of adjusting themselves. Yet, ever since the Hubble Space Telescope started sending amazing images to Earth, the benefits of space telescopes have been obvious. Now there are several popular space telescopes, with more being planned for the future.

Hubble space telescope (NASA)

Earth-based telescopes are still used extensively, and there remain many discoveries to be made with these devices. The ability to perform more refined experiments from space, however, has tremendous implications for the advancement of astronomy.

Activity What are the challenges that limit the utility of telescopes located on Earth? How are these challenges overcome by placing telescopes in Space? What are some of the limitations of space-based telescopes? How might these challenges be overcome? Using images from the Hubble Space telescope and from Earth-based telescopes, use photos to compare what we saw without Hubble and the same place with Hubble.

There are several different kinds of telescopes currently in use in space. Why do you suppose this is? What new telescopes are likely to be launched in the coming years? What will we hope to learn from these instruments?

Duration 1 week

Resources General internet research

Benchmarks S

Desired Student Outcome Students will understand the benefits and limitations of space-based telescopes, and learn about future telescopes being designed today.

Why explore the Moon?

The Moon is our closest natural satellite. It is often the most distinguishing object in the night sky, and has been the muse to poets and scientists alike for thousands of years. Because of its close distance to Earth (only 382,500 km), many details of the Moon can be seen with the unaided eye. Even small telescopes reveal amazing details of the Moon.

Once curiosity of the Moon is that it rotates on its axis at the same rate as it revolves around the Earth, so we only get to see one side of this object. In 1959 the Soviet Luna 3 probe photographed the far side and scientists are still not convinced they understand why the far side of the Moon has some different features from the side closest to Earth.

The US sent people to the Moon through the Apollo program in the 1970's, and new lunar missions are in the planning stage now. It is hoped that by understanding more about the moon, we can learn how to explore and colonize other planets such as Mars.

Facing earth

Did you know? Jules Verne's classic books on lunar exploration captured the imagination of many in the years following the US Civil War.

Background When visible, the Moon is the most dominant object in the night sky. It has captured the imagination of people for thousands of years, and it has impacted life on Earth in numerous ways. Our tides, for example, are caused by the gravitational pull of the Moon.

As we look at the Moon from Earth, we always see the same side. This means that, as the Moon rotates around the Earth every 28 days, it revolves on its axis at the same rate. This is not the behavior we see with other celestial objects – our Sun or other planets, for example.

The moon we see at night (NASA)

In fact, we did not even know what the back side of the Moon looked like until the Soviet Luna 3 probe sent back images in 1959.

Activity Why does one side of the Moon always face the Earth? Are there other moons on other planets that demonstrate the same behavior?

Duration 1 week

Resources General internet research

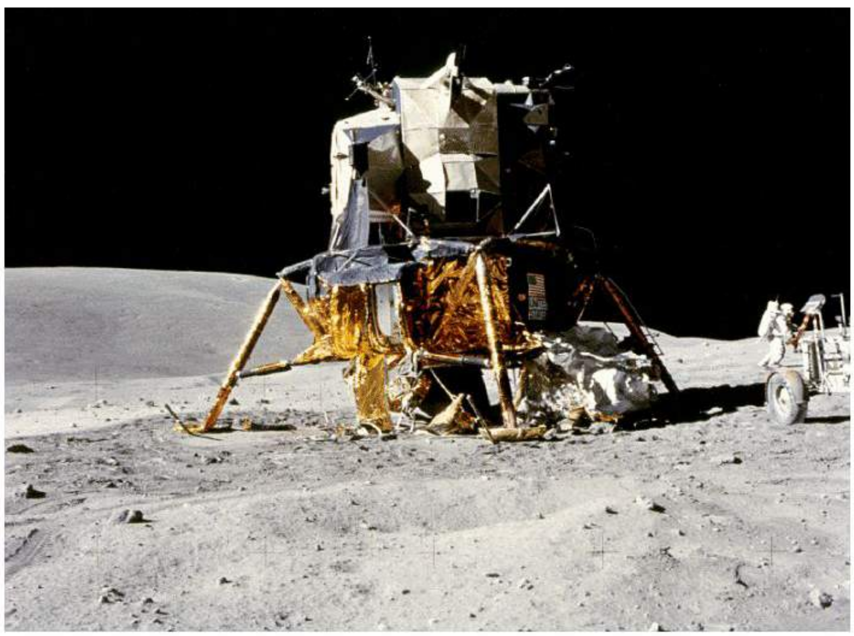
Benchmarks STEM

Desired Student Outcome Students will learn about spin-orbit resonance as a force that locks the Moon's position so that one side always faces the Earth.

First trips to the Moon

Did you know? No nation has sent people to the moon since 1972?

Background The Apollo mission successfully allowed twelve people to walk on the moon. New lunar missions are being planned for early in the next decade.



An Apollo lander on the Moon (NASA)

Activity What was the rationale for the original Apollo missions to the Moon? What discoveries were made as a result of these trips? How did astronauts repair broken equipment after they landed? What was the impact of the photographs taken during these missions? What impact did these trips have on people here on Earth? What were some of the greatest challenges faced by the astronauts during their missions?

How were lunar rovers used? What impact did the low gravitational pull of the moon have on the astronauts?

Duration 2 weeks

Resources Various Apollo resources from www.nasa.gov, the films *In the Shadow of the Moon* and *Apollo 13*, CNN special, *Apollo 11*, https://www.cnn.com/shows/cnn-films.

Benchmarks STEM

Desired Student Outcome Students will learn the challenges and rewards of the original Apollo program.

Returning to the Moon

Did you know? Lunar travel in the next decade will encounter new challenges and open new opportunities.

Background Early explorations here on Earth tended to take place in two stages: discovery, and settlement. For example, the journey of Lewis and Clark exploring a path to the western part of North America set the stage for the pioneering settlers who followed years later. The same thing is happening with our trips to the Moon.

The Apollo project was a series of discovery flights to the Moon, and the Artemis missions being designed now will build on what we learned many years ago, and set the stage to settlement of this desolate body. NASA has identified six lunar exploration themes by asking the question, "Why should we return to the Moon?"

The answers included the following:

- **Human Civilization**
  Extend human presence to the Moon to enable eventual settlement.

- **Scientific Knowledge**
  Pursue scientific activities that address fundamental questions about the history of Earth, the solar system and the universe – and about our place in them.

- **Exploration Preparation**
  Test technologies, systems, flight operations and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.

- **Global Partnerships**
  Provide a challenging, shared and peaceful activity that unites nations in pursuit of common objectives.

- **Economic Expansion**
  Expand Earth's economic sphere, and conduct lunar activities with benefits to life on the home planet.

- **Public Engagement**
  Use a vibrant space exploration program to engage the public, encourage students and help develop the high-tech workforce that will be required to address the challenges of tomorrow.

These six themes build on our previous knowledge, and the design of new spacecraft for the lunar journey is influenced by these objectives.

Artist rendering of the Artemis lander heading to the Moon (NASA)

Activity As you explore our future trips to the Moon (starting with the website listed below), think about some of the challenges that will be faced during these trips. For example, there were far fewer satellites and space junk in orbit around Earth during the Apollo missions than there is today. How would you go about avoiding clutter as you travel through the area most likely to contain objects that could damage your spacecraft?

What kinds of missions would you find most interesting? Would you want to be an early settler on the Moon? Earlier trips took advantage of lunar rovers, special vehicles, to carry astronauts from place to place. What kinds of transport devices are being designed for the next set of trips?

Do you think it is worth the cost and effort to go back to the moon, or do you think we learned enough the first few times we went there?

Duration 1 week

Resources https://www.nasa.gov/specials/artemis/

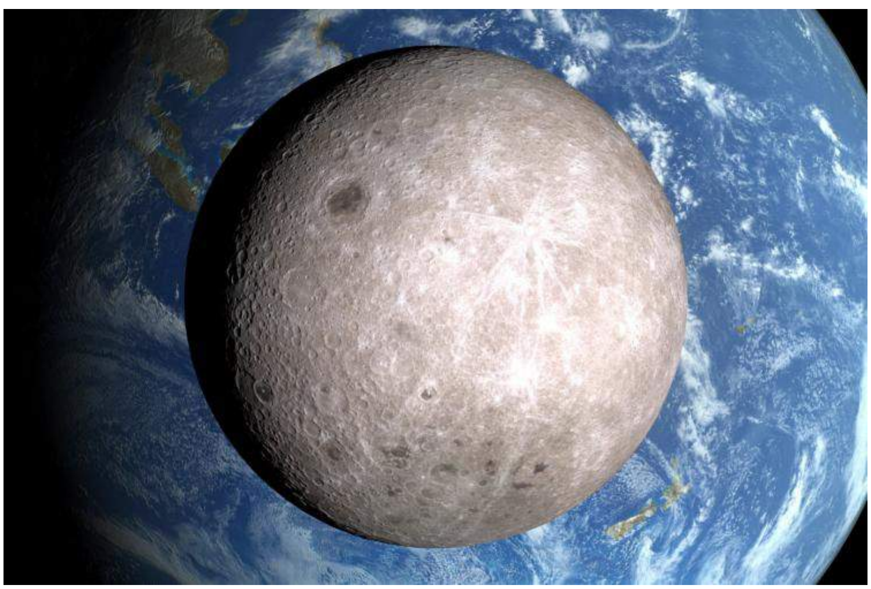
Benchmarks STEM

Desired Student Outcome Students learn about the Constellation project and explore the challenges and opportunities of planned return trips to the Moon.

Exploring the far side of the Moon

Did you know? The far side of the moon is the only place you can never see from the Earth.

Background The Soviet lunar mission, Luna 3, was the first to send back pictures from the far side of the moon. Luna 3's pictures surprised everyone. They showed that the Moon's far side is quite different from the side we can see from Earth. The far side has hardly any low-lying plains. Instead, it's almost totally covered by craters and mountains. Scientists still aren't sure why there should be such a big difference between the Moon's two halves.



Far side of the Moon with Earth in the background (NASA)

Activity You can find high quality images from both sides of the Moon. Look at these on your computer screen. Can you tell which picture represents the side seen from the Earth? What differences between these two images do you see? Can you find any possible explanations for these differences? Scientists have yet to agree as to the cause of the differences between the two sides. Would it be beneficial to explore the far side in person to try and figure this out? If you could go to both sides of the Moon, what experiments would you do to try to figure out the reason for the differences?

Duration 1 week

Resources General internet research

Benchmarks STE

Desired Student Outcome Students observe striking differences between the near and far sides of the Moon and explore current research that tries to explain these differences.

How could we live on the Moon?

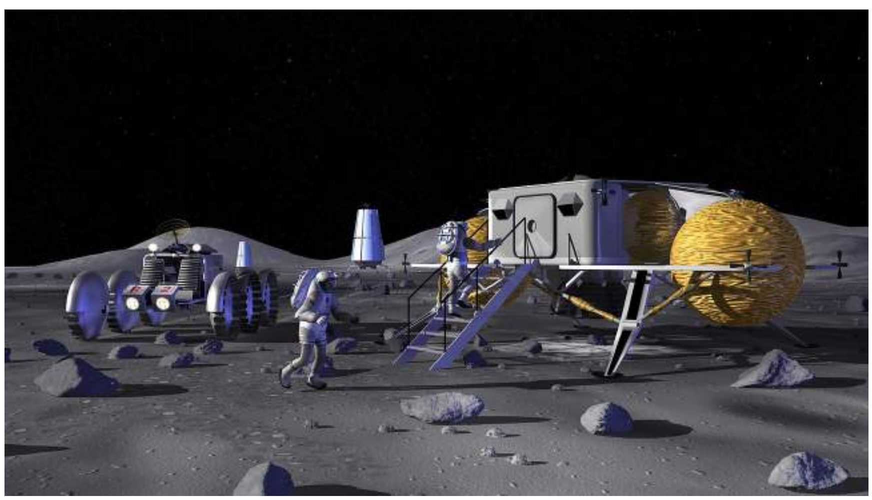
When we last visited the Moon, our task was to explore this world very quickly. We explored the surface and brought back rock and soil samples, but did not go prepared for a long visit.

Our next visits may start with short-duration trips, but we are also examining the opportunity to build a colony on the Moon that would stay there for an extended period of time. In some ways this is similar to explorations conducted on our own planet. The early explorers discovered new lands, and then following groups established colonies. While Earth-based colonies encountered people who already lived in these “new” lands, the Moon appears to be devoid of life, so we will not encounter other life forms. This means that our colonies will have to figure out how to build an environment that supports life – a challenge that did not face us in our explorations of Earth.

Benefits of a lunar colony

Did you know? The topic of colonizing the Moon is the subject of many early science fiction stories.

Background The Moon is not a very inviting place to live. It has no breathable atmosphere, is subject to temperature extremes, and does not support life on its own. This said, there are many reasons why a colony of lunar explorers might make sense. For example, the lack of an atmosphere makes the Moon a good location for a large telescope, since there is no air to distort the images. Unlike satellite-based telescopes, a fixed Lunar telescope could be quite large, allowing more detailed images than can be obtained today.



One design for a lunar colony (NASA)

Activity Make a list of benefits that could come from having a colony on the Moon. These might range from scientific projects to topics related to social interactions. Do some research on why others are interested in colonizing the Moon.

What are the compelling benefits of building a lunar colony?

What challenges need to be overcome to make these benefits possible?

While there is no atmosphere to interfere with a lunar telescope, there are dust storms on the Moon (see reference below). How can the effect of these storms be minimized to make a Moon-based telescope as useful as possible?

Duration 1 week

Resources Lunar dust fountains:
https://www.nasa.gov/topics/solarsystem/features/leaping-lunar-dust.html

Benchmarks STEM

Desired Student Outcome Students will explore and see some benefits of establishing a colony on the Moon.

Lunar colony resources from Earth

Did you know?

Our first trips to the Moon required that we bring everything we needed from Earth.

Background

The Apollo missions carried everything needed to support the astronauts on the short trips to the lunar surface. Future missions will last longer, and be more elaborate. It is important to think carefully about what should be brought to the Moon, and how best to take advantage of the limited storage space on the landing module.

Activity

If you were going to the Moon for an extended visit, what would be essential for you to bring? In addition to breathable air, water and food, what other items would you want to have?

If you were constructing a building or a piece of complex equipment on the Moon, how would you get the materials for your project to the surface safely? (Remember that parachutes won't work because the Moon lacks enough atmosphere to make a parachute work.) Some spacecraft have landed on Mars enclosed in flexible plastic bubbles to cushion the fall. Would this approach work on the Moon?

If you were bringing a building to the Moon, what would it take to have the building construct itself after landing?

What materials might you find on the Moon that could be used for construction, etc., so you wouldn't have to bring them from Earth?

Duration

1 week

Resources

General internet research

Benchmarks

STEM

Desired Student Outcome

Students develop an understanding of the challenges of bringing support materials to the Moon and speculate on what lunar materials could be used for some constructions.

Growing lunar crops

Did you know? When humans go to the moon or Mars, they'll probably take plants with them. NASA-supported researchers are learning how greenhouses work on other planets.

Background Is it true that plants cannot grow in Moon dirt? Scientists are not sure.

Soil-based plant cultivation uses plants in dirt. The most frequent objection in this case is that plants can't grow in Moon-dirt, so you'd have to ship up tons of Earth dirt for the plants to grow in. This will certainly be true in the beginning though not to the tune of tons, and we probably will be shipping up small quantities of high quality humus.

Confused? Then you're just like plants would be in a greenhouse on the Moon.

Possible greenhouse design for lunar use (NASA)

No greenhouses exist there yet, of course. But long-term explorers, on the Moon, will need to grow plants: for food, for recycling, for replenishing the air. And plants aren't going to understand that off-earth environment at all. It's not what they evolved for, and it's not what they're expecting.

Activity Review the research on the web sites below and make some conclusions about the best way to raise plants on the moon. What kinds of plants would be the best to cultivate? What does soil need to support plant growth? How does the soil on Earth maintain these nutrients? How can Lunar soil be prepared to sustain plant growth?

