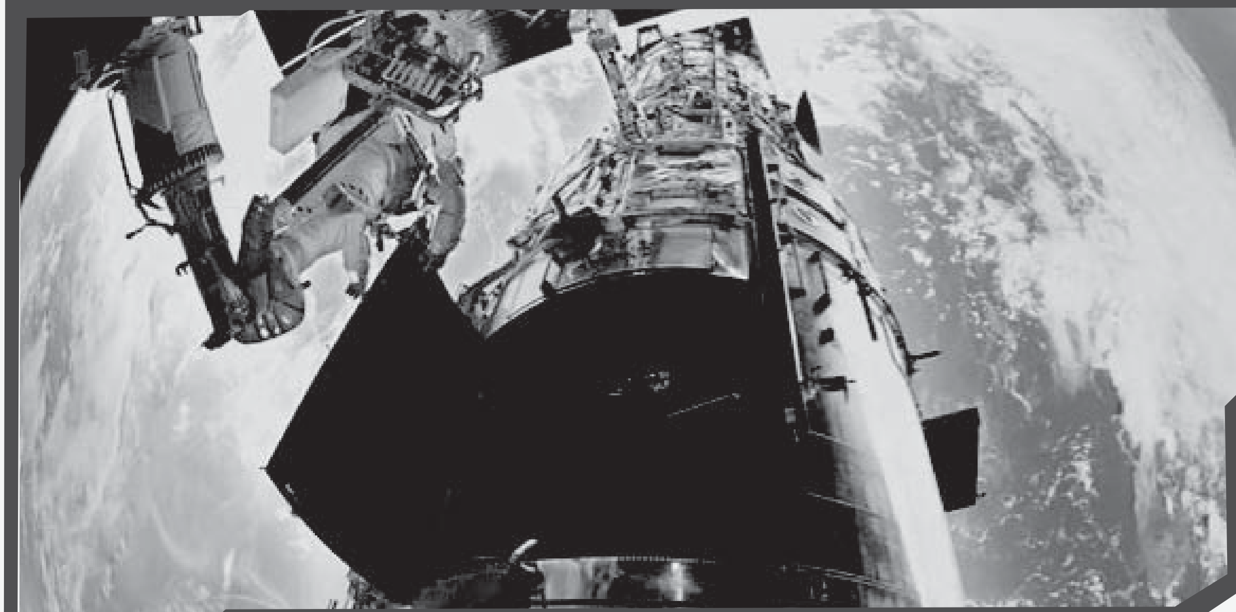
Educators Guide to

JOURNEY TO SPACE

K2 Communications and Giant Screen Films



Written by Jennifer Jovanovic
Illustrated by Dennis Smith

K2 Communications and Giant Screen Films would like to thank the California Science Center for its contribution to the development of the Educators Guide to *Journey to Space*.

California ScienCenter

Welcome to *Journey to Space*

The Space Shuttle was the first reusable, piloted spacecraft. Its engineering and software were so bulletproof that it could be flown by computers less powerful than today's smartphones. At 235 miles per hour, the Shuttle had the fastest touchdown speed of any flying vehicle ever built.
– Astronaut Chris Ferguson

Before 1981, there had never been spacecraft that could go into Space and back home again. A dream became a reality through creativity, engineering, science and hard work. Imagine being one of the first astronauts to climb onboard the Space Shuttle or one of the NASA mission engineers watching it take off and land. *Journey to Space* takes you from that time, far into the future. It's a wild ride.

