American Museum of Natural History

Educator's Guide

BEYOND PLANET EARTH

the future of space exploration

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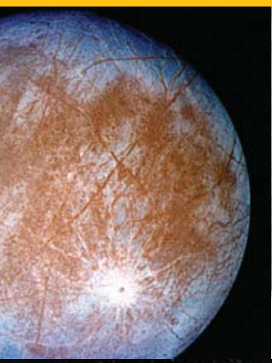
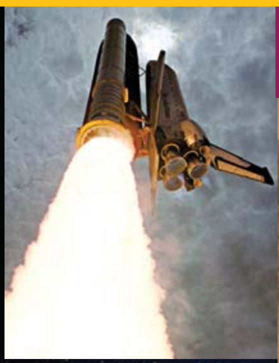




amnh.org/education/beyond

essential QUESTIONS

Ever since we first looked up at the night sky, space has captured our imagination. This exhibition is a journey across the solar system and into the future, from the first manned space mission to the colonization of Mars. **Use the Essential Questions below to connect the exhibition's themes to your curriculum.**

WHY EXPLORE SPACE?

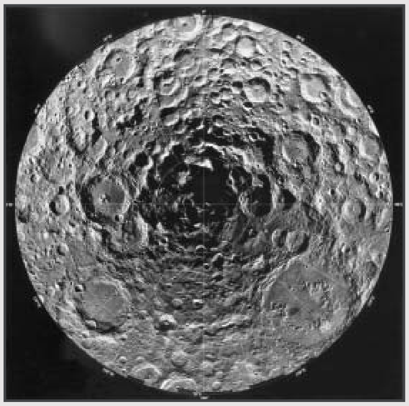
As humans, we seek to understand our world. We inhabit every continent, have planted flags at the Poles, and descended into deep ocean trenches. Looking beyond Earth, the potential for new discoveries is tremendous, but many unknowns remain. Will space tourism become commonplace? How can we protect our planet from an **asteroid** impact? Is there life beyond Earth? Can we establish a research station on the Moon? Could we make Mars habitable for humans?

HOW WILL WE EXPLORE SPACE?

People first "explored" space with the naked eye, but they observed only a small fraction of what we now know exists. The telescope brought more things into view: smaller and more distant planets, dimmer stars. Hand-held telescopes gave way to larger ones like those atop Hawaii's dormant Mauna Kea volcano, above much of the haze of the atmosphere. Telescopes like **Hubble** now orbit Earth, transmitting detailed images of the cosmos. Humans have walked on the Moon, and hundreds have lived and worked in the International Space Station. Unmanned spacecraft carry out missions too distant or dangerous for humans; the *Voyager* 1 and 2 space probes have even left our solar system.

Soon, the **James Webb Space Telescope** will look further into space than ever before, connecting our Milky Way to the Big Bang. Commercial spacecraft will take thousands of people into space — even if only for a few minutes each! What's next? Here are some possibilities, some closer to being realized than others:

Nearer term:



- **establishing a semi-permanent base on the Moon:** scientists and explorers may live for weeks or months at a time in expandable modules along the rim of the South Pole's **Shackleton Crater**.

This visualization shows how *Curiosity*'s arm would examine rocks on Mars for signs of ancient life.

- **searching for life on Mars and Europa:** scientists hope to find evidence of life beneath the Martian surface; robots may search the salty ocean of Jupiter's moon Europa for **extremophiles**.
- **discovering exoplanets:** researchers have already identified well over a thousand planets orbiting other stars, and many more such discoveries are certain. If some of these faraway worlds prove Earthlike, scientists will investigate them for evidence of life.

Longer term:

- **building a lunar elevator:** tethered to a space station, it could help transport goods and people between Earth and the Moon.
- **docking with asteroids:** astronauts could mine space rocks for **rare metals** and deflect those that might collide with Earth.
- **terraforming Mars:** one day, scientists and engineers will be able to transform the planet's surface and atmosphere, making it habitable for our descendants.