Duration 1 week

Resources

https://www.nasa.gov/feature/lunar-martian-greenhouses-desi gned-to-mimic-those-on-earth

Benchmarks STEM

Desired Student Outcome Students will understand the challenge of growing plants on the Moon.

Bottle biosphere

Did you know? The term "Biosphere" was coined by Russian scientist Vladimir Vernadsky in 1929. The biosphere is the life zone of the Earth and includes all living organisms, including man, and all organic matter that has not yet decomposed. Life evolved on earth during its early history between 4.5 and 3.8 billion years ago and the biosphere readily distinguishes our planet from all others in the solar system.

Background Artificial biospheres can be built, and it will be essential to construct self-sustaining living environments when we build colonies on the Moon or elsewhere. A large biosphere supporting human life would have to produce food, breathable air, drinkable water, and maintain a healthy environment. Furthermore it would have to do this on a much smaller scale than the biosphere on Earth.

In the following activity you will attempt to build a biosphere in a bottle.

Small biosphere design

Materials

- bottle (2L soda bottle, gallon glass jar, 5 gallon water bottle or whatever else you can find)
- plants(algae, duckweed, small house plants, weeds, or whatever you can find),
- animals (fish, crickets, snails, pill bugs, or worms
- soil
- rocks
- water
- something else that you want to put in it.
- tape
- marker

Activity Do some research on artificial biospheres on the internet. Then, build an ecosystem which you feel contains all the components needed for the life in the ecosystem to survive. Seal it up with tape and bring it to school, and write your name and the date across the top in such a way that the ecosystem cannot be opened and resealed without showing. Leave your ecosystem in the classroom for two weeks and then see how well it did. If it survives, you provided a balanced ecosystem! If it does not survive, write an autopsy report to explain what went wrong. Here are some questions to think about: does it matter if you use pond water, or water from the faucet in your classroom or home? Did you select animals (bugs, etc.) that can eat the food that is grown (algae, etc.)?

What is the simplest artificial biosphere you can imagine?

Thinking now about a larger system for human life support, where would breathable oxygen come from? How would food be produced and made ready to eat? How would waste products be converted into useful materials to keep the system working well?

Duration 2 weeks

Resources
https://www.nasa.gov/stem-ed-resources/lunar-biosphere.html

Benchmarks STEM

Desired Student Outcome Students will explore the construction of a small biosphere and learn about ecology and the importance of the environment on the cycles of life.

What does a colony need?

Did you know? The five primary elements of life are carbon (C), oxygen (O), hydrogen (H), nitrogen (N), and calcium (Ca). Together these make up about 98% of the biomass. We also use iron and silicon to make computers and machines. The problem with colonizing the Moon is that it has plenty of iron, silicon, oxygen, and calcium, but very little hydrogen, nitrogen, or carbon, making it relatively hostile to life.

Small deposits of hydrogen-containing ice have been observed at the Moon's poles, where NASA plans to set up a permanent base by 2025. Otherwise, trace amounts of H, N, and C come in via the solar wind, asteroids, and comets. For colonizing the Moon on a larger scale – not just using it as a research base – large quantities of these elements would need to be brought to the lunar surface.

Background Carbon could come from carbonaceous asteroids, which make up 75% of all asteroids, and are extremely rich in the element. Hydrogen could be mined from the poles at first, but might later need to be imported from Earth. Nitrogen would be the most expensive to obtain - it would all need to be imported directly from Earth, unless there are nitrogen deposits under the lunar surface we don't know about, which is unlikely. The good news is that once all the necessary elements are brought over, they could be indefinitely recycled as long as measures are taken to ensure that the elements don't float off into space. Colonizing the Moon would be challenging to get started, but once a reliable cycle is formed, our ancestors may forget that it was ever so hard.

Judging by human history and our spirit of exploration, it seems that in the long enough term, colonizing the Moon is quite likely. A feasible colonization project would require launch costs to come down substantially. A number of proposals to decrease the cost of space transit to $200/kg. or less are in the works, although it may be a few decades before they bear fruit. Once they do, colonizing the Moon will not be in the grasp of only governments, but also private entrepreneurs. The Moon could gain an economic foothold by exporting Helium-3, which would be an ideal fusion fuel. Helium-3 is extremely rare on Earth.

Placing a colony on a natural body would provide an ample source of material for construction and other uses, including shielding from radiation.

The energy required to send objects from the Moon to space is much less than from Earth to deep space. This could allow the Moon to serve as a construction site or fueling station for spacecraft. Some proposals include using electric acceleration devices (mass drivers) to propel objects off the Moon without building rockets.

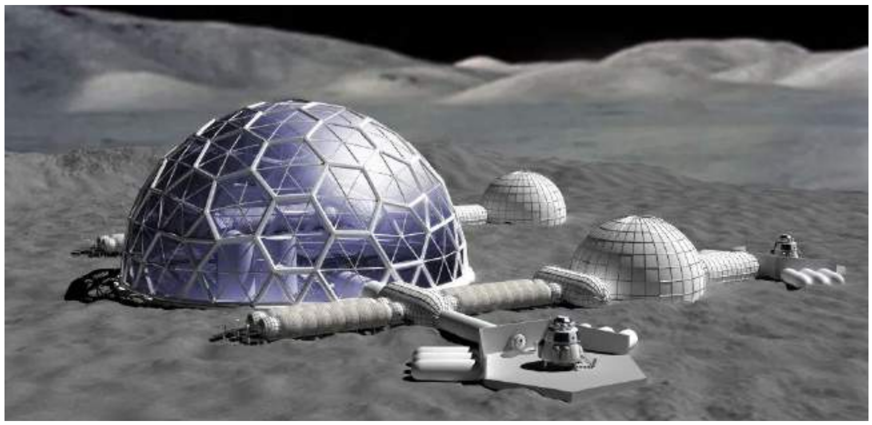
Furthermore, the Moon does have some gravity, which, experience to date indicates, may be vital for fetal development and long-term human health. Whether the Moon's gravity (roughly one sixth of Earth's) is adequate for this purpose, however, is uncertain. In addition, the Moon is the closest large body in the solar system to Earth.

While some Earth-crosser asteroids occasionally pass closer, the Moon's distance is consistently within a small range close to 384,400 km. This proximity has several benefits:

- The energy required to send objects from Earth to the Moon is lower than for most other bodies.
- Transit time is short. The Apollo astronauts made the trip in three days. Other chemical rockets such as would be used for any Moon missions in the next one to two decades at least, would take a similar length of time to make the trip.
- The short transit time would also allow emergency supplies to quickly reach a Moon colony from Earth, or allow a human crew to evacuate relatively quickly from the Moon to Earth in case of emergency. This could be an important consideration when establishing the first human

colony.

- The round trip communication delay to Earth is less than three seconds, allowing near-normal voice and video conversation. The delay for other solar system bodies is minutes or hours; for example, round trip communication time between Earth and Mars ranges from about eight minutes to about forty minutes. This again would be of particular value in an early colony, where life-threatening problems requiring Earth's assistance could occur. (See, for example, Apollo 13.)
- On the lunar nearside, the Earth appears large and is always visible as an object 60 times brighter than the Moon appears from Earth, unlike more distant locations where the Earth would be seen merely as a star-like object, much as the planets appear from Earth. As a result, a lunar colony might feel less remote to humans living there. The Apollo 8 astronauts, when behind the Moon, were the first humans to have no view of the Earth.
- A lunar base would provide an excellent site for any kind of observatory. As the Moon's rotation is so slow, visible light observatories could perform observations for days at a time. It is possible to maintain near-constant observations on a specific target with a string of such observatories spanning the circumference of the Moon. The fact that the Moon is geologically inactive along with the lack of widespread human activity results in a remarkable lack of mechanical disturbance, making it far easier to set up interferometric telescopes on the lunar surface, even at relatively high frequencies such as visible light.



Design for a lunar colony (NASA)

Activity Read and research this topic. Create a debate that will help people to think about financing a lunar settlement. Share how you would plan to do this and a timeline of steps toward making this happen.

Create a blueprint of the planned colony. Make a 3 dimensional model of it.

What would a Moon-based colony need in order to be a nice place to live? What would the government of a Moon colony be like? How many nations should be represented in the first Moon colony? What sporting activities make sense in the reduced gravity of the Moon? How will Lunar colonists entertain themselves? What would a "night out on the town" be like for people living on the Moon? What would a Lunar "house" be like?

Duration 2 weeks

Resources
http://www.wisegeek.com/what-are-the-prospects-for-colonizing-the-moon.htm

Benchmarks STEM

Desired Student Outcome Students will explore many factors, including social ones, associated with the design of a Lunar colony.

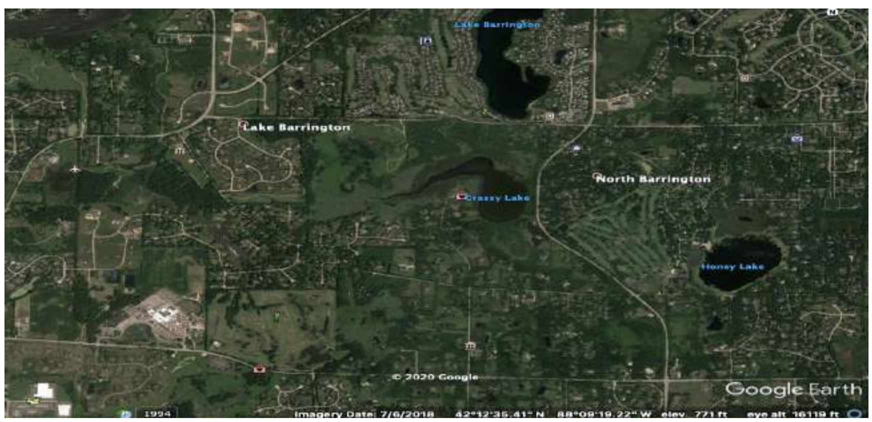
How do we use space to study the Earth?

The Apollo 8 mission to the Moon was one of the first during which a photograph of the whole earth was taken from space. The impact of these images on those of us on the ground was amazing. Since that time, we have continued to explore the Earth from space. This information is used for everything from daily weather forecasting to the study of long-term climate changes, location of natural resources, etc. It is fair to say that space exploration has given us tremendous insights to our own planet and its future.

Exploring the Earth from space

Did you know? Some of the most significant changes taking place on Earth today are best studied with the use of satellites orbiting overhead.

Background With the concern over global warming we have one way to think about problems we need to solve for all mankind. Browse the Google Earth site listed below to explore the study of the Earth from space.



Sample Google Earth map

Pick ten cities in the world in different regions to compare and contrast using this site

Give the latitude and longitude of each city. Locate then on a paper map using some earth projection map.

This database was compiled to illustrate some very interesting Earth features and processes, including cities as seen by Astronauts from space.

Activity Locate nearly any place on Earth, search and print historical, weather, and population maps, and more with Google

Earth.

How do we collect these images? Why is it important to collect earth images? What tools help astronauts? Do the astronauts use the same tools as mapmakers? Why or why not? Why are there different projections of the Earth?

Duration 2 weeks

Resources https://www.google.com/earth/

Benchmarks STEM

Desired Student Outcome Students will know why the exploration of Earth from space provides valuable information for the health of our planet.

Global climate change

Did you know? Global climate change may take place slowly, but the consequences of even small changes in climate can be severe.

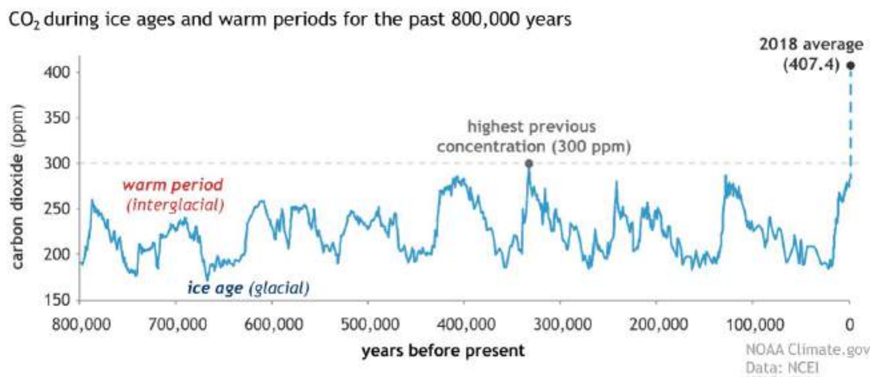


Chart of carbon dioxide concentrations over time (NOAA)

Background To figure out the future of climate change, scientists need tools to measure how Earth responds to change. Some of these tools are global climate models. Using models, scientists can better understand how the Earth works and how it will react to change in the future.

Global climate models (GCMs) use math to describe how the Earth works. Supercomputers are needed to run large global climate models. These speedy computers can sometimes do more than 80 million math problems in an hour.

Climate models usually try to take into account all the parts of the Earth system including:

- The animals and plants (the biosphere)
- The oceans, lakes, and rivers (the hydrosphere)
- Icebergs, glaciers and ice sheets (the cryosphere)

- Air (the atmosphere)
- Volcanoes and moving continents (the geosphere)

Activity Explore articles on this topic from magazines, newspapers and other resources.

How do changes in the Earth System cause changes in global temperature? What changes are purely seasonal, and which ones seem to be changing in one direction over a period of years?

Climate isn't the same thing as weather. Weather is the condition of the atmosphere over a short period of time; climate is the average course of weather conditions for a particular location over a period of many years.

What do climate models predict for the future? What can we do to reduce the rate of global warming? How can you convince others to understand the challenges facing our planet?

Make a presentation, a collage, a model, a movie, to share what you have learned.

Duration 2 weeks

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students learn the nature of global climate change, and how this topic can be explored from space.

How satellites help us find our way

Did you know? A smartphone that fits in your pocket is a better navigational tool than anything the great explorers used when they came to the "New World."

Background Our ancestors had to go to pretty extreme measures to keep from getting lost. They erected monumental landmarks, laboriously drafted detailed maps and learned to read the stars in the night sky.

Things are much, much easier today. Today's smartphones have GPS capability built in. As long as you have a GPS (Global Positioning System) receiver and a clear view of the sky, you'll never be lost again.

In order for a GPS receiver to work, it needs to be able to receive signals from several satellites placed in various orbits so that, at any time, at least four of 24 satellites are in view. (They would be hard to see since they are over 19,000 km above Earth, but their radio signals can be detected.) A GPS receiver's job is to locate four or more of these satellites, figure out the distance to each, and use this information to deduce its own location. The resulting information is so accurate you can pinpoint your location to a few meters!

Activity Using information you find on the internet, explore exactly how the signals from the satellites are used to pinpoint a location here on Earth.

GPS technology was originally developed for military use. Today it is available to anyone with a smartphone. What interesting applications for this technology can you think of?

Duration 1 week

Resources General internet research

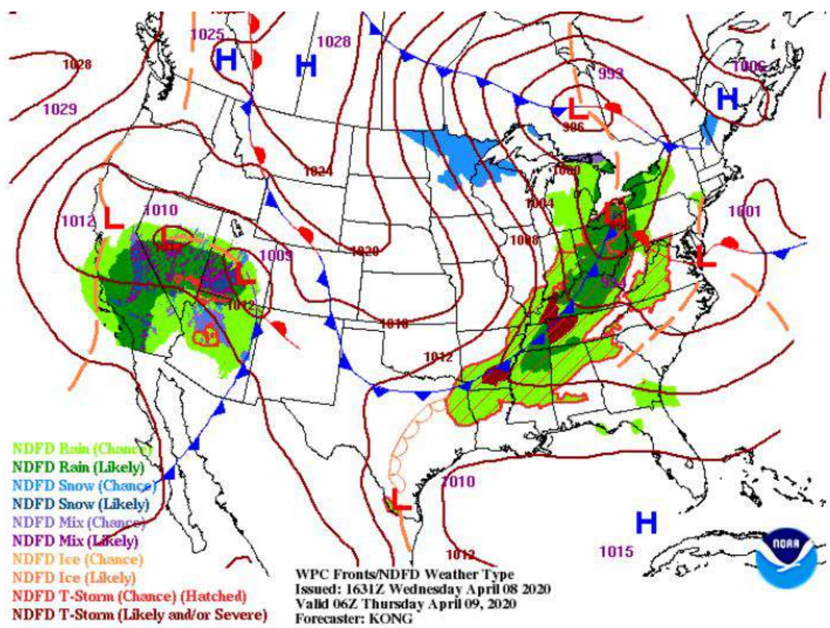
Benchmarks STEM

Desired Student Outcome Students learn how GPS receivers work, and think of creative applications for this technology.