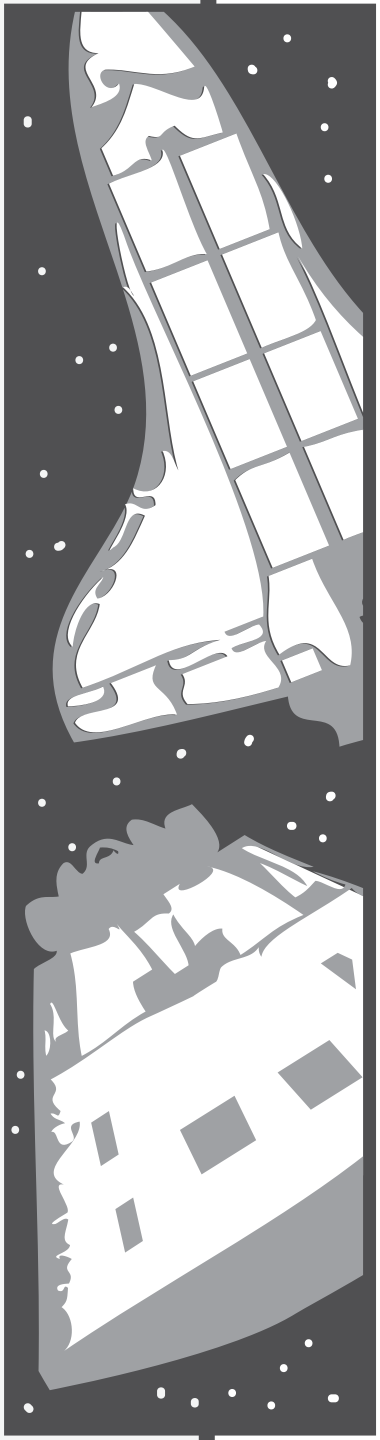
"The flight test of Orion is a huge step for NASA and a really critical part of our work to pioneer deep space on our journey to Mars," said NASA Administrator Charles Bolden on December 5, 2014. *Journey to Space* brings astronauts' excitement about the Orion spacecraft's future travel to Mars into the theater. This educators guide brings that excitement into your classroom or home, with "Next Generation," standards-based, STEM activities to inspire students to be part of it all.

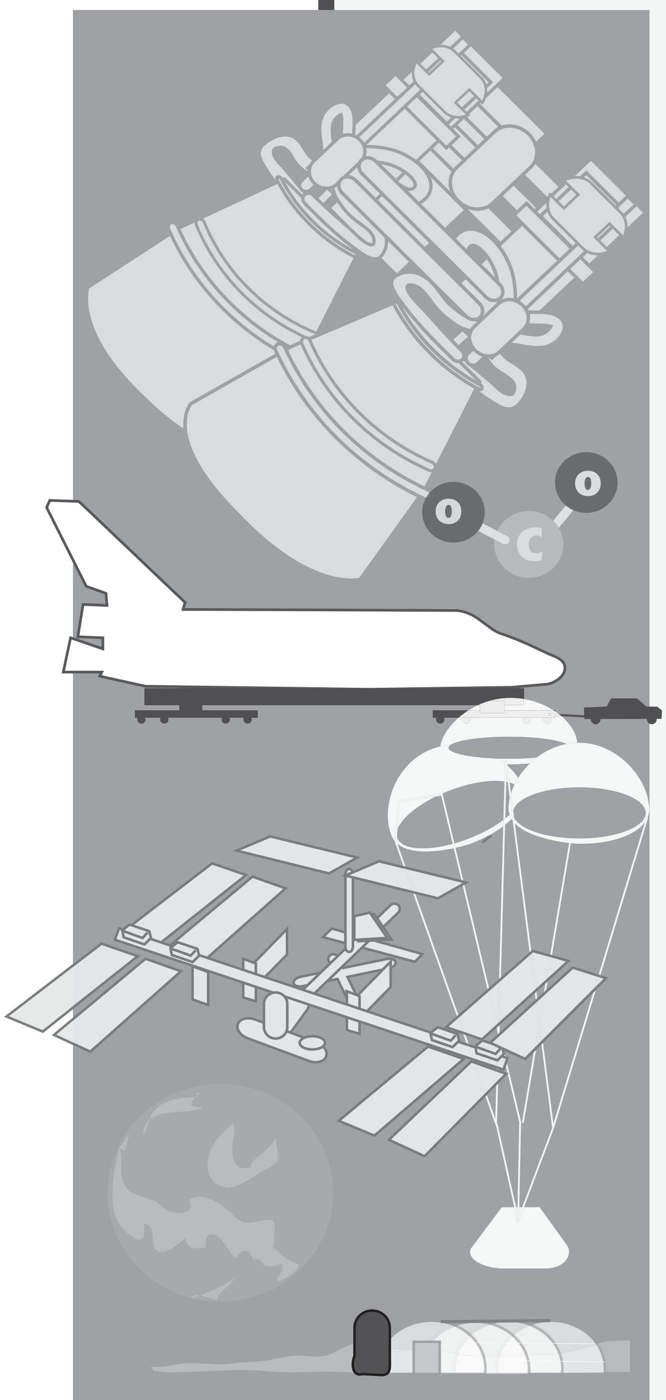
Journey to Space is a celebration of space exploration, a tribute to international cooperation in space research and a vision toward our near-term future beyond Earth's orbit—a manned mission to Mars within a generation. The film is a capstone space film, building on the groundbreaking and seminal giant screen space productions of the past 30 years—films that are themselves a part of our proud history in space, beautifully and inspiringly chronicling the Space Shuttle orbiter program, Mir, the International Space Station and the Hubble telescope. *Journey to Space* recognizes these accolades in the context of our future in space, what we've learned, and how to apply this knowledge to deep space missions. The film takes us on a behind-the-scenes tour of the international effort to send astronauts to Mars within the next 20 years, culminating in a virtual voyage to the Red Planet. Dazzling computer imagery depicts the Orion spacecraft, habitats, landers, vehicles and rockets necessary to achieve interplanetary travel, touchdown and colonization.