WHAT ARE THE CHALLENGES OF SPACE EXPLORATION?

Earth's atmosphere provides living organisms with breathable air and a temperate climate, and also shields us from dangerous radiation and most meteor impacts. Traveling and living beyond its protection presents massive challenges. To survive en route, we would need to bring our own air, food, and water; avoid debris; shield ourselves from high-energy radiation; and prevent the debilitating effects of long-term weightlessness. Extreme isolation and long confinements in small spaces could take a psychological toll, as could the possibility of never returning to Earth. Once at our destinations, supplies and spare parts would be severely limited, and the margin for error tiny. To protect future generations of astronauts, engineers are at work on innovations such as improved space suits and micrometeoroid shielding. Faster propulsion systems would reduce or eliminate many of these challenges — and put ever more distant destinations within our reach.

GLOSSARY

ASTEROIDS: small rocky and metallic bodies, most of which orbit the Sun between Mars and Jupiter. Meteors ("shooting stars") are small pieces of asteroids or comets that enter Earth's atmosphere, where most burn up. The few that land on Earth are called meteorites.

EXOPLANETS: planets that orbit stars other than our Sun

EXTREMOPHILES: organisms adapted to harsh environments, including extreme cold, dryness, radiation, darkness, and chemicals that would be toxic to most other organisms. Examples on Earth include bacteria in the cooling pools of nuclear reactors, in hydrothermal vents on the ocean floor, and in the dry valleys of Antarctica.

HUBBLE SPACE TELESCOPE: a telescope launched in 1990 into low-Earth orbit, whose detailed images of cosmic objects have led to many important discoveries. Hubble's cameras detect ultraviolet, visible, and infrared light.

JAMES WEBB SPACE TELESCOPE: scheduled to launch in 2018 and designed primarily to detect infrared light, this large telescope will observe extremely distant objects — including the first stars and galaxies that formed in the universe.

POTENTIALLY HAZARDOUS OBJECT: any near-Earth asteroid or comet that is longer than 150 meters (500 feet) and that comes within 8 million kilometers (5 million miles) of Earth's orbit

RARE EARTH METALS: a group of metals that have many commercial uses but are expensive to mine on Earth

SHACKLETON CRATER: a crater near the Moon's South Pole that contains ice. The rim, which has abundant sunlight, has been proposed as a possible location for a lunar base camp.

TERRAFORM: the process of making another planet or moon more Earthlike

COME PREPARED

Plan your visit. For information about reservations, transportation, and lunchrooms, visit **amnh.org/education/plan**.

Read the Essential Questions in this guide to see how themes in *Beyond Planet Earth* connect to your curriculum. Identify the key points that you'd like your students to learn from the exhibition.

Review the Teaching in the Exhibition section of this guide for an advance look at the specimens, models, and interactives that you and your class will be encountering.

Download activities and student worksheets at **amnh.org/resources/rfl/pdf/beyond_activities.pdf**. Designed for use before, during, and after your visit, these activities focus on themes that correlate to the NYS Science Core Curriculum:

K–2: Objects in the Sky
3–5: Observing Our Solar System and Beyond
6–8: Modeling the Solar System
9–12: The Future of Space Exploration

Decide how your students will explore *Beyond Planet Earth*. Suggestions include:

- You and your chaperones can facilitate the visit using the **Teaching in the Exhibition** section of this guide.
- Your students can use the **student worksheets** to explore the exhibition on their own or in small groups.
- Students, individually or in groups, can use copies of the **map** to choose their own paths.

CORRELATIONS TO NATIONAL STANDARDS

Your visit to the *Beyond Planet Earth* exhibition can be correlated to the national standards below. See the end of this guide for a full listing of New York State standards.