Mapping and predicting weather

Did you know? Weather is becoming more predictable with new tools for new learning. Some supercomputers can do more than 200 trillion calculations a second Supercomputers are used in climate modeling and research.

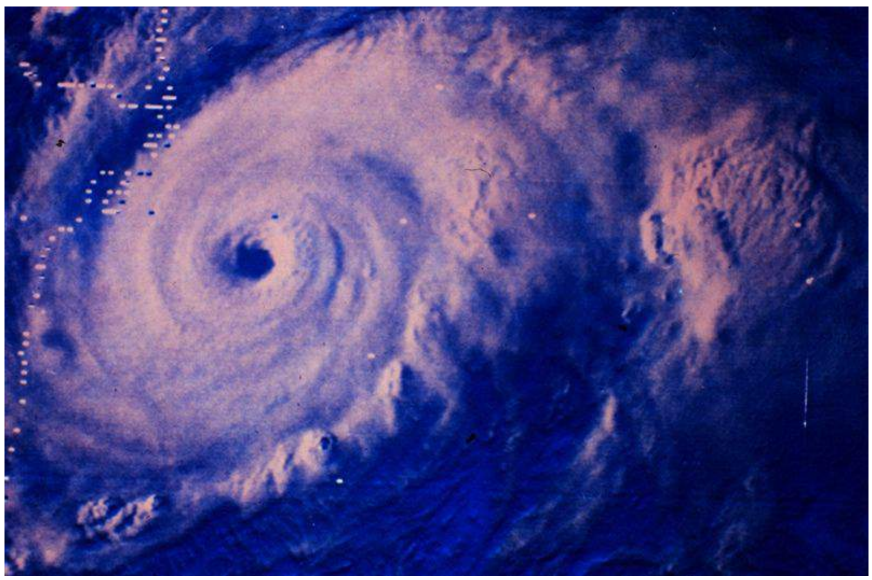
Background Weather forecasters use a variety of tools to help them gather information about weather and climate. Some more familiar ones are thermometers which measure air temperature, anemometers which gauge wind speeds, and barometers which provide information on air pressure. These instruments allow meteorologists to gather data about what is happening near Earth's surface. Collecting data from other sources — and other parts of the atmosphere — helps to create a more descriptive picture of weather.



NOAA weather map

For viewing large weather systems on a worldwide scale, weather satellites are great tools. For example, the NASA Aqua satellite sends back almost 90 GB of data per day!

Satellites show cloud formations, large weather events such as hurricanes, and other global weather systems. With satellites, forecasters can see weather across the whole globe: the oceans, continents, and poles. Satellite data can be very detailed, even to the point of showing states and counties.



Satellite view of hurricane (NOAA)

Weather satellites generally have two types of sensors. One is a visible light sensor called the "imager," which works like a camera in space and helps gather information on cloud movements and patterns. This sensor can only be used during daylight hours, since it works by capturing reflected light to create images. Since different surface features reflect light in distinctive ways, they can be distinguished from each other in the images. Water reflects very little light, making it appear black on the satellite image. Land masses tend to appear as shades of gray, depending on their temperature and moisture.

The second sensor is called the "sounder." It's an infrared sensor that reads temperatures. The higher the temperature of the object, the more energy it emits. This sensor allows satellites to measure the amount of energy radiated by Earth's surface, clouds, oceans, air, and so on. Infrared sensors can be used at night — a helpful feature for forecasters, considering that the imager can only pick up data during daylight hours.

Activity Even with all the information provided by satellites and other tools, the weather forecasts are sometimes wrong, especially forecasts that look a week or so into the future. Why is this?

In your research on this topic you may come across something called the "butterfly effect." What is this effect, and why is it important? Can you build a simple computer program or spreadsheet model that shows this effect in action?

Do you suppose that our models of weather will ever improve to the point that we will know, with certainty, what the weather will be like at a particular location on any chosen date? Alternatively, is the problem so complex that it will never be possible to provide a truly accurate long-range forecast?

Duration 1 week

Resources http://www.nasa.gov/mission_pages/terra/

http://www.nasa.gov/mission_pages/aqua/

Benchmarks STEM

Desired Student Outcome Students explore the current use of satellites to help forecast the weather and also learn that weather prediction is hard to do accurately over the long term because slight changes at one time can produce large effects later.

What is the history of rocketry?

The first rockets were made by the Chinese sometime after their discovery of gunpowder. While the early applications of rockets were primarily military, many people dreamed of peaceful uses as well. As rocketry advanced over the centuries, other rocket fuels were developed. Today, it is common to see both solid and liquid rocket fuels being used, sometimes in the same rocket.

Rocketry is closely tied to space exploration, as rockets currently seem to be the only devices capable of carrying objects into space. This does not mean that alternate launching devices may not be developed, only that, for now, space exploration and rocketry are closely connected.

Why were rockets invented?

Did you know? The first rockets may have been bamboo tubes filled with gunpowder that flew away when the gunpowder was ignited.

Background While the origins of rocketry are unknown, the earliest rockets were probably developed in China, and used for military purposes. Over the following years this technology migrated to Europe and was used in warfare in many countries, including British attacks on the US during the War of 1812.

Activity As you explore the history of rocketry, build a timeline showing when important events relating to rockets occurred. At what point did rockets start to be used for non-military applications? What kinds of peaceful applications for rockets emerged? What is the situation today? Is there a good balance between military and peaceful applications of rockets? What new applications might be found for this technology?

Duration 1 week

Resources General internet research

Benchmarks SE

Desired Student Outcome Students learn the rich history of rocketry going back many centuries, and spanning numerous nations.

Who were the pioneers of rocketry?

Did you know? Many rocket scientists developed an interest in this area when they were children.

Background While the names of the inventors of rocketry are lost in the dust of history, many more recent inventors are well known. Names like Robert Goddard and Werner von Braun are well-known, but there are other names to be added to the list of people who made significant discoveries in this field.

Robert Goddard and liquid fueled rocket (NASA)

Activity Use the internet to research the names and biographies of the world leaders in rocket science. What were their contributions? Who funded their work? What impact do their discoveries have today (if any)? Is rocketry a "mature" science with little left to be discovered, or is it likely that other significant discoveries might be made soon? What areas of rocket science look most promising today?

Duration 1 week

Resources General internet research

Benchmarks S

Desired Student Outcome Students explore the people behind the major discoveries in the field of rocket science and speculate as to where the next promising areas in this subject are likely to be.

Choosing solid or liquid fuel

Did you know? The Space Shuttle (now retired) used solid fuel for the booster engines, and liquid fuel for the Shuttle engines.

Background All rocket fuels have the property that, as they burn, they produce a stream of gas that is ejected from the rocket, causing it to fly. There are two general classes of fuels: solid fuels and liquid fuels. Solid fuels have the advantage that they can be stored for long periods of time. Many liquid fuels are extremely cold (liquid oxygen, liquid hydrogen) and must be pumped into the rocket shortly before launch. One advantage of liquid fuels is that they are easier to control so the rocket thrust can be adjusted while the rocket is in flight.

Activity What are the common materials used in solid fuels for rockets? What allows these materials to burn in a controlled way instead of exploding all at once?

What materials are used for liquid fueled rockets? When more than one liquid fuel is used in a rocket, are the liquid fuels held in separate tanks, or are they mixed together? What special precautions are needed for handling liquid fuels?

Which kinds of rocket fuels are safest to work with? Which ones produce the most thrust per kilogram of fuel?

Duration 1 week

Resources General internet research

Benchmarks SE

Desired Student Outcome Students learn the relative features and drawbacks of liquid and solid rocket fuels.

Why did it take so long to put an object in orbit?

Did you know? The Sputnik launch in October, 1957 was the culmination of many years of research looking into sending an object into space.

Background Rockets have been around for centuries, but it took until 1957 to successfully launch an object into space. The rocket that carried the Sputnik into orbit was the first to achieve this goal. Since that time, rocketry has improved to the point where rocket launches hardly make the news!

Activity Explore the state of rocket design prior to 1957. What seemed to be missing that kept us from getting into space? Successful space launches are generally made with multi-stage rockets. Why is this? How many stages does it take to launch today's heavy payloads?

What future rocket designs are being considered today? What will they let us achieve that has not been possible until now?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students learn that rocket design has improved over time, and that this field is continuing to improve every year.

How do rockets fly?

Movies of rocket launches show flaming gases being pushed out of the bottom of the rocket as it rises off the launch pad into space. The rocket engine provides the power to make the rocket fly, but at the same time there are other forces (e.g., gravitational attraction, drag) that are pulling the rocket back down. It is only when the rocket thrust is greater than all the other forces acting on the rocket that it is able to take off!

Just as there is a lot of research being done on rocket engine design, engineers and scientists are also looking for better rocket shapes that reduce some of the other forces that are keeping the rocket from achieving better performance.

Physics of rockets

Did you know? The flight of a rocket depends on several forces acting in different directions. Rocket shape plays an important role in the success of a rocket flight.

Background If you look at a video of a shuttle launch, the most visible effect is the thrust produced by the flaming gas being ejected from the bottom of the rocket that lifts the shuttle off the launch pad. This force is called the thrust. While not visible, there are at least two other forces acting on the rocket, both of which are pushing in the opposite direction. Gravity is the most obvious of these. The friction between the rocket and the atmosphere produces another force, called drag. In order for a rocket to fly, the thrust has to be greater than the force of gravity plus the drag force. While the force of gravity is determined by the mass of the rocket, drag is caused by the shape of exposed rocket parts ranging from the nose of the rocket to the fins. Careful design of these elements can go a long way to improving the efficiency of the rocket's design. Slender rockets with smooth surfaces tend to have less drag than fat rockets with rough edges on the fins.

The equations for the two resisting forces (measured in Newtons) are as follows:

Gravity force (calculated for the Earth) –

$$F_g = g m_r$$

where g is the Earth's gravity conversion factor (9.8 Newtons per kilogram) and m_r is the mass of the rocket in kilograms.

Drag force –

$$F_d = \frac{1}{2} \rho v^2 C_d A$$

where ρ is the density of air (kg per cubic meter), v is the rocket's velocity (meters per second), A is the cross sectional area of the rocket facing in the direction of flight (square meters) and C_d is the drag coefficient which takes into account the parts of the rocket surface that resist the smooth flow of air as the rocket moves.

Activity In order for a rocket to fly straight upwards, the thrust force must be greater than the combined forces of gravity and drag:

$$F_t > F_g + F_d$$

Notice that the drag force increases with the square of the rocket's speed (velocity). In other words, if you double the rocket's speed, the drag force increases by a factor of four!

Aside from keeping the rocket as light as possible, there isn't much we can do about the force of gravity. The drag force can be reduced with careful rocket design. What shapes of rockets have the lowest drag coefficients? How important is the design of fins in reducing the drag force? Once a rocket leaves the Earth's atmosphere, does the shape of the rocket matter any more?

Any object moving through air (*e.g.*, a car) experiences drag forces. What have designers done to improve the shapes of cars to reduce drag? As fuel prices rise, what is the importance of reducing drag forces in automobile designs?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students learn that there are at least three forces acting on rockets as they are being propelled through the atmosphere, and learn what rocket shapes produce the least amount of drag.

Wind tunnel construction

Did you know? Wind tunnels are powerful tools for exploring rocket shapes before they are launched into space. Designs can be tested inexpensively to increase the likelihood that the final design will work perfectly.

Background Professional wind tunnels can be large enough to hold entire airplanes or spacecraft. These devices provide a steady stream of air that interacts with the object being tested. The "lift" of an airplane wing can be measured in a wind tunnel, as can the "drag" of various rocket designs. For classroom use, a wind tunnel can be easily constructed that lets you explore the merits of different shapes for small rockets.

Activity Using the NASA information listed below of wind tunnel construction, build a small wind tunnel using a computer cooling fan. This project can be built by the entire class using a fan and a few dollars worth of materials. Test your wind tunnel using the projects described in the NASA document.

How would you use this wind tunnel to test rocket body designs of your own design? Does the shape of the nose (front) of the rocket have a big influence on drag? You want to have the smallest amount of drag possible. What happens when you change the shape and position of rocket fins? Based on your experiments, build a model of the best rocket shape you can make. What parts of this shape make it ideal?

Duration 1 – 2 weeks

Resources
https://www.grc.nasa.gov/WWW/K-12/smokie/SmokeyWindTunnelFinal3.pdf

Benchmarks STEM

Desired Student Outcome Students learn how to build a wind tunnel and use it to test their own rocket designs for minimum drag.

Static test stand construction

Did you know? Engine thrust is the primary force that allows rockets to take off and fly. Rocket engines are usually tested on the ground before being used in flying rockets.

Background Rocket engines are tested on the ground during the design process to ensure they generate the maximum thrust possible for the duration of the engine "burn". Because the engine is not moving at the time, the device to which they are connected is called a static test stand. These stands need to be very strong so they don't move, even though a huge rocket engine is pressing all of its force against them.

Engine going through static test (NASA)

Small rocket engines do not require large test stands, and some rocket test stands can be set on the ground with the engine pointing downward. The goal in testing engines is to measure the force during the "burn" cycle, and generate a graph showing the force over time. This information, along with rocket drag, can be used to show whether the final rocket will have a good flight pattern.

Activity After doing some research on static test stands, design a test stand of your own that could be used to measure the thrust of one of your own engine designs. If you are testing a water bottle rocket, you will be able to conduct the test with the bottle upside down, so your test stand may have to take this into consideration.

The plot of thrust over time is called a "thrust curve." What do you think produces the best rocket flight – a high amount of thrust for a short period of time, or a lower amount of thrust for a longer period of time? Can you find any information to support your hypothesis?

How would you measure thrust in your test stand? How would you gather thrust data over time so you could plot a thrust curve?

Duration 1 – 2 weeks

Resources General internet research

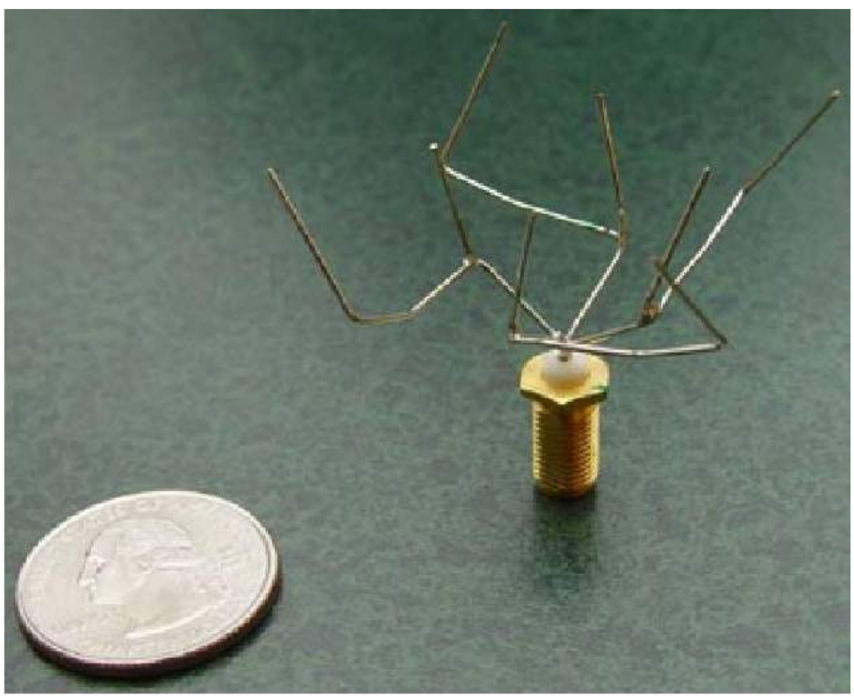
Benchmarks STEM

Desired Student Outcome Students learn the benefits of using static test stands to test engine performance during the design phase, and may choose to build a small test stand of their own design.