The Orion spacecraft's unmanned flight included rigorous testing of heat shields, parachutes, and many other critical systems. Like NASA engineers, students will design and conduct tests to experience why science is important to living in space. We have suggested grade levels of either 1-5 or 4-8, recognizing that every student is different and allowing you to customize to your classroom.

"We challenged our best and brightest to continue to lead in space," Orion Lead Flight Director Mike Sarafin said. "While this was an unmanned mission, we were all on board Orion." *Journey to Space* and this guide invite you to climb on board.

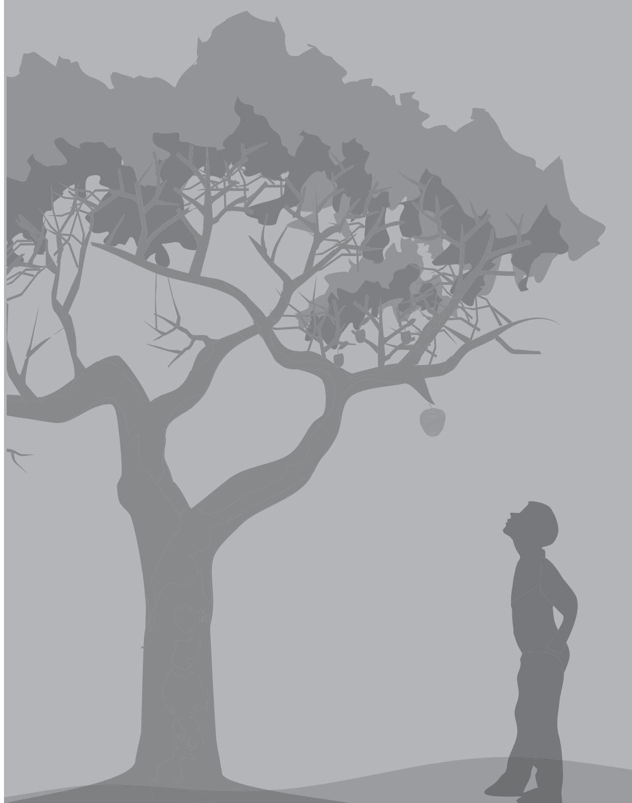
Excerpts from: nasa.gov/2014/December/ and news.yahoo.com/nasa-tries-again.





Contents

Next Generation Science Standards Alignment with Film and Activities



Fourth and Fifth Grade Science Standards	
4-PS3-2.	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents.
4-LS1-1.	Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
5-PS2-1.	Support an argument that the gravitational force exerted by Earth on objects is directed down.
3-5-ETS-1.	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS-2.	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS-3.	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
	Middle School Science Standards
MS-PS2-4.	Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
MS-LS2-1.	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-4.	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESSI-2.	Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-ETS1-1.	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit solutions.
MS-ETS1- 2.	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Science and Engineering Practice Alignment

The activities in this guide encourage students to use the same practices that engineers do, as described in the Next Generation Science Standards.