Science Education Standards

All Grades • A2: Understanding about scientific inquiry • E1: Abilities of technological design • E2: Understanding about science and technology • F1: Personal health • G1: Science as a human endeavor

K–4 • B2: Position and motion of objects • D2: Objects in the sky • D3: Changes in Earth and sky • F3: Types of resources

5–8 • B2: Motions and forces • D3: Earth in the solar system • F2: Populations, resources, and environments • F3: Natural hazards • G3: History of science

9–12 • B4: Motions and forces • D2: Objects in the sky • D3: Changes in Earth and sky • E4: Origin and evolution of the universe • F3: Natural resources • G3: Historical perspectives

teaching in the **EXHIBITION**

What would it be like to travel beyond Earth? Starting with the Moon, our closest neighbor, and heading out across our solar system, this exhibition uses models, artifacts, videos, dioramas, and hands-on and computer interactives to immerse visitors in the high-stakes adventure of space exploration. **The main sections of the exhibition represent different destinations in space.** Have students explore each environment, and consider how scientists and engineers would approach the unique challenges that each presents.

HISTORY OF SPACE EXPLORATION

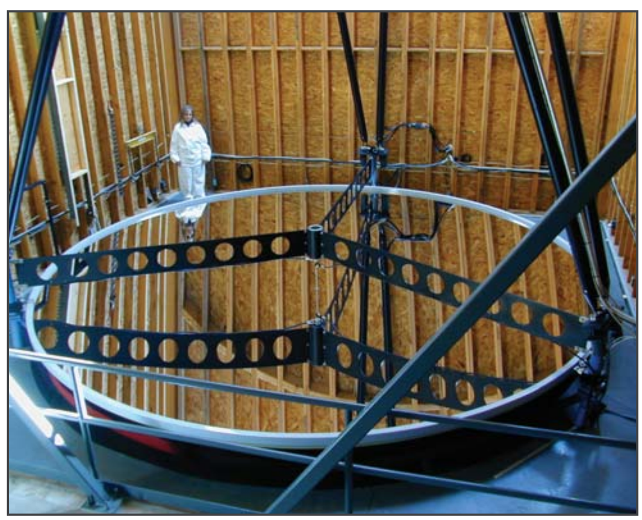
As you enter, examine some **artifacts of manned and unmanned space voyages**, which include models of *Sputnik* and a Mars Rover, and a diorama depicting the final Hubble Space Telescope upgrade. Have students watch the six-minute film in the theater, and then discuss which destinations they find the most intriguing.

DESTINATION: MOON

OVERVIEW: The historic *Apollo* missions of the 1960s and '70s brought back rocks that taught us a great deal about the history of the Moon — and of Earth. Astronauts visited the surface of the Moon, but only for a few days at the most. The next step could be to establish a semi-permanent scientific research station. Have students imagine what it would be like to live and work in this desolate environment. Encourage them to look for their home planet in the sky.

CHALLENGES & APPROACHES:

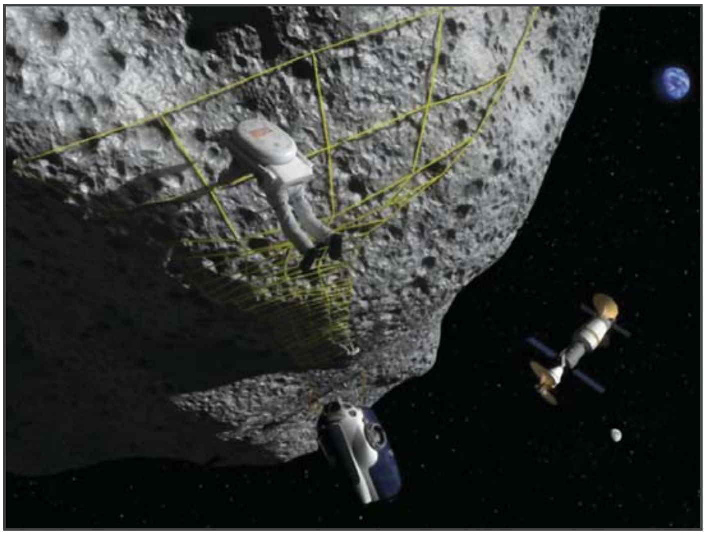
- **Base Camp, Moon's South Pole:** Have students explore this lunar crater and consider why scientists think the rim would be a suitable location for a base camp. Ask what hazards astronauts would face on the surface of the Moon, and how they could protect themselves.
  (Answers may include: The expandable spacecraft would shelter astronauts from solar radiation and meteoroid barrages, keep them warm, and provide air to compensate for the Moon's lack of atmosphere.)
- **Liquid Mirror Telescope Interactive:** Ask students what problems astronomers confront when using tele-scopes on Earth's surface.
  (Answers may include: haze of the atmosphere, rain clouds, light pollution)
  What makes conditions on the Moon more favorable for astronomy?
  (Answers may include: On the Moon, there is no atmosphere to obstruct visibility, and no wind or weather to affect telescopes.)
- **Lunar Elevator Model:** Held in place by gravity, this solar-powered elevator would travel between a space station and the Moon. Ask the class to consider the advantages of an elevator over a rocket.
  (Answers may include: Launching rockets from Earth or the Moon is expensive. And if we ever had a base on the Moon, we'd have to do that an awful lot to get materials to and from the Moon and back to Earth. While building a lunar elevator would be really expensive at first, it might prove less pricey in the long-term, since it would use little power once built.)
  Have students find information that helps them imagine what a trip on this "space elevator" might be like.



This liquid mirror telescope, the largest on Earth, is 6 meters (20 feet) across. On the Moon, undisturbed by wind or weather, the surface could be larger than a football field.

DESTINATION: ASTEROIDS

OVERVIEW: Most asteroids orbit between Mars and Jupiter, but some cross Earth's orbit. Collisions are rare but can be devastating, so scientists are developing technologies to deflect near-Earth asteroids (NEAs). Some asteroids may also contain rare Earth and other valuable metals.



This is an a illustration of a possible system for anchoring to the surface of an asteroid.

CHALLENGES & APPROACHES:

- **Itokawa Model:** Invite students to examine a model of this NEA and the robotic Japanese spacecraft that docked with it. Ask them to think about what it would be like to study an object that has so little gravity that they couldn't stand on it.
  (Answers may include: Although Itokawa is 1770 feet (540 meters) long, it is too small for a spacecraft to orbit. The craft would have to hover over the asteroid, and astronauts would have to tether themselves to its surface in some way.)
- **Potentially Hazardous NEAs:** Suggest that students use the interactive kiosk to explore different ways to alter an asteroid's course. If an object looks like it might collide with Earth, what could we do about it?
  (Answers may include: An atomic bomb might seem like the best, but actually bombing an asteroid could make things worse by breaking up the space rock into lots of pieces that then would all impact Earth. There are other options like a "gravity tractor," which is a spacecraft that would use its gravity to pull the asteroid off course over a long period of time.)

DESTINATION: MARS

OVERVIEW: Mars is more likely to harbor life than any other known planet. Features like immense dry riverbeds hint at an ancient environment that could have supported life — and still might, if liquid water exists below the surface. Orbiters have mapped the entire Red Planet, rovers and probes have studied the surface in detail, but no humans have traveled there. Some scientists wonder whether, in the distant future, we might make this dusty planet habitable for humans.