Designing nature's way

Did you know? Many practical designs are the result of "trial and error" experiments. If something does not work the first time, sometimes a simple modification of the design produces much better results. In some cases, many thousands of experiments are needed to develop an optimal design.

Background Imagine a process of artificial evolution that applies to mechanical objects or other designs in which a supercomputer or many microcomputers networked together "evolve" and test millions of generations of designs to finally come up with the best one possible to meet a given set of requirements. The resource below contains activities related to this concept.



Antenna designed through evolutionary methods (NASA)

Activity Based on these activities, what kinds of things can be best designed through this process? Do you think this approach could lead to improved rocket designs? Why or why not? Could the method be used for the design of fuel-efficient aircraft wing design, or to create an optimal glider shape?

Duration 1 week

Resources
https://www.nasa.gov/centers/ames/research/exploringtheuniverse/exploringtheuniverse-evolvablesystems.html

http://bit.ly/2PJpDpz

Benchmarks STEM

Desired Student Outcome Students develop an understanding of how new kinds of computer modeling can rapidly generate optimal designs.

Soda bottle rockets

Did you know? Rockets don't always need burning fuels. Compressed air and water can be used to power a rocket you can build yourself.

Background One popular kind of student rocket uses scrap soda bottles, water and compressed air injected into the bottle with a bicycle pump. These rockets can fly quite high!

Soda bottle rocket

Activity Using the plans provided in the resources, build the bottle rocket and launch stand. Once you have built and tested your rocket, try building it with different sized bottles. What bottle size works best? Why do you think this is? What happens if you change the amount of water in the bottle? What is the best amount of water to use?

Note: Be sure to wear protective goggles over your eyes, and be prepared to get wet!

Duration 1 week

Resources
https://www.instructables.com/id/Soda-Bottle-Water-Rocket/

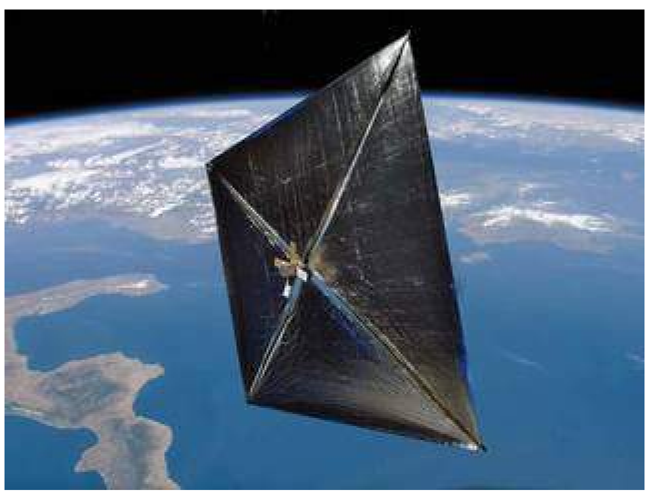
Benchmarks STEM

Desired Student Outcome Students build and test a simple bottle rocket and notice how performance changes with changes in water level and rocket housing.

Alternate propulsion methods

Did you know? Once a rocket has left the friction of our atmosphere, other types of propulsion systems can be used for very long journeys.

Background Solar sails (also called light sails or photon sails, especially when they use light sources other than the Sun) are a proposed form of spacecraft propulsion using large membrane mirrors. Unlike rockets, solar sails require no reaction mass. Although the thrust is small, it continues as long as the light source shines and the sail is deployed. In theory a lightsail powered by an Earth-based laser can even be used to decelerate the spacecraft as it approaches its destination. Ion engines are another propulsion system being used for travel once the spacecraft is far enough away from the Earth.



Working solar sail design (NASA)

Activity What are the characteristics of these and other propulsion systems for spacecraft? How does the propulsion system impact spacecraft design? Can you create a design for a solar sail spacecraft? How does this design change for one that uses ion engines? What other alternative propulsion systems are being explored today?

Duration 2 weeks

Resources Solar sails:

http://www.solarsails.info/

www.howstuffworks.com/solar-sail.htm

Ion engines:

http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/

Benchmarks STEM

Desired Student Outcome Students will develop an understanding of alternative propulsion systems that can be used once a spacecraft has left the Earth's atmosphere.

How do we return from space?

While a great deal of attention is paid to the complexity of launching astronauts into orbit, it is equally important that we are able to return them safely to Earth. From the very first manned flights by the Soviet Union and the United States, the decision was made to let the re-entrant vehicle coast down. Initially, parachutes were used to reduce the velocity to the point where the spacecraft (or capsule) could land in the ocean which would absorb the energy of the fall without crushing the astronauts. The US designed space shuttle took a different approach by having it land on a glide path, similar to the landing of airplanes. The big difference is that, unlike airplanes, the returning space shuttle does not have a powered flight path. Once it is committed to landing, it can not pull up and try again.

The design of craft that can safely return people to Earth is quite complex and is the subject of a tremendous amount of ongoing study.

How gliders work

Did you know? Paper "airplanes" are usually unpowered gliders and can fly great distances if properly designed.

Background A glider is a special kind of aircraft that has no engine. Paper airplanes are the most obvious example, but gliders come in a wide range of sizes. Toy gliders, made of balsa wood or styrofoam, are an excellent way for students to study the basics of aerodynamics. Hang-gliders are piloted aircraft that are launched by leaping off the side of a hill. The Wright brothers perfected the design of the first airplane and gained piloting experience through a series of glider flights from 1900 to 1903. More sophisticated gliders are launched by ground based catapults, or are towed aloft by a powered aircraft then cut free to glide for hours over many miles. The Space Shuttle flew as a glider during reentry and landing; the rocket engines are used only during liftoff.

Compared to a powered aircraft, a glider has only three main forces acting on it: lift, drag, and weight. Forces have both a magnitude and a direction. The weight acts through the center of gravity and is always directed towards the center of the earth. The magnitude of the weight depends on the mass of the vehicle plus its payload. The lift and drag are aerodynamic forces and act through the center of pressure. The drag is directed opposite to the flight direction, and the lift is directed perpendicular to the flight direction. There are many factors that influence the magnitude of the lift and drag forces.

In order for a glider to fly, it must generate lift to oppose its weight. To generate lift, a glider must move through the air. But the motion of a glider through the air also generates drag. In a powered aircraft, the thrust from the engine opposes drag. But a glider has no engine to generate thrust. With the drag unopposed, a glider quickly slows down until it can no longer generate enough lift to oppose the weight.

Activity Using web-based and other resources, build a collection of paper "airplanes" (gliders). Which ones seem to work the best? Why do you think some designs are better than others? Do you think you can improve on some glider designs? If so, try your changes out and see how they work.

Gliders carrying humans have a rich history going back over 100 years. Who were some of the pioneers of gliders? What contributions did they make? Did their contributions make it easier to design powered airplanes? What are the uses of gliders today?

Duration 1 week

Resources General internet research

Benchmarks SE

Desired Student Outcome Students experiment with a variety of glider designs and learn the rich history of manned gliders in the early days of aviation.

The space shuttle as a glider

Did you know? When the space shuttle returned to Earth, it flew as a glider with no active propulsion system.

Background Do you think you have what it takes to land the Space Shuttle? There's nothing quite like it. The Space Shuttle is harder to land than a conventional airplane. In fact, it's been compared to a flying brick—big, heavy, and less aerodynamic than most aircraft. And, you only get one shot at landing safely. Since the Shuttle doesn't have jet engines, you can't circle around and try again if you make a mistake. Space Shuttle commanders have to be very confident about their landing skills before they try it the first time.

Space shuttle landing (NASA)

In this activity you will design, construct, fly, and land a flying brick. Using a shoe box to represent the brick, you will add wings, stabilizers, rudder, etc., to improve its flight capabilities. The finished product will represent a Shuttle coming in for a landing.

Will their bricks fly and land like the Shuttle is supposed to?

Activity Start with an empty shoe box and experiment with wing designs made from poster board or other still cardboard to turn your "brick"into a glider. You should think about wings, the tail, and other things your shoe box might need to make it into a useful glider. You may want to add some weight to the inside of the shoe box to make it fly better. Be sure to use duct tape to hold your weights in place so they don't shift around during flight.

Why do you think the shuttle was designed to look like a "flying brick" instead of having a more aerodynamic shape like traditional gliders?

Traditional gliders that carry humans can "ride thermal currents" and change their altitude and direction while flying. What kids of flight capabilities does the shuttle have?

Why was the space shuttle designed to land as a glider instead of like a traditional airplane?

Duration 1 week

Resources General internet research, Movie: "Space Cowboys" (has shuttle training and landing scenes.)

Benchmarks SE

Desired Student Outcome Students develop an understanding of the aerodynamics of the Space Shuttle as a glider, and build a "flying brick" of their own.

What is the impact of the atmosphere on re-entry?

Did you know? Shuttle tiles need to withstand very high temperatures and to keep the shuttle cockpit from getting too warm.

Background The US Space Shuttle was a reusable spacecraft. One of the keys to this reusability is the Thermal Protection System, or TPS. The most visible aspect of the TPS are the external tiles. But in reality, the TPS consists of a combination of materials and technologies that work together to protect the spacecraft and its human occupants. The TPS represents significant advances in aerodynamic design, metallurgy, and the understanding and manufacture of materials, a discipline known as materials science. Underneath its protective layer of tiles and other materials, the Space Shuttle is of rather ordinary aluminum construction, similar to many large aircraft.

Early vehicles that had to reenter the Earth's atmosphere used a variety of techniques to keep from burning to a crisp. Some used heat sinks to absorb the heat. Others used ablative material that charred and vaporized. But none of the early vehicles had to be reusable and so they could use materials and techniques that protected the vehicle but rendered it essentially unusable afterwards. Some spacecraft designers did propose developing heat shields for spacecraft that could be completely replaced after flight, allowing a space capsule, such as the Apollo Command Module, to be reused, but these proposals never advanced very far. When spacecraft designers started thinking about reusable vehicles, they figured that they would have to use some combination of metals and ceramics that could survive high temperatures.

When the Space Shuttle was first proposed in the late 1960s, planners from NASA wanted a vehicle that would be much larger than any that had flown in space before. But the amount of high-temperature metal required to protect a large vehicle would have been very heavy and this would have affected vehicle performance. Designers chose to use conventional aluminum for the main body and to protect it with a layer of heat resistant material.

The properties of aluminum demand that the maximum temperature of the shuttle's structure be kept below 175 degrees Celsius in operations. But aerothermal heating during liftoff and reentry (in other words, heating caused by friction with the air) will create surface temperatures high above this level and in many places will push the temperature well above the melting point of aluminum (660 degrees Celsius). Clearly an effective insulator was needed.

Fortunately, during the 1960s, Lockheed developed a silica-based insulation material for NASA. NASA designers decided to use this and similar materials to manufacture heat-resistant tiles and other coverings to protect the shuttle's airframe.

Activity Explore the construction and mounting of the thermal tiles used on the Space Shuttle. How do these tiles keep the body of the Space Shuttle from overheating?

Find rods or sticks about 30 cm long made of aluminum, wood, plastic, and other materials. Heat a pot of water until it boils. One at a time, hold one end of the rods with your hand and put the other end in the hot water. How long can you hold each material before it gets too hot? (Be sure to wear safety goggles and let go of the rods before they get hot enough to burn your hands!) NOTE: DO NOT DO THIS ACTIVITY WITHOUT ADULT SUPERVISION

AND BE SURE THE RODS ARE COOL BEFORE TOUCHING THEM.

Which material could you hold the longest? Which one got hot the fastest? If you hold the rods while wearing oven mitts, does this change the results? Why?

What kinds of materials conduct heat (get hot faster) better? What kinds of materials are poor conductors of heat? Why do you think these differences exist?

Duration 1 week

Resources Materials mentioned in activity, General internet research

Benchmarks SE

Desired Student Outcome Students develop an understanding of thermal conduction and the role of insulating tiles to protect the Space Shuttle on its re-entry to the Earth's atmosphere.

Human response to the return of gravity

Did you know? The ISS has exercise equipment similar to that found in health clubs on Earth.

Background Imagine the sensations of being an astronaut - the force of rocket thrust pushing you skyward while Earth's gravity struggles to keep you in its grip; the view from the cockpit as you climb higher and higher; and finally, many minutes later, when the space shuttle has reached its orbit and is in freefall around Earth, the giddy freedom of "floating" through air as you "swim" from spot to spot, tumbling in a slow-motion somersault now and then, just because you can.

But there's more. Now imagine the cold-like sinus and nasal stuffiness you get as fluids shift upward in your body, no longer pulled to your feet by gravity. Though you would not be able to feel it, there is a gradual weakening of your heart and other muscles since they are no longer challenged to resist the pull of gravity. Similarly, there is bone loss as your limbs no longer have to bear the skeletal weight they do every day on Earth. These are a few of the adaptations the body makes when an astronaut travels on the International Space Station (ISS) or on any other orbiting spacecraft.

Exercise on ISS (NASA)

All these adjustments can make work in space more difficult, and they definitely pose problems when an astronaut re-enters Earth's gravity at the end of a mission. Upon returning to Earth, the muscles and bones weakened in space need to readjust to gravity's pull, and fluids that have shifted and been expelled by the body need to be replaced.

Activity What kinds of exercises do you think astronauts could do to keep their bodies in good shape while in orbit?

If you were in the ISS for a few months, how do you think your body would react to the return of gravity on Earth? What things would be easier for you to do? Which would be harder?

Duration 1 week

Resources
http://www.nasa.gov/directorates/esmd/home/index.html

Benchmarks SEM

Desired Student Outcome Students develop an understanding of the impact of prolonged weightlessness on their bodies.

How do satellites stay aloft?

Prior to Sputnik, rockets launched from the Earth came back down when they ran out of fuel. The thing that made Sputnik unique was that it was the first object launched into orbit around the Earth where it would travel around the planet many times before reentering the atmosphere. Today there are thousands of satellites in orbit around the Earth providing communications, GPS services, photographs of the Earth and space, and research laboratories. As different as each of these satellites is, they all obey the same laws of physics and are subject to the gravitational attraction of the Earth. This topic explores the mathematics of orbits and the conditions needed to keep a satellite from falling back to the Earth. It also explores special types of orbits (e.g., geostationary) needed for certain purposes.

Orbital mathematics

Did you know? Communication satellites were predicted by science fiction author Arthur C. Clarke in 1945.

Background Using the equation for orbital movement, students will explore the velocity needed to put an object in orbit around the Earth and Moon.

Activity The velocity needed to keep an object in orbit around a body of mass *M* is

$$v_o = \sqrt{\frac{GM}{r}}$$

where velocity is measured in meters/sec, *G* is the universal gravitational constant (6.673×10^{-11} m^3 kg^{-1} sec^{-2}), Start with *M* as the mass of the Earth (5.9742×10^{24} kg) and *r* as the distance from the center of the Earth to the satellite. The radius of the Earth is 6.3781×10^6 meters, and you need to add the height of the satellite above the surface to get the desired value of *r*.

Using these values of constants, what is the velocity needed to place an object in orbit around the Earth? Find the mass and radius of the Moon and repeat the calculations. How are the results different? Is it easier to put an object in orbit around the Earth or the Moon? How long does it take to orbit the Earth at the altitude you chose? What altitude is needed for a satellite to orbit the Earth in one day, providing a geostationary orbit? What is the impact of drag caused by the atmosphere at different satellite altitudes? How far away from the surface of the Earth should a satellite be to minimize the impact of atmospheric drag?