Asking Questions and Defining Problems

Developing and Using Models

Planning and Carrying Out Investigations

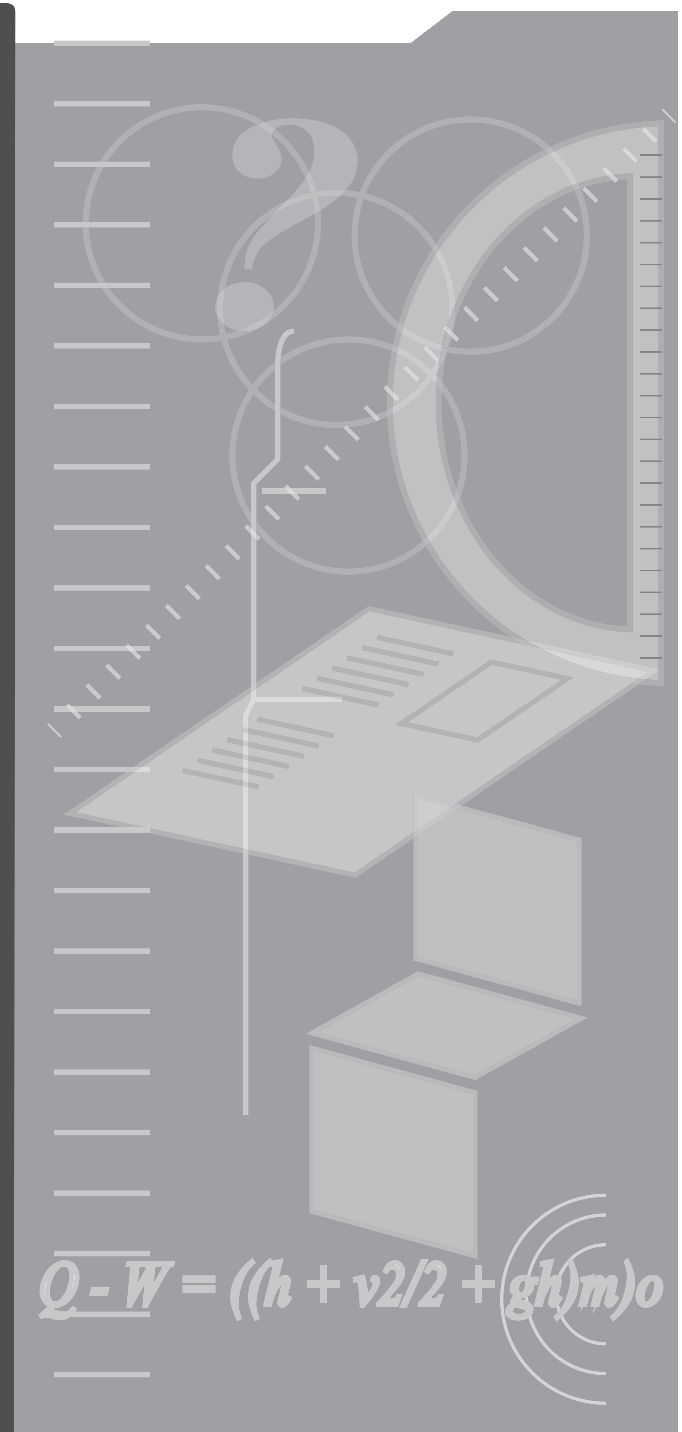
Analyzing and Interpreting Data

Using Mathematics and Computational Thinking

Constructing Explanations and Designing Solutions

Engaging in Argument from Evidence

Obtaining, Evaluating and Communicating Information



The Space Shuttle

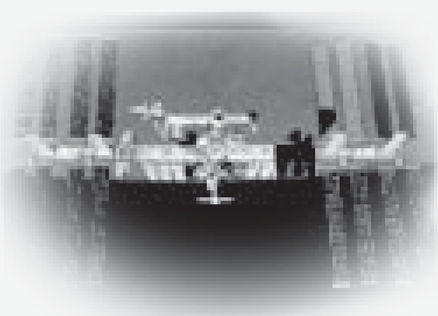
As an Astronaut, I definitely felt I was saying goodbye to a long-time friend when the last shuttle landed. – Astronaut Chris Ferguson

When the Space Shuttle rocketed off the launch pad for the first time in 1981, it became the world's first reusable spacecraft to carry humans into orbit. Over the thirty-year course of the Space Shuttle program, the shuttles and their crews assembled parts of the International Space Station (ISS), deployed and serviced the Hubble Space Telescope and Chandra X-Ray Observatory, sent probes to Venus and Jupiter, and more. Five different orbiters flew into Space—Columbia, Challenger, Discovery, Atlantis and Endeavour—for a total of 135 missions. Space Shuttles docked with Russia's Mir space station nine times, and with the ISS over 35 times.