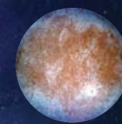
CHALLENGES & APPROACHES:

- **Getting There and Daily Life:** On the outbound journey, astronauts might spend six to nine months in very tight quarters, coping with the effects of weightlessness and solar radiation. Have students explore this section to see how people could stay safe and healthy (and keep stuff from floating away).
  (Student observations may include: Our bones and muscles are used to fighting gravity, and exercise is essential to keep them strong in space. Spinning compartments for sleeping would generate artificial gravity and help prevent bone loss and other health problems. Shielding and emergency shelters would protect astronauts from deadly solar radiation.)
- Have them take the Mars Personality Test to see if they have what it would take to reach the Red Planet and live and work there.
  (Student observations may include: Traveling to Mars would mean sharing a small space with other people for many months, which requires patience, an easy-going temperament, and a sense of humor. Astronauts would also need to be able to follow detailed instructions and make quick, independent decisions.)
- **Mars Explorer and Mars Environment:** Have students use the interactive to examine the surface of Mars. Ask what features they observe that Mars shares with Earth.
  (Answers may include: Like Earth, Mars has volcanoes, canyons, polar ice caps, and many places where liquid water once flowed on the surface.)
  In what ways are the two planets very different?
  (Answers may include: The surface of Mars is dry and barren, and has no liquid water.)

- ***Curiosity* Mars Rover:** The primary mission of this roving science lab is to search for signs of habitable environments. Ask students what kinds of tools *Curiosity* carries, and what they measure. *(Answers may include: The one-ton robot is packed with tools, including 3-D cameras that rotate in every direction; a laser beam that vaporizes rock samples for analysis; a robotic arm that analyzes rocks, digs holes, and scoops up samples; and a weather station that monitors wind, temperature, humidity, and air pressure.)*
- **Terraforming Table:** Explain that terraforming is the process of making a planet more Earthlike so that it could become habitable for humans. Ask students to investigate how to turn this cold and barren planet into a wet, warm, fertile world. *(Answers may include: Terraforming would involve many stages, such as adding heat to release frozen water and carbon dioxide to trigger the greenhouse effect that keeps Earth warm; inserting life (hardy lichens, algae, and bacteria first) that would begin building soil and enriching the atmosphere; releasing liquid water; and making an oxygen-rich atmosphere.)*

These illustrations show how, over hundreds or even thousands of years, Mars might be transformed from a frigid, barren planet into a warm and fertile one like Earth.

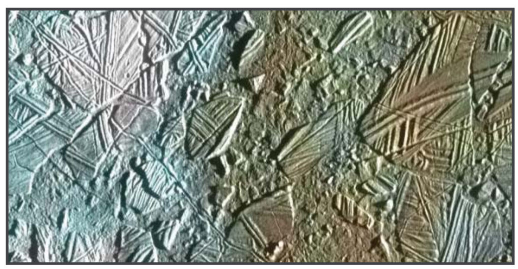
DESTINATION: EUROPA



OVERVIEW: The giant planets of the outer solar system — Jupiter, Saturn, Uranus, Neptune — together have more than 160 moons. One of Jupiter's moons, Europa, intrigues scientists because they think it may have a deep saltwater ocean that could contain life.

CHALLENGES & APPROACHES:

- **Europa Theater and Model of Submersible:** Ask students to think about this moon's unique environment. Have students watch the six-minute movie and reflect on how this mission would compare to journeys to Mars or the Moon. *(Answers may include: Robots may someday search for life in Europa's ocean, but such a mission is probably decades away. A manned voyage would be even farther in the future because Europa is so far away — a 17-year trip by Apollo spacecraft.)*



An enhanced color photograph of Europa's cracked ice surface.

BEYOND: All the places that your class has explored so far belong to our own solar system. But **scientists have already found evidence of over 1,000 other solar systems** — stars with planets orbiting them — in our Milky Way galaxy alone. How many more remain to be discovered?

As students experience the holographic representation, ask them to think about other worlds we may explore someday. What do they imagine we might find?

online RESOURCES

OUR MOON
sciencebulletins.amnh.org/?sid=a.v.moon.20061004
This visualization shows how a violent collision could have given birth to our Moon in just one month.

GEOLOGISTS ON MARS
sciencebulletins.amnh.org/?sid=a.f.mars.20040401
This 8-minute video describes the 2004 Mars Exploration Rover mission that found evidence of liquid water.