Duration 1 week

Resources Wikipedia (www.wikipedia.org)

Benchmarks SM

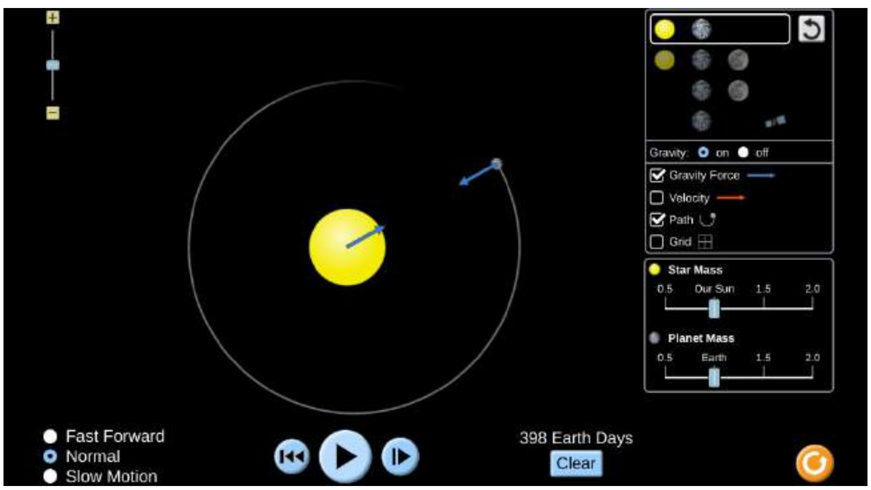
Desired Student Outcome Students will be able to calculate the velocity needed to place an object in orbit around the Earth and other celestial objects.

Experimenting with orbits

Did you know? The gravitational interaction of three objects is too complex to be calculated by hand.

Background Using software for orbit simulation, students can examine orbits of more than one object around a central mass.

Activity Use PhET's orbit simulator to experiment with different orbits and objects with different masses. Start with two objects, and use various starting velocities and masses. Why does the central (larger) object move? Is there a mass for this object that will keep its location fixed? How does the motion of the Earth influence the movement of the sun?



PhET orbit simulation

If a third object is added, what do you think will happen? Add a third (smaller) object to the model and run it. What happens?

Duration 1 day

Resources PhET software on orbits

Benchmarks TM

Desired Student Outcome Students will experiment with orbit simulation software to see how complex orbits can become when a third object is added to the system.

What orbits are best for satellites?

Did you know? Satellite television signals are sent from satellites located in "fixed" positions above the equator.

Background Once launched, satellites can be placed in a wide variety of orbits. Low Earth orbits are those close to your planet. Geostationary orbits are much further out and place the satellite in a location fixed to a point on the earth. These are used for communication where the Earth-based antenna remains fixed (e.g., satellite television). Polar orbits provide the opportunity for the satellite to pass over most of the surface of Earth (as opposed to, for example, passing over the area near the equator.)

Activity Explore the wide variety of orbits used for different kinds of satellite missions. Do communication satellites require different orbits from weather satellites? Which kinds of orbits are best for making accurate photographs of the Earth's surface? Which orbits are easiest to achieve? Which ones are the most popular? Are there orbits whose available space is getting "crowded"?

Duration 1 week

Resources
https://www.nasa.gov/smallsat-institute/space-mission-design-tools

Benchmarks STEM

Desired Student Outcome Students will learn about various kinds of orbits and be able to identify missions for which certain types of orbits are required.

How are missions designed?

Earthbound studies often make use of specialized equipment and instruments. Sometimes, special environments are created (very clean rooms, refrigeration, vacuum chambers, etc.) which complicates the task of conducting experiments. Missions to space are another challenge altogether. First, while the mission tasks can be modeled on Earth, the reality is that, until the mission is conducted in space, we may not know if our models work. For example, the assembly of small items on Earth is fairly easy. Gravity can be counted on to keep some objects in one place, and we have tremendous freedom of movement to work with tools, etc. Plus, assuming we are not working in a vacuum or under water, we don't have to worry about breathing.

Once we move off the Earth, missions become much trickier. Astronauts are likely to encounter strong vibrations, weightlessness, and a whole list of other challenges that require that space-based missions are designed quite differently from missions done on Earth.

The projects in this section address the challenge of designing space-based missions.

Cockpit design

Did you know? Thistles and cockle burrs were critical to the development of Velcro, a valuable component in manned space missions.

Background Pilots of spacecraft need to perform many actions under conditions of extreme vibration and forces on their bodies. This activity explores optimal cockpit design for use in these conditions.

Activity Explore the layout of various cockpits used for manned missions throughout history. What are the factors that need to be considered when designing a good cockpit? What are the optimal layouts for controls, gauges and other displays? What information is best conveyed through voice, and which information is best communicated through switches and dials? Take into consideration spacecraft vibration when the rockets are on, and the need to be able to operate equipment while wearing a spacesuit (in the event of a loss of cabin pressurization).

Old space shuttle cockpit view (NASA)

Compare and contrast the design of cockpits for space travel with those used in commercial aircraft. What is similar, what is different? What accounts for the differences?

Duration 1-2 weeks

Resources NASA, other online resources.

Benchmarks STEM

Desired Student Outcome Students will know how cockpit design is influenced by the nature of the craft being flown based on complexity of the needed controls, craft vibration, ground control, and other factors.

Designing a payload for unmanned launch

Did you know? Sputnik, the first satellite, had a mass of only 83.6 kg when launched in 1957. Fifty years later, the Jules Verne vehicle carried 4600 kg of materials to the ISS.

Background This activity explores the functional and environmental factors that determine the design of various payloads (e.g., weather satellites)

Activity Consider a communication satellite being designed for geosynchronous orbit at a height of 35,000 km above the Earth. What shape should the satellite have? How will it be powered? How will it maintain proper orientation to the Earth? What (if anything) is likely to damage the satellite? How long can the satellite be expected to function properly? What design considerations are likely to extend the useful life of a satellite?

Duration 1-2 weeks

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students will learn how the design of a satellite is driven by its function, power requirements, and other factors.

ISS project design

Did you know? The US component of the International Space Station (ISS) has been declared a national research laboratory.

Background This activity explores projects that pertain to microgravity environments.

US National Laboratory on the ISS doing research on 3D-printed human tissue (NASA)

Activity The ISS is set up to conduct research on topics for which the near absence of gravitational attraction is essential. Given that the ISS is only 400 km from the surface of the Earth, why is the force of gravity negligible in this laboratory? What factors are important when designing research projects for the ISS? What kind of experiments using living organisms are suitable for the ISS? What kinds of experiments using non-living materials or processes are appropriate for the ISS? How long should research projects take? How long do scientists stay aloft in the ISS before returning to Earth? Does this influence the kinds of experiments that are done?

Duration 1 week

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students will learn the kinds of experiments that are being conducted in the microgravity environment of the ISS, and why these experiments can not be done on Earth.

Design your own ISS project

Did you know? Several countries conduct numerous experiments on the ISS that can not be conducted here on Earth.

Background Create a project of your own design that could be sent to the ISS

Activity Think of a research project that would make sense to be done on the International Space Station. How long would the experiments take? What special apparatus and materials would have to be sent to space? How could the weight and size of the experiment be minimized to minimize cost? If the experiment can be done for you by someone following your directions, prepare the instruction document. What results do you think your experiment would produce? What would be the benefits of this project?

Duration 2 weeks

Resources General internet research

Benchmarks STEM

Desired Student Outcome Based on the previous project, students will learn how to design an experiment of their own that might be conducted on the ISS.

Design and build a crew exploration vehicle (CEV)

Did you know? Crew vehicles have different shapes depending on their applications. Surface rovers look like cars, and the current space shuttle looks like a flying moving van.

Background Design and build a model of a crew exploration vehicle (CEV) for use on the Moon.

Lunar rover from Apollo 15 (NASA)

Activity Once we land on another surface (e.g., the Moon) it is useful to have a vehicle that can carry astronauts and equipment to various locations.

Assuming you are going to the Moon, what are the factors you should consider when designing your vehicle? (surface texture, size of obstructions, etc.) What sorts of experiments do you want to be able to conduct from this vehicle? How fast should it go? Should it have living quarters, or be more like an automobile? How should it be powered? What kinds of tools would it need to carry if you needed to fix it? How and why does your design differ from a vehicle you would use on the Earth?

Build a scale model of your CEV. This can be a static model, or one that actually moves.

Duration 2 weeks

Resources General internet research

Benchmarks STEM

Desired Student Outcome Students will explore the criteria needed to design a CEV for use on the moon, and will build a model of their design highlighting its various features.

Ground control training for shuttle launch

Did you know? It takes a huge ground crew to safely launch missions into space. Each member of the team has to think quickly and solve problems as fast as they emerge.

Background This activity takes you through a shuttle launch countdown where you have to make decisions based on problems that arise. This activity uses the KLASS software listed in the resources section.

Activity The ground control and launch team play an essential role in any shuttle launch. The web-based simulation listed below takes you through a description of the many systems involved with the shuttle, and provides a simulated countdown to launch during which various challenges arise. You and your group will need to decide how best to handle the challenges you are presented. Many of the challenges relate to things that have happened on real shuttle launches, so this software provides you with real tasks.

As you conduct the launch, and afterwards, what challenges do you think are the most difficult to handle? What are the consequences of some of these challenges if they are ignored? What kinds of challenges require that the launch be canceled? What happens to the crew if the launch is delayed for a long period of time?

Duration 2 weeks

Resources http://www.nasa-klass.com/

Benchmarks STEM

Desired Student Outcome Students will appreciate and demonstrate the kind of thinking that is used by actual ground control team members and develop an appreciation for the challenges associated with the launch of the space shuttle.

Shuttle launch simulation

Did you know? When Apollo 13 encountered problems on the return to Earth, the team on the ground worked with the crew to find a solution that allowed them to return safely.

Background Explore the role of the ground team in launching the Space Shuttle. As with the previous activity, this activity also uses the KLASS software.

Activity A successful mission is in the hands of many people who never leave the Earth, including the team that launches the shuttle itself. This activity lets you become part of the launch team for a simulated shuttle launch using NASA software. You will be monitoring one critical aspect of the flight (health of the astronauts, environmental control (cabin environment), weather, main engines, and solid booster rockets. During the countdown, problems may arise that require delaying the launch until they are fixed. Your concern is the safety of the crew, and preservation of the mission.

This activity uses special software from Kennedy Space Center and requires a specialized hookup of multiple computers in the Space Exploration room.

Duration 3-4 weeks

Resources http://www.nasa-klass.com/

Benchmarks STEM

Desired Student Outcome Students as a class will assume the roles of actual launch team members, each using a computer geared to specific systems that must be monitored. They will demonstrate the ability to make complex decisions under pressure in order to assure the success of the mission and the safety of the crew.

Spaceports and space tourism

Did you know? Some people predict that hotels will be built in space sometime in the next ten years.

Background Today a big trip often starts at an airport. Perhaps you and your family are headed to a vacation destination, or are going to visit relatives who live far away. Depending on the size of your local airport, planes may be landing and taking off for points all over the world. While not as well known (yet), there are several facilities under construction as spaceports – places where you may someday go to be launched into orbit around the Earth, to spend a few days in a space hotel, or perhaps even travel to the Moon and beyond. Unlike space programs funded by the world's governments, these flights will be provided by commercial carriers – companies like Virgin, for example.

Rendering of the Orion Span space hotel

Activity If you were designing a spaceport, how would it work? What kinds of shops would you have for passengers to visit? What would be sold there? If you have restaurants in your spaceport, what kinds of food would they serve?

Before you take off in a commercial airplane, a safety message is read to the passengers. What kind of safety message would you write for passengers of a commercial spacecraft? How would meals be served on board in a weightless environment? How would your spacecraft dock to a space hotel?

If you were to design a hotel for space, what services would it offer? How would guests get to their rooms? Where would they put their clothes and other items they brought with them?

Duration 1 week

Resources General internet research, http://www.virgingalactic.com/

https://www.dezeen.com/2019/08/29/space-hotel-architect-von-braun-space-station

Benchmarks STEM

Desired Student Outcome Students as a class will explore the emergence of commercial spaceports and the idea of space tourism, including the challenges of building hotels and other recreational facilities in space

Is space empty?

Many people think of space as being empty. While it is devoid of a gaseous atmosphere such as we have on Earth, it is far from empty. Space is occupied with various kinds of radiation, subatomic particles, small mineral rocks, various satellites and human-made equipment. Because of the lack of a dense atmosphere in space, many of these objects are free to move without burning up or being absorbed by the gas layer that protects us on the Earth.

The activities in this topic examine the “emptiness” of space, leading students to a better understanding of what occupies the vast regions between stars and planets.

Is space a vacuum?

Did you know? The higher you get from the Earth, the less air there is to breathe. This presents a problem for some people who live at sea level when they visit cities at high altitudes (*e.g.*, Denver, Colorado)

Background This project explores the transition from Earth's atmosphere to the vacuum of space.

Activity Our planet is covered with a thin layer of gas. At sea level, most of the gas is nitrogen (78%), and 21% is oxygen, with other gases available in much smaller amounts. How does the composition of earth's atmosphere change as altitude is increased? What gases are more concentrated at sea level? Which ones are more concentrated at higher altitudes? What determines where various gases might be located? What roles does our atmosphere play in our lives? How high can humans go above sea level and still breathe without special equipment? Some people experience "altitude sickness" when visiting high cities (*e.g.*, Denver, Colorado, Mexico City, Mexico). What steps can people take to adjust to the atmosphere in these cities?

At what height do we reach the "edge of space?" What is the atmospheric pressure 1,000 km from Earth?

What is a vacuum? If space is a vacuum, why doesn't it "suck" the atmosphere off the Earth?

Duration 1 week

Resources General internet research

Benchmarks SM

Desired Student Outcome Students develop an understanding for atmospheric pressure and the distribution of gases at various altitudes. They also learn about the near-vacuum of space.

Is space hot or cold?

Did you know? Space suits need to provide a uniform comfortable temperature for the astronauts, even though they may get very hot or very cold on the outside depending on the presence of solar radiation.

Background This activity explores the temperature of space.

Activity Space is often described as a cold forbidding place. We are used to living in a temperate environment, and adjusting temperature for our comfort when we need to. What is temperature? How is it measured? What causes items to heat up or cool down? Can a vacuum have a temperature? If so, how can it be measured? What research has been done in the area of measuring the temperature of space?

Duration 2 weeks

Resources General internet research

Benchmarks STM

Desired Student Outcome Students learn about temperature extremes in a climate where there is no atmosphere to distribute heat from hotter to cooler regions.

What other objects are traveling through space?

Did you know? While space may not have a gaseous atmosphere, it has lots of other natural objects and radiation traveling through it.

Background This activity explores the kinds of materials and radiation passing through the vacuum of space.

Activity Nearly microscopic rock particles traveling at very high speeds can damage spacecraft. What kinds of natural objects are zipping through space in the region between the Earth and the Moon? What are their sizes and speeds? What protections are needed to keep spacecraft and astronauts safe in this environment? What kinds of radiation are found in space? Design a space suit that provides protection to an astronaut yet is flexible.

Duration 2 weeks

Resources General internet research

Benchmarks SEM

Desired Student Outcome Students learn about rapidly moving dust particles and radiation that can be a risk to astronauts working outside their spacecraft.

How are orbits changed after launch?

Did you know? The International Space Station needs periodic "boosts" to keep it in orbit because of a very slight atmospheric drag.

Background Satellites are launched in an easterly direction to take advantage of the Earth's rotation. While many different orbits are possible for satellites launched this way, there are other space journeys that require a change in orbit once the satellite has left the Earth. Some of these changes are just "boosters" to keep a satellite from decaying from a chosen orbit. Others are far more dramatic – having a satellite go from an orbit around the Earth to an orbit around the Sun. This kind of orbital change is sometimes needed for space-based telescopes. In missions to the Moon or other planets, the orbital changes are quite complex, and missions that leave our solar system are even more so. In all cases, the laws of physics remain the same, and mission designers have to do lots of calculations to find the most efficient way to get the satellite or spacecraft into the proper trajectory. It is not just a matter of steering the rocket as we would a car. This would likely require too much fuel. Instead we might need to take advantage of gravity when we can, to function as a slingshot to help move to another orbit.