The International Space Station (ISS)

The Shuttles' truest legacy crosses the sky above us every 90 minutes. The International Space Station could never have been built without the Shuttles' payload and space-walk capabilities. Space Shuttles and Russian Soyuz and Proton rockets made more than 40 flights to construct the ISS -- a true engineering miracle. All three of my Orbiter missions were to the ISS. The 15 nations that designed, built and crew the ISS, forever changed space exploration into a cooperative international program and made a true home and science lab like no other. – Astronaut Chris Ferguson

The ISS is a large spacecraft in orbit around the Earth, traveling at 17,500 mph. It's a unique science laboratory where astronauts and cosmonauts live.

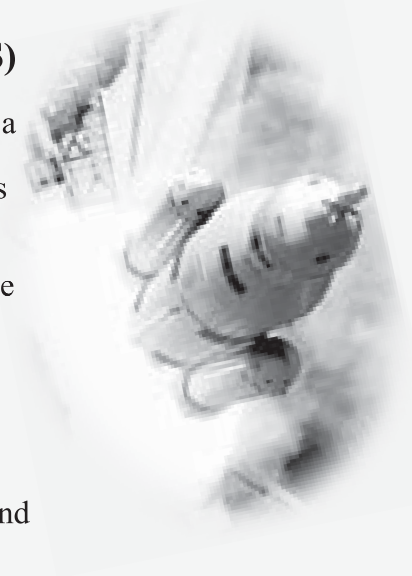


Orion

The Orion spacecraft is built to take humans farther than they've ever gone before. Orion will serve as the exploration vehicle that will carry the crew to Space, provide emergency abort capability, sustain the crew during space travel, and provide safe re-entry from deep space return velocities. On December 5, 2014, Orion launched atop a Delta IV Heavy rocket from Cape Canaveral Air Force Station's Space Launch Complex. The Orion Flight Test evaluated launch and high-speed re-entry systems such as avionics, attitude control, parachutes and the heat shield. In the future, Orion will launch on NASA's new heavy-lift rocket, the Space Launch System. Orion is designed with heat shields to protect the crew from solar storms, radiation, and other obstacles they will encounter on the journey. Although it can carry six astronauts, for the first mission, there will only be four. Orion's living space is quite limited, so, to facilitate the astronauts' need for exercise, sleeping, and personal hygiene, a large inflatable habitat will be attached to Orion for its journey to Mars.

The Space Launch System (SLS)

SLS is an advanced launch vehicle for a new era of exploration beyond Earth orbit into deep space. SLS, the world's most powerful rocket, will launch astronauts in the agency's Orion spacecraft on missions that may include an asteroid and, within 20 years, Mars. SLS offers the highest-ever payload mass and volume capability.



Excerpts from:
nasa.gov/mission_pages/station/;
nasa.gov/exploration/systems/orion/; and
nasa.gov/exploration/systems/sls/.

Take Off

About Rockets, Thrust and the Space Launch System (SLS)