IMPACT! TRACKING NEAR-EARTH ASTEROIDS
sciencebulletins.amnh.org/?sid=a.f.nea.20050504
This 7-minute video explores the risks of an asteroid hitting Earth, and how astronomers track the orbits of near-Earth objects.

PLANETARY MYSTERIES
amnh.org/ology/planetology
Learn how scientists study our solar system, and about some of the big questions that remain unanswered.

SPACE TRAVEL GUIDE
amnh.org/ology/spacetravel
This drawing and storytelling activity helps kids combine fact and fantasy on a trip to outer space.

A CLOSER LOOK AT MARS
amnh.org/ology/closer_look_mars
Kids help reporter Stella Stardust learn more about Earth's closest neighbor.

ARE YOU CUT OUT FOR MARS?
amnh.org/ology/mars_quiz
Kids can take this quiz to see if they're up for the challenge.

IN PICTURES: BEYOND PLANET EARTH
amnh.org/ology/inpics_beyond
This photo gallery illustrates some of the places in our solar system that humans might someday explore.

JOURNEY INTO SPACE: GRAVITY, ORBITS, AND COLLISIONS
teacher.scholastic.com/activities/explorations/space
This interactive introduces students to the ways in which gravity shapes the universe.

NASA: EXPLORATION
nasa.gov/exploration
Feature stories about missions, discoveries, and other initiatives describe the next era of space exploration.

NASA: FOR STUDENTS
nasa.gov/audience/forstudents
This NASA portal offers current science content, activities, events, images, podcasts, educational video segments, and more.

GOOGLE EARTH
google.com/earth
Now you can use Google Earth to view stars, constellations, and galaxies, as well as the surfaces of Mars and the Moon.

DID YOU KNOW?

When you're in space, the sky looks black because there's no air for visible light to bounce off of.

Space is silent. We hear because of pressure waves in the air, and there's no air in space.

Everything in the universe — planets, asteroids, and even black holes — gives off light. But almost all of it is at wavelengths that our eyes cannot see.

The light that we see from stars has taken years — typically millions and sometimes billions of years — to reach us. For example, if a star 100 million light years away exploded today, people on Earth wouldn't see the explosion for 100 million years.

CREDITS

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BEYOND PLANET EARTH the future of space exploration

MAP OF THE EXHIBITION

What would it be like to travel beyond Earth?
Starting with the Moon, our closest neighbor, journey across our solar system and into the future in this adventure of space exploration.

① **HISTORY OF SPACE EXPLORATION**
Examine some artifacts of manned and unmanned space voyages.