Activity Research orbital changes needed for projects like the International Space station, the Chandra space telescope, and the Kepler mission. What kinds of orbital changes are needed for these projects to be successful? What kinds of engines are used to change orbits on spacecraft after they are launched?

Duration 1 week

Resources General internet research, http://kepler.nasa.gov/

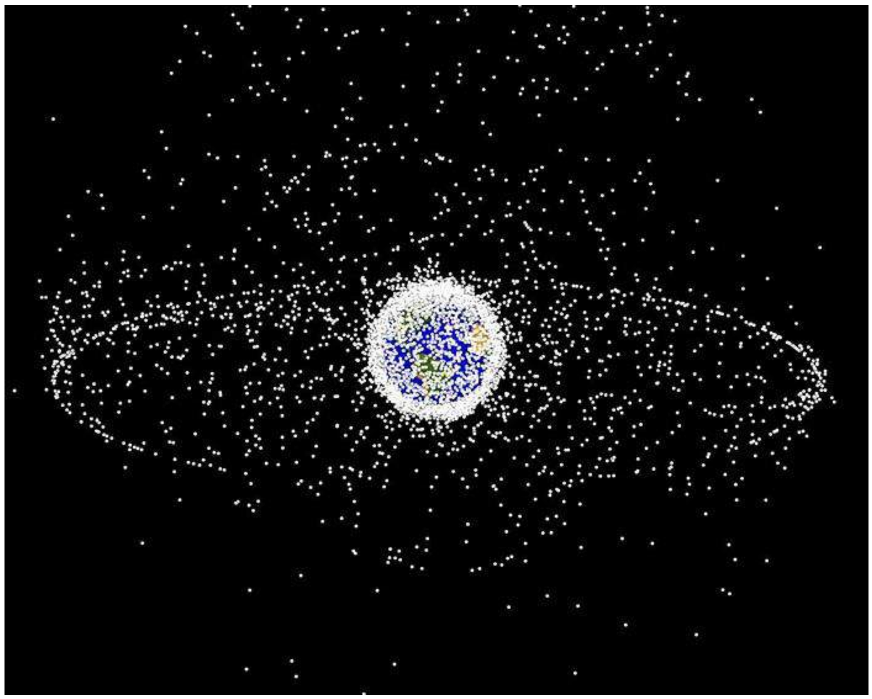
Benchmarks STEM

Desired Student Outcome Students explore the challenge of changing the orbits of spacecraft after they are launched and learn about different kinds of rocket engines that can facilitate this process.

How do we remove space junk?

Did you know? 17,000 human-made objects have re-entered Earth's atmosphere over the past 50 years. Most of them land in the ocean but some land in areas where people live. This still leaves probably 100,000 pieces of space junk in orbit where it presents danger to anyone or anything traveling in the area.

Background From small tools to "dead" satellites, there is a region of space outside our atmosphere that has lots of space junk. While the larger objects can be tracked, there are many objects too small to be easily detected. Unfortunately, these small objects can do a tremendous amount of damage. Have you ever seen what happens to a car windshield when it is hit with a small rock while driving? The damage can range from scratch to a broken window. This is a problem, even though the rock may only be traveling relative to the window at a speed of 100 km/hr. Increase the speed to a thousand km/hr, and the small rock can do tremendous damage! Flecks of paint from satellites have been known to cause pits half a centimeter deep in the windows of the US space shuttle.



NASA map of space junk greater than 10 cm in size

Activity While the space agencies of several nations have rules in place to minimize the addition of more debris in space, and some of the debris re-enters the Earth's atmosphere and burns up before reaching the ground, there is still a tremendous amount of debris to be removed.

Assuming you have been told exactly where the space junk is located, how would you remove it from space? Think about an automated process that would identify space garbage and safely remove it. What would your device look like?

Besides working hard to prevent the growth of new debris, is any nation taking an active role in cleaning up the garbage that already exists in orbit?

If you were designing a satellite that would only operate for a year, how could you design it so it would re-enter the Earth's atmosphere and burn up instead of becoming yet another piece of space junk?

Duration 1 week

Resources http://orbitaldebris.jsc.nasa.gov/

https://sst-soa.arc.nasa.gov/12-passive-deorbit-systems

Benchmarks STEM

Desired Student Outcome Students learn about the tremendous amount of space debris that can damage satellites and injure astronauts, and think about ways of safely eliminating space junk.

Space exploration instrumentation

The bulk of what we have learned from our explorations of space has come from a variety of unmanned activities conducted with satellites, Mars rovers, and other data gathering devices that send their data back to us on Earth.

It is a lot easier, and safer, to send equipment aloft than to send humans, although these missions pave the way for future human exploration in the future.

There are wonderful physical computing devices like the HyperDuino and MakerBit that can be used in the construction of working models of the kinds of systems being sent into space. With these tools, students can conduct experiments and gather data that mirror the kinds of things being explored in our own Solar system and beyond.

For example, you could design and build a working rover that makes measurements of temperature, humidity, and other characteristics as it moves around a surface. Devices of this complexity go beyond the scope of this book but we'll explore one easy project for you to explore, and leave more complex projects up to you.

Building a Mars lander

Did you know? When we land items on Mars, we usually drop them on the surface, rather than lowering them by landing a rocket.

Background A popular STEM project in many classrooms is to design a container that allows a raw egg to be dropped from a few meters to the floor without cracking the shell. This project is engaging for students and fosters creative problem solving at any grade where it is used.

What may not get explored is the fact that this is a very practical project if the challenge is to provide a soft landing for objects on another planet. For example, the landing of rovers on the surface of Mars is quite challenging (https://mars.nasa.gov/mer/mission/tl_entry1.html). When the landing starts, the equipment enters the thin Martian atmosphere at a speed of almost 20,000 km/hr and the goal is to get this speed to zero just as the package touches the Martian surface.

A combination of technologies is used to do the work, including a parachute, a heat shield, and even balloons to cushion the package when it touches down. Once the landing is complete, the package must be able to open itself so the rover can drive off to start its explorations. The failure of any step in the process can ruin the entire mission.

While it may seem to be a huge leap to go from dropping eggs to landing a rover on Mars, the underlying physics is the same: gravitational attraction provides the force bringing the package down, and this force needs to be dissipated on landing to keep anything from breaking.

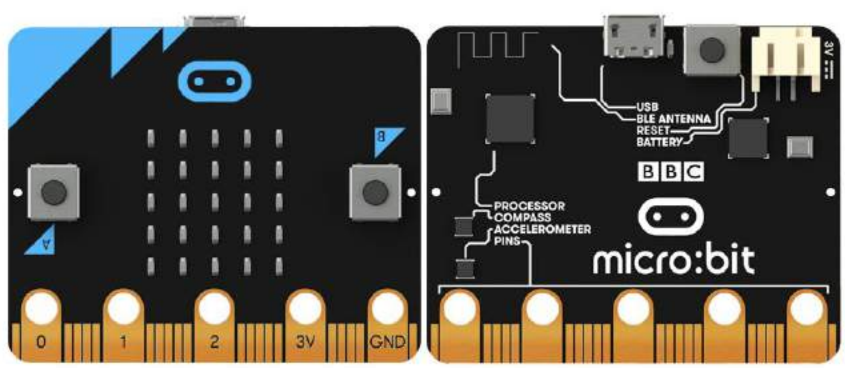
In this project, we'll design and build a "Mars lander" carrying a BBC micro:bit card containing a three-axis accelerometer whose data can be sent to a remote computer using wireless Bluetooth communication. Unlike the egg experiment, you will be capturing data over time that can be plotted in a spreadsheet and compared with other data sets associated with different types of cushioning. This data lets you refine your design and gives actual acceleration data rather than just checking to see whether or not the egg broke. The housing you design starts with no protection at all, giving you the freedom to add additional kinds of cushioning to minimize the impact of landing.

Activity The project housing was designed using BlocksCAD and you can print the final object on your 3D printer. This housing holds the BBC Microbit used to gather the data and send it using Bluetooth to your phone or tablet as a spreadsheet for analysis. Rather than go through the design process of this module, you can download the 3D printable file from here (http://www.tcse-k12.com/MarsLander.stl).

This "lander" has two holes near the top to hold a parachute or other support string used in the experiments you'll do with the finished device.

micro:bit Programming

The micro:bit programmable controller was developed with the support of BBC in the UK to bring coding of programmable devices to millions of children. The micro:bit board contains a lot of things.



micro:bit front and back

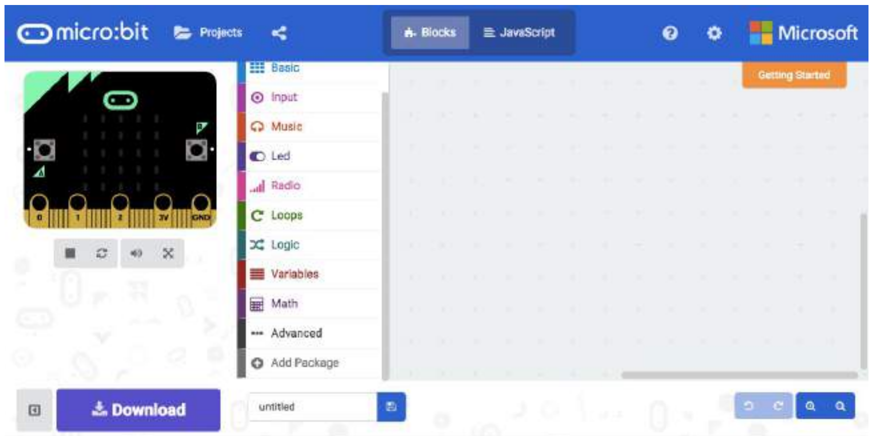
The front has two programmable push switches and a 25-LED array that can be used to display images or text. The back side contains a USB port, a reset switch, and a battery connector on the top right of this side. Also visible is a low-power Bluetooth device, a magnetometer, accelerometer, thermometer and a radio system to allow multiple micro:bits to communicate with each other, The row of pins at the bottom contains 19 inputs/outputs that can be connected to external devices,

For this project, these pins are not needed since we will be using the built-in accelerometer to measure the impact of the lander as it hits a surface after being dropped. This means that the only things that go in the housing you just made are the micro:bit and the 3V battery holder.

Several tools are available for writing programs for the micro:bit. We'll use the JavaScript Blocks Editor (https://makecode.microbit.org/) because it supports Bluetooth so we can capture data from the micro:bit accelerometer, and it uses a block programming language similar to BlocksCAD or Scratch. Our program is very easy to write.

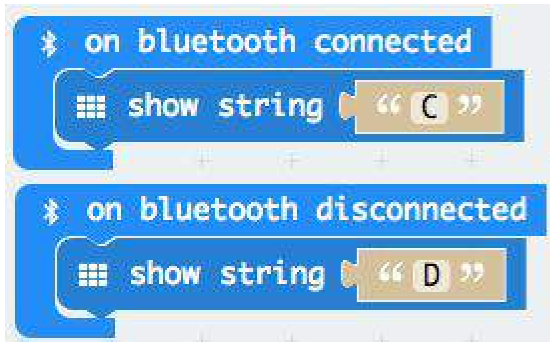
1. When you go to start a new project, you'll see three major areas of the screen . On the left is a picture of the front of the micro:bit that might be used in some simulated displayed images, or respond to button clicks. (We will not be using this feature in this project.) The middle area of the screen shows a list of various block types that can be used in your program. We'll just be using a couple of these. The right side of the screen is where your program will be assembled from different blocks, just as you've been doing with BlocksCAD.

The bottom of the screen contains a Download button that compiles your program into a "hex" file you will transfer to your micro:bit later. The line containing this button also lets you give your program a name before downloading it.

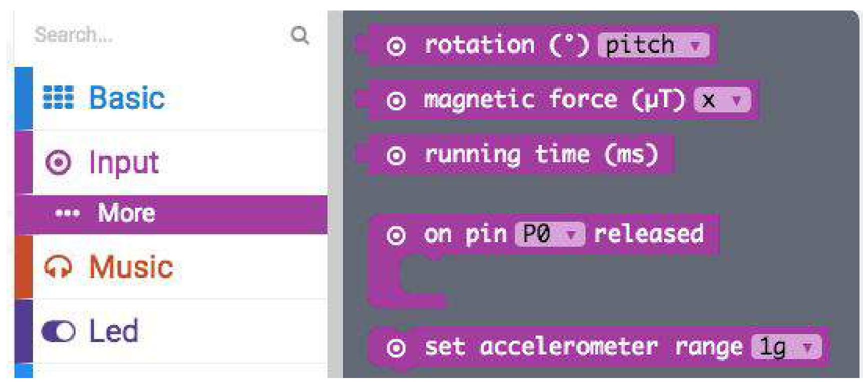


2. By default, the makecode language has a master block for the radio transceiver that allows micro:bits to communicate with each other. In our case, we want to use Bluetooth instead. The Bluetooth commands can be chosen to replace the Radio commands by clicking on the Add Package button at the bottom of the column showing various block types. This brings up a window allowing you to choose (among other things) the Bluetooth commands. You'll be told that these will replace the Radio commands since the micro:bit doesn't support both of these at the same time. Once you've made the choice, the list of command types changes to show the Bluetooth option.

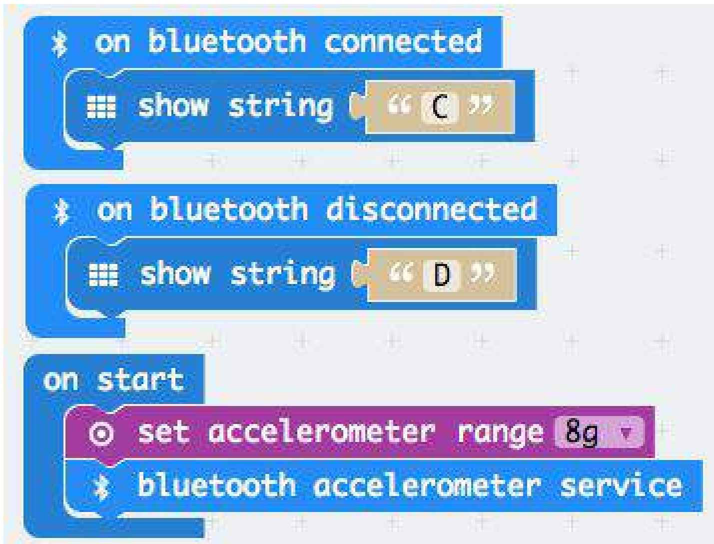
3. Now you can use the on bluetooth connected and on bluetooth disconnected blocks to show when bluetooth is connected and disconnected. One way to do this is to use the show string blocks from the Basic block list to display a letter on the built-in display. I used C when Bluetooth is connected and D when it is disconnected,



4. Next our program needs to capture data from the 3-axis accelerometer. Your data range has several options ranging from a maximum of 1 g (one times the gravitational acceleration on Earth) to 8 g. To make this setting, click on the Input item. This brings up another item called More, in which you'll find the set accelerometer range block. Click on this block to add it to your program. Once you do that, it will be greyed out because it needs a command to make it active. The default range is 1 g, and you can change this to another value (I used 8 g) with the drop down selection at the right end of this block.



5. To finish our program, add an on start block to the program from the Basic blocks and drag in the set accelerometer range block and a bluetooth accelerometer service block (found in the collection of Bluetooth blocks). This completes your program.



6. Name your program and click on the Download button to compile and download your finished program to your computer. This file will have the name of your program followed by a .hex extension.