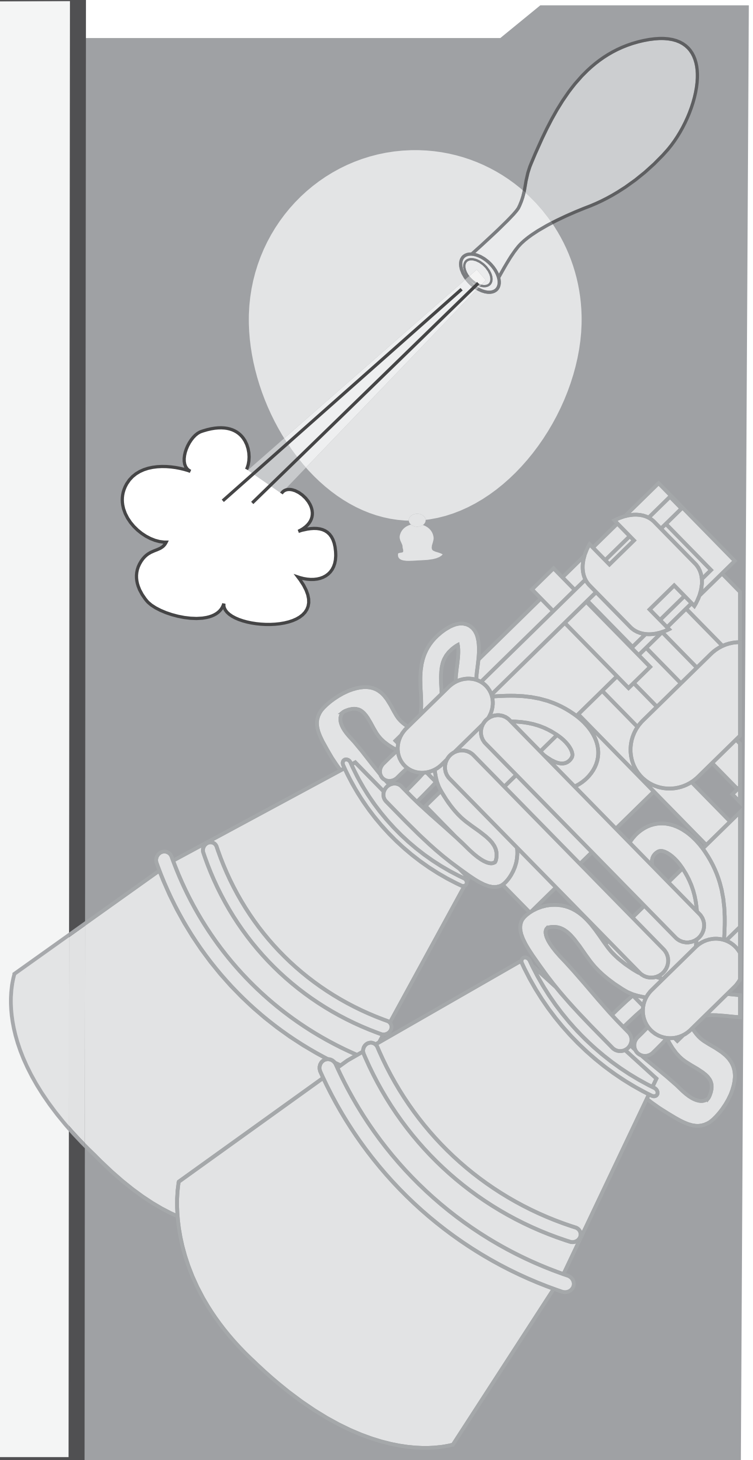
When the giant Space Launch System, built by Boeing, is complete, the new rocket will stand as tall as a 38-story building and burn 12 tons of fuel per second to make over 9 million pounds of thrust, enough to lift 22 elephants into space. – Astronaut Chris Ferguson

Rockets work much like a balloon filled with air. When a balloon is filled with air and the neck is held closed, the pressure inside the balloon is higher than that of the surrounding atmosphere. The balloon won't go anywhere because the internal pressure of the balloon is equal in all directions, thus the net force acting on the balloon is zero. When you let go of the neck of the balloon, there is now surface area on which the internal pressure can act. The internal pressure on the front of the balloon is greater than the internal pressure on the back of the balloon, thus creating an imbalanced force on the balloon. The result is a net force, called thrust, acting forward on the balloon.

In activity #1, the pressure from the air you pump into your SLS water bottle, and from the water that is released, provides enough force, or thrust, to overcome the weight of the bottle and send it flying. When the force of gravity overcomes that force, your SLS falls back to Earth.

The only significant difference between balloons and rockets is the way gas is produced. Rockets produce gas by burning propellants. These propellants can be solids or liquids or a combination of both. Because of the size of rockets and the amount of power they need to get to their destination, they need a lot of propellant. This propellant usually consists of fuel and oxygen. Balloons do not produce gas, but instead, release the carbon dioxide that we add to them as a propellant.

When we think about rockets, propulsion always comes to mind. Rockets are designed with certain quantities of propellants so that the rocket can safely arrive at its destination. Equally as important as propulsion is stability. (In activity #1, the fins provide stability.) The success of a rocket launch depends on precise accuracy. Stability means that the rocket follows a smooth path of flight. If it wobbles, the ride will be rough and extra fuel will be used to get back on track. If the rocket tumbles, it will likely be destroyed.