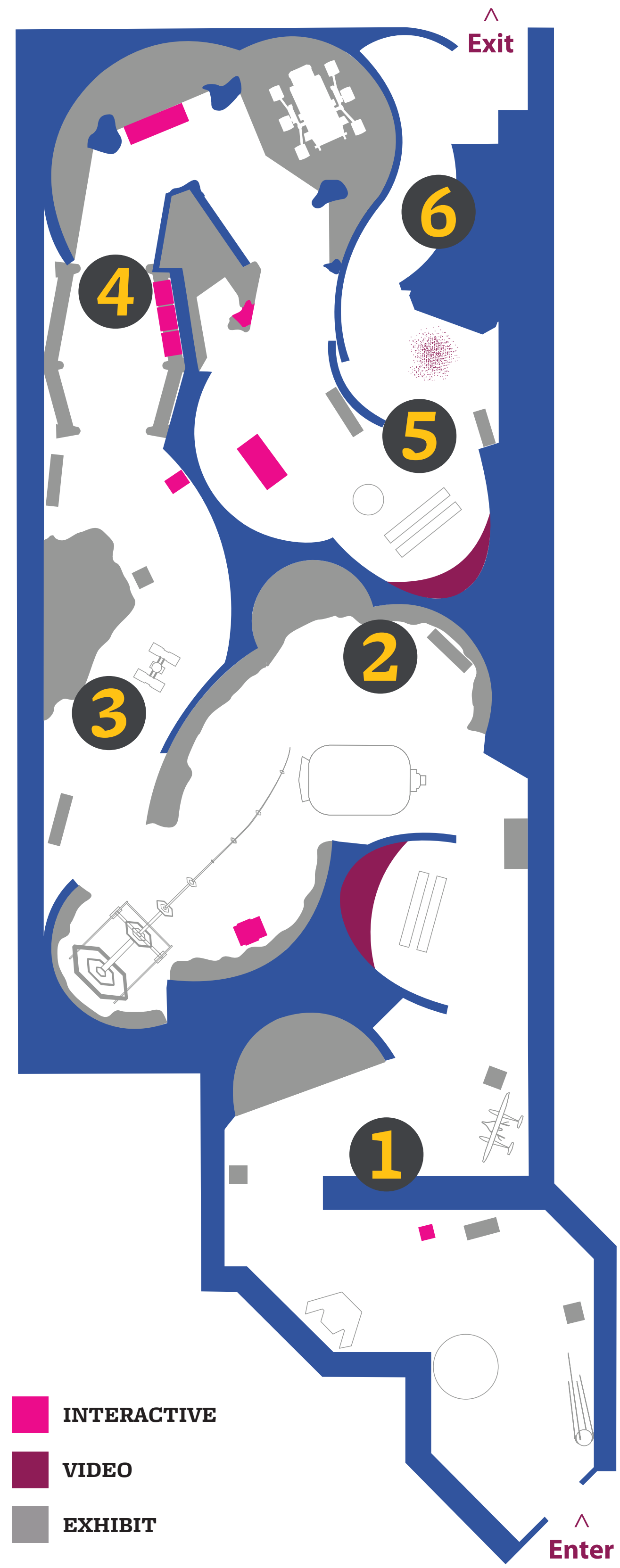
② **MOON**
Astronauts of the 1960s and '70s visited the Moon, but only for a few days at the most. The next step could be to establish a semi-permanent scientific research station. What would it be like to live and work there?

③ **NEAR-EARTH ASTEROIDS**
Most asteroids orbit between Mars and Jupiter, but some cross Earth's orbit. Collisions are rare but can be devastating. How would we deflect near-Earth asteroids that get too close for comfort?

④ **MARS**
Mars is more likely to harbor life than any other known planet. Features like immense dry riverbeds hint at an ancient environment that could have supported life. Could we someday make this arid planet habitable for humans?

⑤ **EUROPA**
One of Jupiter's moons, Europa, intrigues scientists because there is likely a saltwater ocean. Could there be life beneath its surface?

⑥ **BEYOND...**
Scientists have already found evidence of over 1,000 other solar systems. Billions of other worlds remain to be discovered, characterized, and eventually explored.



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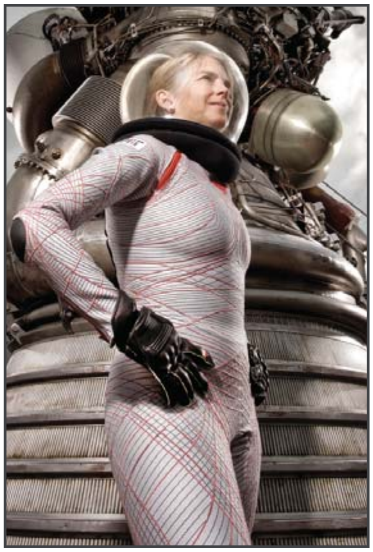
DOING SCIENCE in space

Science in space involves extraordinary challenges. Here are some of the questions scientists are asking, and some of the technologies that are enabling them to travel farther more safely, and to gather evidence from places too dangerous — or still too distant — for humans to visit.