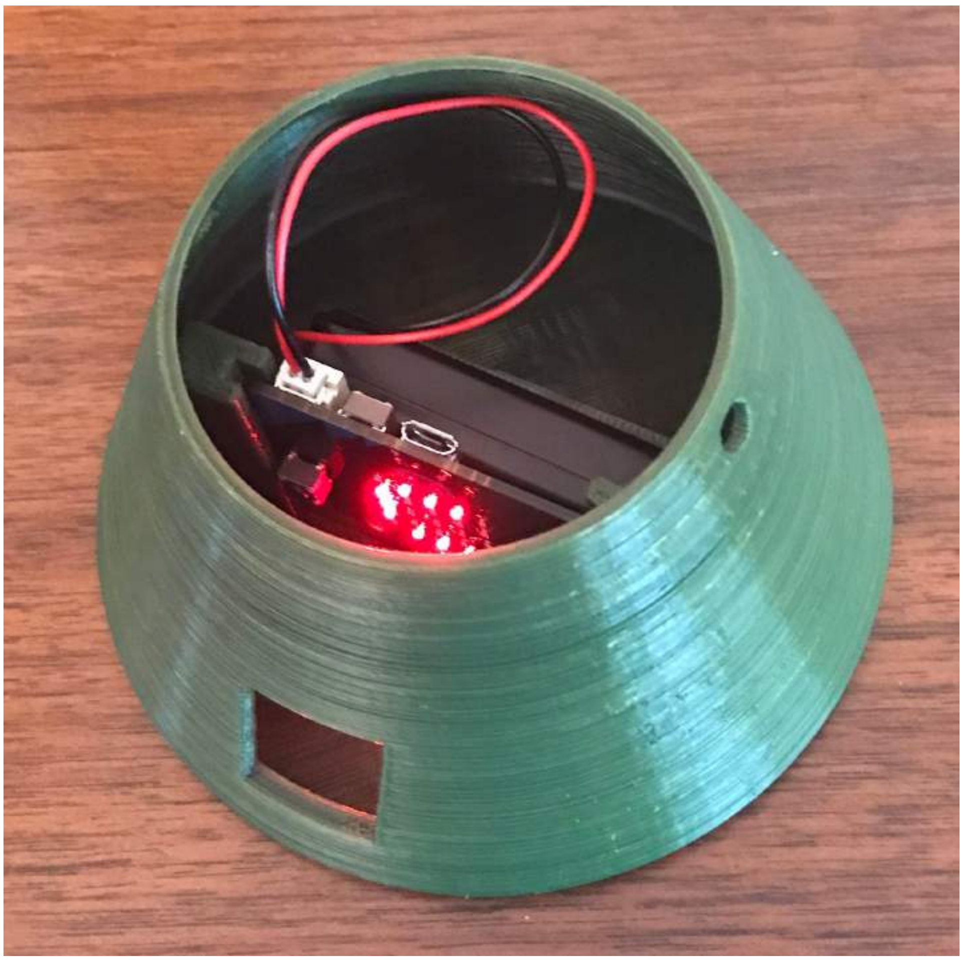
7. Connect micro:bit to USB port and drag your hex code file to the micro:bit which will show up like an external disk drive on your computer. As the file is transferring, the yellow LED on the back of the micro:bit will flash until the file transfer is complete. When you disconnect your micro:bit it will have your new program. This program will stay in your micro:bit's memory until it is replaced with another program, even when the power is disconnected.

Printing & Assembly

The printed Mars lander module has a vertical slot in the front to hold the micro:bit, and another slot right behind it to hold the battery holder. These holders keep everything in place during use, and are just the right size to make assembly easy.

The next picture shows everything after assembly.

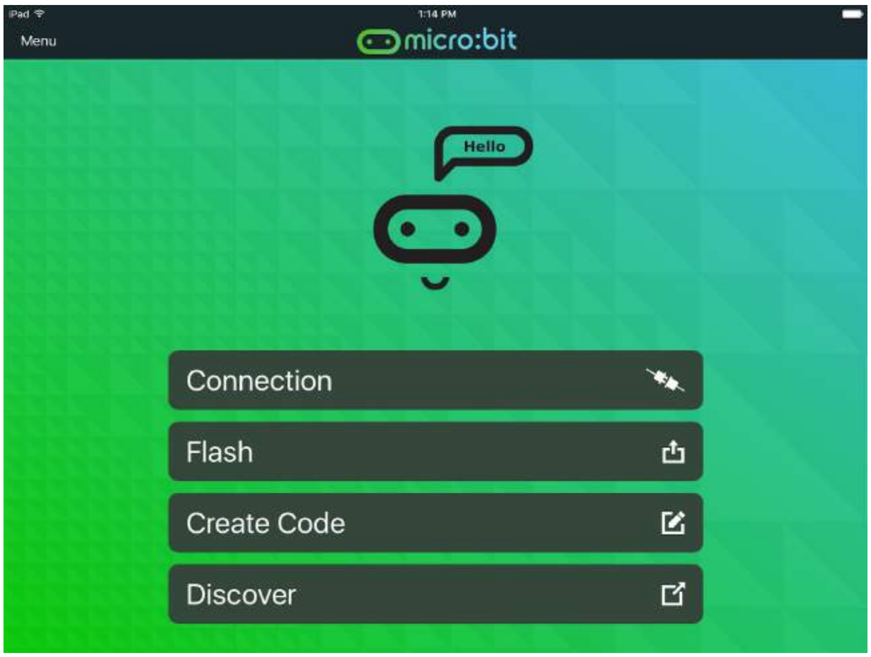
When the micro:bit is connected to the battery and the Bluetooth connection is made to an external device, the letter C will show on the LED's at the front of the micro:bit. This can be seen by looking through the rectangular window on the front of the lander. If the letter D appears, that means Bluetooth has been disconnected.



Assembled Mars lander model

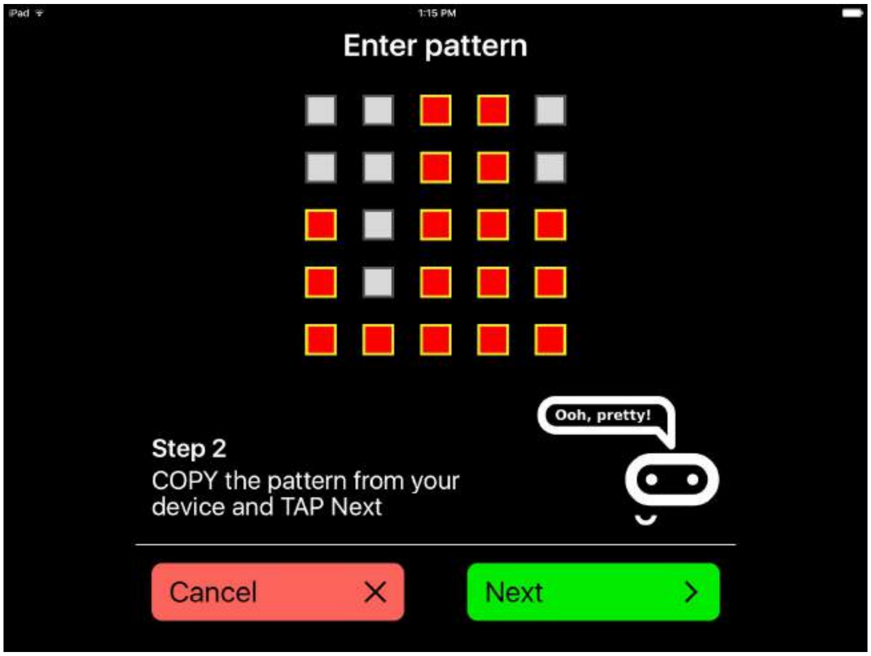
The next step is to install two apps on your smartphone,tablet, or Chromebook. The first of these is the micro:bit app. This app lets you pair your micro:bit with Bluetooth, and even write programs for your device. We'll be using it to pair the micro:bit with your tablet or phone. Be sure your device has Bluetooth turned on first!

When you launch the app the main screen appears.



micro:bit app

Click on the Connection button. This lets you start the pairing process. When you follow the directions on the next screen, you'll see the words PAIRING MODE appear on the built-in display followed by a pattern on the micro:bit display screen. Copy that pattern to the micro:bit app.



This may bring you to another screen to complete the pairing process. Once that is done, you'll see a check mark on the micro:bit letting you know you are done. And, as long as you are using the same tablet or smartphone to connect, you won't need to go through this process again.

The next app to install is the Bitty Data Logger. This app lets you capture data sent from your micro:bit over bluetooth. When you start the app, click on the Scan button. This shows any bluetooth-enabled micro:bits connected to your device.

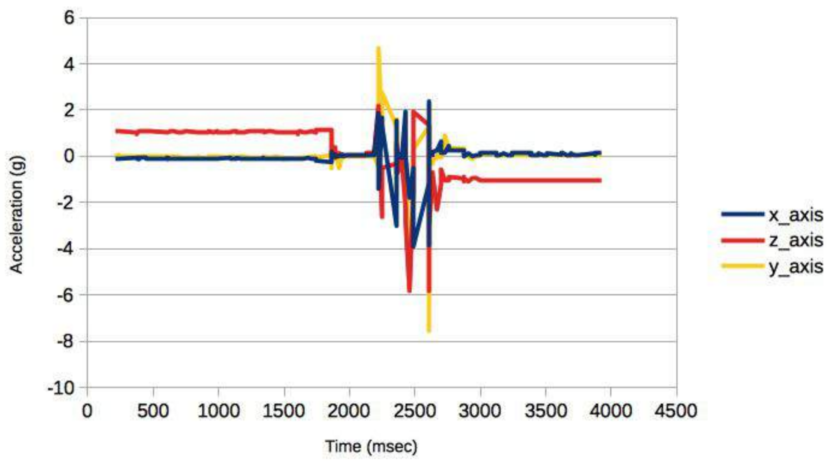
You can change the settings for data capture from the Options button.

The default settings let you export the data as a CSV file you can open with your spreadsheet program. Once you click on Scan and choose your micro:bit you'll start capturing data.

Activity To start experimenting, be sure your Mars Lander is turned on and that the Bitty Data Logger is ready to start capturing data. Initially, start by dropping the lander with the flat part facing down. Start logging the data just before it is dropped, and stop the process right after it lands. You might want to have one person drop the lander, and another one starting and stopping the data logging.

When I dropped the lander onto a carpeted floor from a height of about a meter, it produced the following data.

When the data is exported as a csv file it can be opened with a spreadsheet and plotted there for more detailed analysis.



Exported file as seen in a graph in Google Docs

As you can see, the maximum acceleration is almost 8 g's.

Here are some questions to ask at this point: What happens if you drop the lander on a hard surface (e.g., a stone floor)?

The main challenge though is to find a way to drop the lander that minimises the impact on landing. There are lots of things you can do:

- experiment with a parachute
- cushion the lander with foam
- experiment with different kinds of cushioning materials
- look into hybrid approaches (e.g., parachutes and cushions)

The goal is to see how low you can get the impact. Once the maximum impact is below 2 g's, you may want to reset the accelerometer range so the data is more detailed. As you continue your experiments (especially when using a parachute), pick a greater height from which to drop the lander. For example, dropping by a distance of one floor gives an opportunity to try different kinds of impact reduction methods.

Keep track of your results and photograph all the cushioning methods you used.

Duration 1 week

Resources

3D housing file http://www.tcse-k12.com/MarsLander.stl

http://makecode.microbit.org

BBC micro:bit go kit with battery available from several sources including: http://bit.ly/2v75eDg

Benchmarks STEM

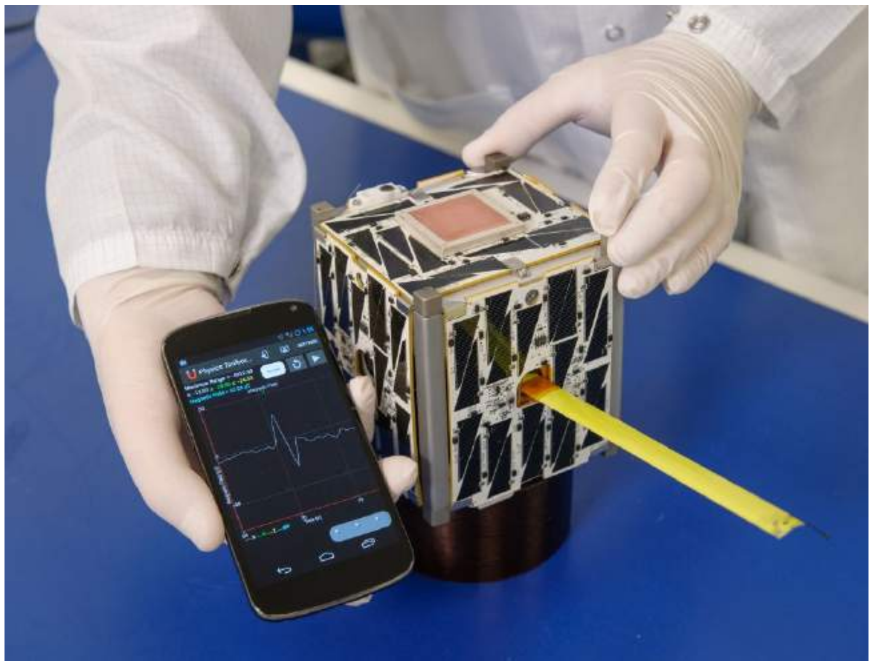
Desired Student Outcome Students learn how to cushion equipment dropped onto the surface of other planets and moons..

Building a Small Satellite

Did you know? NASA's PhoneSat project demonstrated the ability to launch the lowest-cost and easiest to build satellites ever flown in space – capabilities enabled by using off-the-shelf consumer smartphones to build spacecraft.

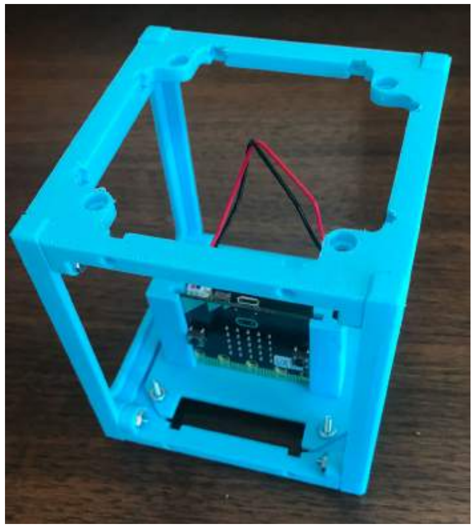
A small team of engineers working on NASA's PhoneSat at the agency's Ames Research Center at Moffett Field, Calif., aimed to rapidly evolve satellite architecture and incorporate the Silicon Valley approach of "release early, release often" to small spacecraft.

To achieve this, NASA's PhoneSat design made extensive use of commercial-off-the-shelf components, including an unmodified, consumer-grade smartphone. Out of the box smartphones already offer a wealth of capabilities needed for satellite systems, including fast processors, versatile operating systems, multiple miniature sensors, high-resolution cameras, GPS receivers, and several radios. PhoneSat 1 was launched in 2013.