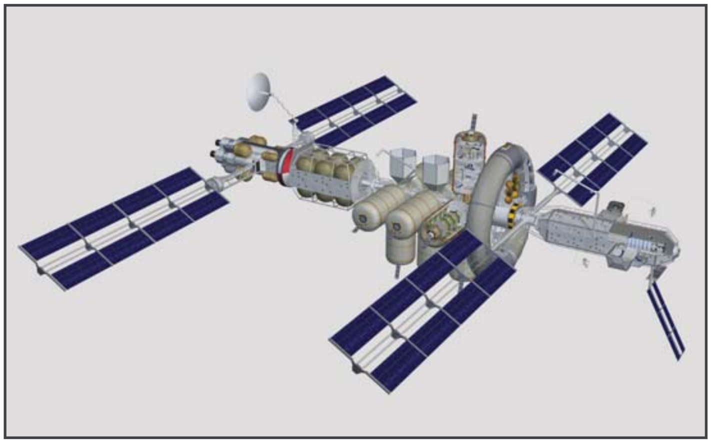
HOW CAN SCIENTISTS INVESTIGATE SPACE FIRST HAND?

Today's bulky, heavy suits surround astronauts with pressurized air. This sleek new **spacesuit** applies pressure directly to the skin by wrapping the body tightly in several layers of stretchy, very tough, spandex and nylon. This makes the suit lighter, safer because it won't lose pressure if punctured or torn, and easier to move and work in.



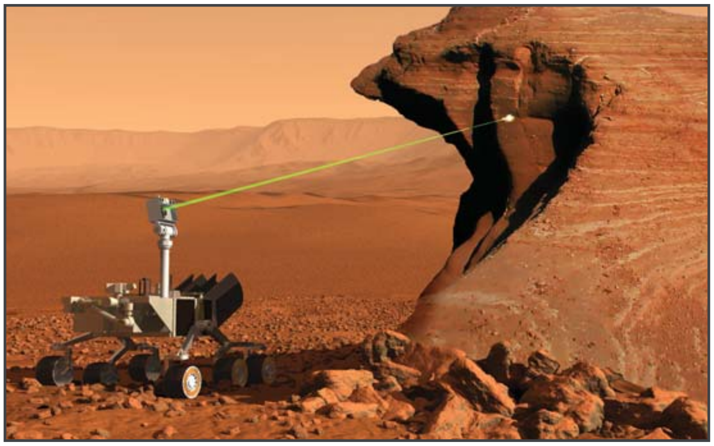
HOW DO WE TRAVEL FURTHER AND STAY LONGER?

The ***Nautilus-X* spacecraft** could carry a crew of nine on a two-year voyage — long enough to reach Mars. It would contain exercise machines, so astronauts could keep their muscles and bones strong. Spinning compartments for sleeping would also prevent bone loss and other health problems by generating artificial gravity. Solid waste from toilets could be used as compost for plants that in turn would provide food and oxygen.



HOW DO WE LOOK FOR EVIDENCE OF LIFE ON MARS?

A one-ton science lab, the ***Curiosity* rover** will land on Mars inside Gale Crater, which is thought to have once been a lake. The rover will make its way to the top, studying each layer of sediment in order to obtain a cross-section of the crater's history when it was wet, and possibly home to living things. *Curiosity* can pick up samples and test them onboard, fire a laser at objects to see what they're made of, and it even contains a small weather station.



HOW CAN WE SEE FURTHER INTO SPACE AND BACK IN TIME?

A **liquid mirror telescope** at the Moon's South Pole could detect infrared light from the earliest days of the universe, some 13.7 billion years ago. Larger than a football field, the telescope would have a main mirror made of a slowly spinning, highly reflective liquid. A rotating dish naturally forms a parabolic shape, which focuses light from diffuse sources such as incoming starlight. With no interference from wind or weather, this surface would be so smooth it looks solid. Once spinning on electromagnetic bearings, the telescope would need little maintenance.

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