Early Cubesat based on cell phone (NASA)

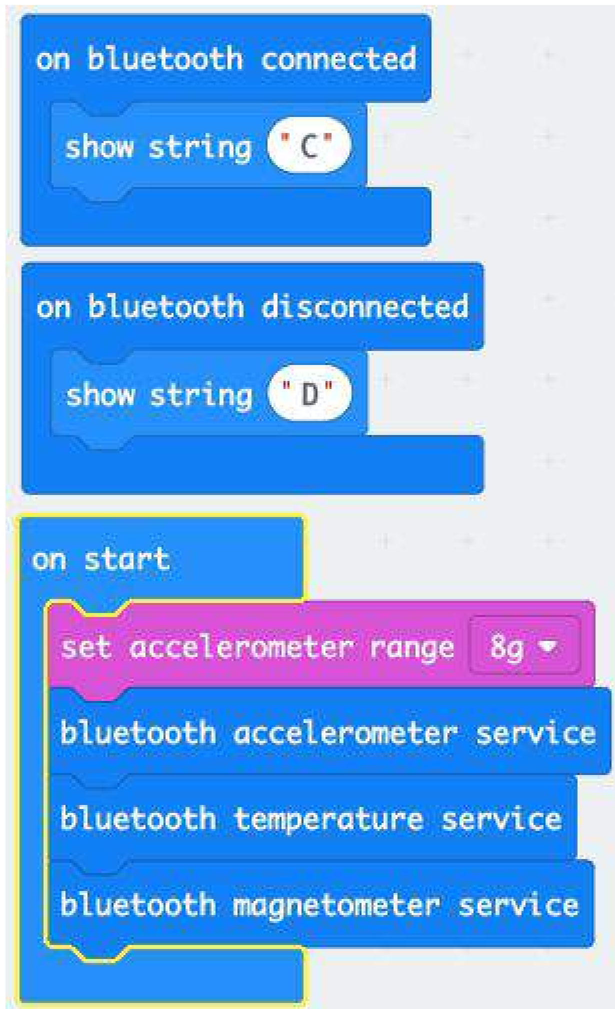
Background The development of the CubeSat by Stanford professor Bob Twigs was based on a housing 10 cm on a side, based originally on the size of a plastic box designed to hold Beanie Babies. This size provided enough surface area to hold the photocells needed to power the satellite. As with the NASA PhoneSats, most Cubesat designs are built around existing electronics. In this project, you will design your own earth-based CubeSat built around the BBC micro:bit because it is small, and has some useful sensors built in.



micro:bit Cubesat in 3D printed housing

Activity Using the STL files listed below, use a 3D printer to make two bottom pieces, two side pieces, and the micro:bit base, and assemble everything as shown in the picture above. The micro:bit base holds both the micro:bit and the 3V battery pack. If you want, you can cover the surface with solar cells like those listed in the Resources, instead of using a battery. The choice is yours.

The test program is created with MakeCode, as described in the previous activity. As before, we'll send data to your smartphone or tablet using Bluetooth using the Bitty Data Logger app. The only difference is that, in addition to capturing data from the accelerometer, we'll also get data on magnetic field and temperature.



Code for micro:bit Cubesat

Since it would cost $40,000 or so to launch your CubeSat into space, you'll be making measurements here on Earth. You should do some research on the range of temperatures and magnetic fields you would need to measure if you were in low-earth orbit. Also, when the CubeSat is launched, it would be spinning. How would you add a feature to make the satellite stop spinning and, for example, always have one side facing Earth?

Duration 2 weeks

Resources http://www.tcse-k12.com/cubesat.zip, 3D printed parts, eight 4-40 x 5/8" machine screws and nuts, four 4-40 x 1.25" machine screws, 12 4-40 nuts

optional photocells: https://amzn.to/2QfYOd1

https://www.nasa.gov/offices/oct/crosscutting_capability/edison/phonesat.html

https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf

https://spinoff.nasa.gov/Spinoff2016/ee_1.html

Benchmarks STEM

Desired Student Outcome Students will build and program a prototype CubeSat.

The search for extraterrestrial intelligence

The Drake equation is a probabilistic argument used to estimate the number of active, communicative extraterrestrial civilizations in the Milky Way galaxy.

The equation was written in 1961 by Frank Drake, not for purposes of quantifying the number of civilizations, but as a way to stimulate scientific dialogue at the first scientific meeting on the search for extraterrestrial intelligence (SETI). The equation summarizes the main concepts which scientists must contemplate when considering the question of other radio-communicative life. It is more properly thought of as an approximation rather than as a serious attempt to determine a precise number.

Criticism related to the Drake equation focuses not on the equation itself, but on the fact that the estimated values for several of its factors are highly conjectural, the combined effect being that the uncertainty associated with any derived value is so large that the equation cannot be used to draw firm conclusions.

The Drake equation is:

$$N = R_{*} f_p n_e f_l f_i f_c L$$

where:

N = the number of civilizations in our galaxy with which communication might be possible (i.e. which are on our current past light cone);

and

R_* = the average rate of star formation in our galaxy

f_p = the fraction of those stars that have planets

n_e = the average number of planets that can potentially support life per star that has planets

f_l = the fraction of planets that could support life that actually develop life at some point

f_i = the fraction of planets with life that actually go on to develop intelligent life (civilizations)

f_c = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space

L = the length of time for which such civilizations release detectable signals into space.

Looking for Goldilocks

In 2018, after nine years in deep space collecting data that indicate our sky to be filled with billions of hidden planets – more planets even than stars – NASA's Kepler space telescope has run out of fuel needed for further science operations. NASA has decided to retire the spacecraft within its current, safe orbit, away from Earth. Kepler leaves a legacy of more than 2,600 planet discoveries from outside our solar system, many of which could be promising places for life.

Kepler has opened our eyes to the diversity of planets that exist in our galaxy. The most recent analysis of Kepler's discoveries concludes that 20 to 50 percent of the stars visible in the night sky are likely to have small, possibly rocky, planets similar in size to Earth, and located within the habitable zone of their parent stars. That means they're located at distances from their parent stars where liquid water – a vital ingredient to life as we know it – might pool on the planet surface.

When the mission started 35 years ago we didn't know of a single planet outside our solar system. Now that we know planets are everywhere, Kepler has set us on a new course that's full of promise for future generations to explore our galaxy.

Launched on March 6, 2009, the Kepler space telescope combined cutting-edge techniques in measuring stellar brightness with the largest digital camera outfitted for outer space observations at that time. Originally positioned to stare continuously at 150,000 stars in one star-studded patch of the sky in the constellation Cygnus, Kepler took the first survey of planets in our galaxy and became the agency's first mission to detect Earth-size planets in the habitable zones of their stars.

The observation of over 500,000 stars allowed scientists to better understand stellar behaviors and properties, which is critical information in studying the planets that orbit them. New research into stars with Kepler data also is furthering other areas of astronomy, such as the history of our Milky Way galaxy and the beginning stages of exploding stars called supernovae that are used to study how fast the universe is expanding. The data from the extended mission were also made available to the public and science community immediately, allowing discoveries to be made at an incredible pace and setting a high bar for other missions. Scientists are expected to spend a decade or more in search of new discoveries in the treasure trove of data Kepler provided.

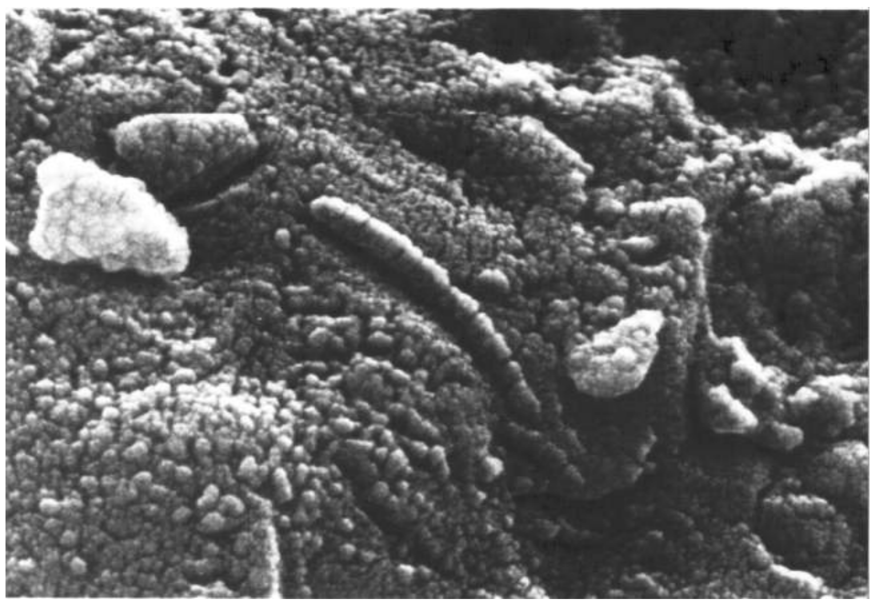
Kepler's replacement, TESS

The Transiting Exoplanet Survey Satellite (TESS) is the next step in the search for planets outside of our solar system, including those that could support life. The mission will find exoplanets that periodically block part of the light from their host stars, events called transits. TESS will survey 200,000 of the brightest stars near the sun to search for transiting exoplanets. TESS launched on April 18, 2018, aboard a SpaceX Falcon 9 rocket.

TESS scientists expect the mission will catalog thousands of planet candidates and vastly increase the current number of known exoplanets. Of these, approximately 300 are expected to be Earth-sized and super-Earth-sized exoplanets, which are worlds no larger than twice the size of Earth. TESS will find the most promising exoplanets orbiting our nearest and brightest stars, giving future researchers a rich set of new targets for more comprehensive follow-up studies.

Finding life on Mars

Did you know? In 1996, NASA scientist David McKay and his colleagues published a paper in the journal Science suggesting that evidence of fossilized bacteria may have been found in a meteorite from Mars.



Micrograph of possible bacterial fossil in the Allan Hills meteorite (NASA)

Background The structures found on ALH84001 are 20–100 nanometers in diameter, smaller than any Earth-based cellular life known at the time of their discovery. If the structures were fossilized lifeforms, as was proposed by the biogenic hypothesis of their formation, they would have been the first solid evidence of the existence of extraterrestrial life.

Activity Explore the possibility of life on other planets. NASA has several projects, including the search for life on Mars.

What would Martian life be like? Think about the Martian climate, and its lack of protection from cosmic radiation. Is it possible Mars may have had life in the past, but it became extinct millions of years ago.

Mars has seasonal plumes of methane, a known byproduct of living organisms. Is Martian methane made by living cells, or by inorganic processes?

Duration 1 week

Resources Mars methane

https://science.sciencemag.org/content/360/6393/1093

Benchmarks STEM

Desired Student Outcome Students will explore the possibility of microbial or other life on Mars.

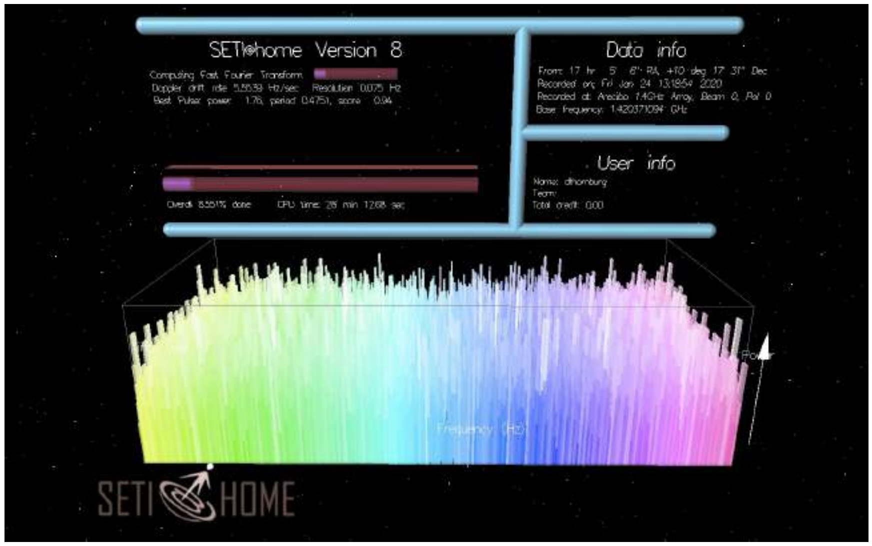
Listening for ET

Did you know? While radio waves in space are generated at many wavelengths, a relatively quiet region is at a wavelength of 21 cm, corresponding to a frequency range between Hydrogen and Oxygen. This area is known as the water hole. Since humans have long gathered around real watering holes, this frequency is quite poetic, as well as being a logical (by human standards) place to listen.

Background Since its inception, SETI has been on its quest to detect radio signals from alien civilizations, using radio telescopes around the world.

One of the largest telescopes that has been used is the Arecibo telescope in Puerto Rico.

Activity You can run the SETI@home program on your computer to analyse signals collected from various telescopes to see if any transmitted signals can be detected. This program runs in the background on thousands of computers like yours, sending results to scientists at the University of California to further analyse any possible signals you’ve found.



Of course the big challenge is to identify whether any possible signal from another planet represents a message. As the author Neal Stephenson once wrote, “All information looks like noise until you break the code.”

Duration 1 week

Resources

https://seti.org/education-outreach/life-universe-litu-curriculum-files

https://setiathome.berkeley.edu/

Snow Crash, Neal Stephenson, 1992.

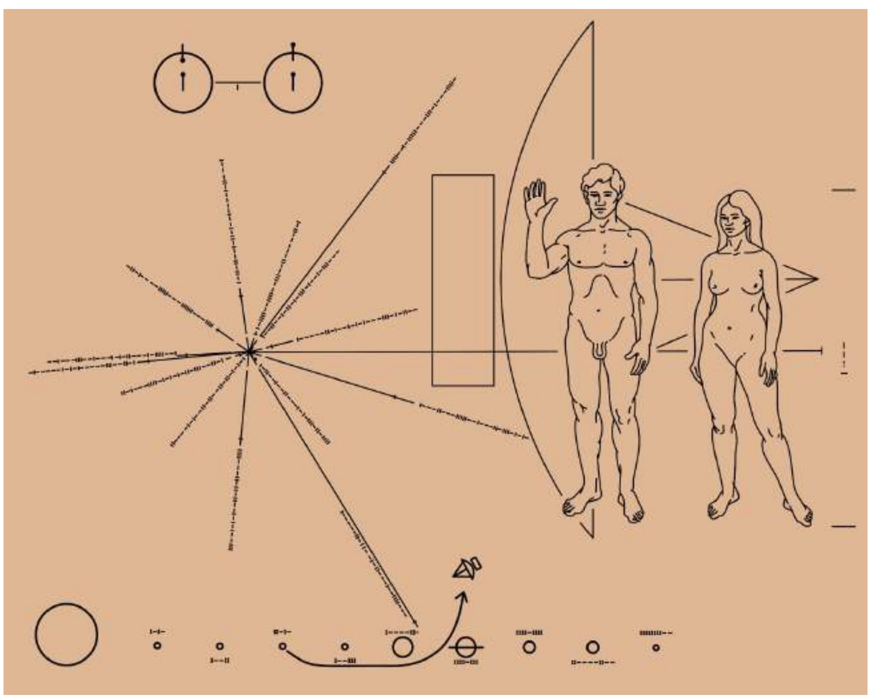
Benchmarks STEML

Desired Student Outcome Students will learn how radio signals might be used by alien civilizations to communicate with others in space.

Messaging extraterrestrial intelligence

Did you know? In the 19th century, there were several proposed schemes to communicate with Martians by using mirrors and lamps. In a New York Times article How To Signal To Mars on May 23, 1909, Nikola Tesla proposed the use of radio signals to communicate with Martians.

Background In 1983, the Pioneer 10 spacecraft was the first man-made object to leave the Solar system. This craft contained a plaque depicting human beings, the location of our planet, and other information in the hope it will be intercepted by an extraterrestrial civilization



In 1992, SETI started listening for radio signals from intelligent life on other planets. Around this time, some linguists started asking themselves how alien languages would work, and how we could learn to communicate with intelligent life forms from other planets.

Activity There are currently about 6,500 languages spoken on Earth, and some ancient writings have never been translated. Some basic questions for you to explore include the role language plays in how we think. What is the role of metaphors in understanding language? What role do epic myths play in our thinking and communication with each other? Do other animals (e.g., dogs) learn to understand our languages? Do animals (e.g., bees) use their own language to communicate with others of their species?

Duration 2 weeks or more

Resources General internet research

Star Trek Next Generation, season 5, episode 2 (Darmok) available on Netflix

Benchmarks STEML

Desired Student Outcome Students will learn to think about the structure of language itself and to build informed speculations on the languages that might be used by extraterrestrial intelligences.

Next steps

My goal in this book has been to explore a number of activities through which students can develop skills across the curriculum through the exploration of space. You are invited to modify and expand on this list of projects based on your interests and needs.

As we prepare students for the future, we need to acknowledge that new careers will be developed and that our students need new skills and the growth of creative thought needed to thrive in a world in which science fiction has become science reality. While much of the focus in this book has been on STEM skills, other subject areas (language, etc.) are just as important.