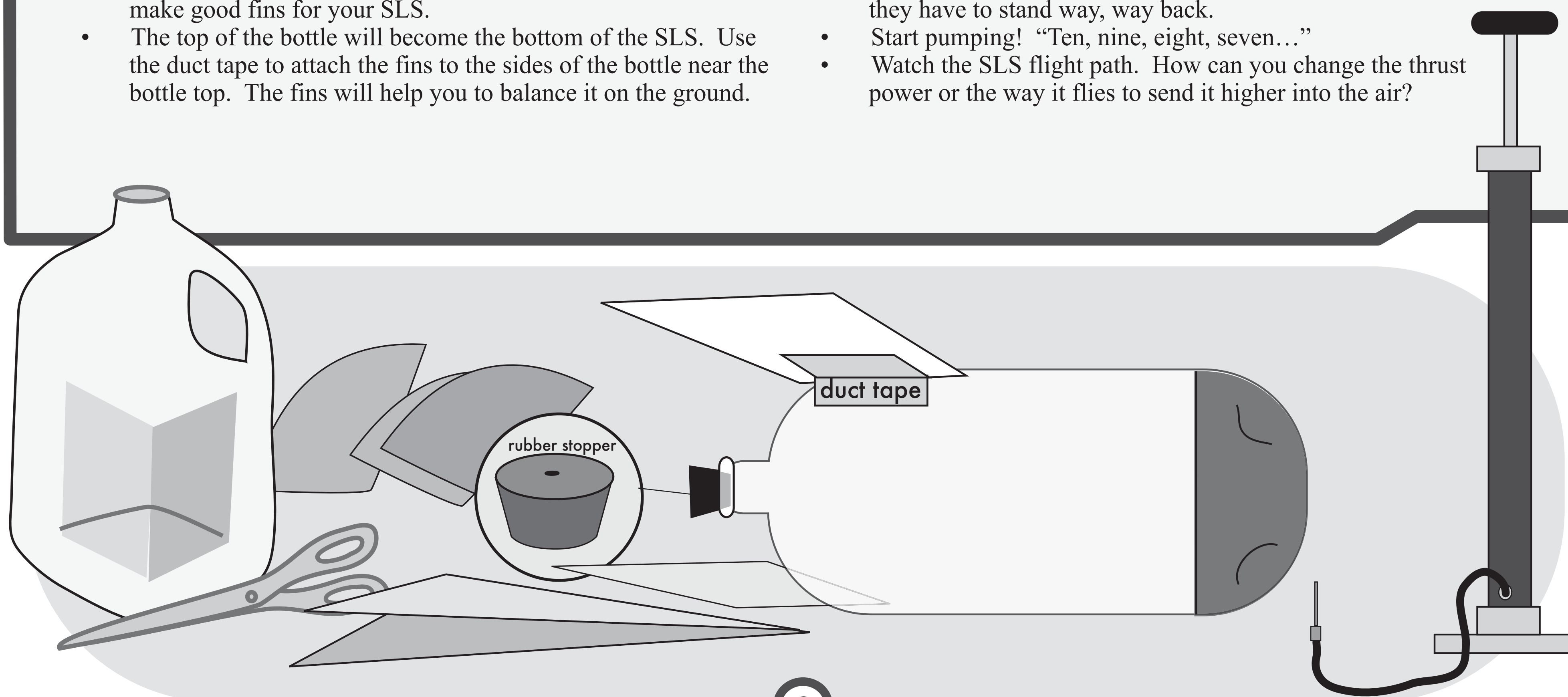
1

Could you really go to Mars and back someday? (grades 4-8)

Nearly four decades of robotic exploration on Mars has blazed a path for humans to follow craft like Pathfinder and Curiosity. Maybe I'll get to kick the dust off their tires. – Astronaut Serena Auñón

You will need: 2-liter plastic bottle, rubber stopper that fits the bottle with a small hole in it (drilled by an adult ahead of time), large plastic milk bottle, scissors, duct tape, water, goggles, bicycle pump

- Make sure that the hole in the stopper is just the right size for the bicycle pump needle to fit snugly. Now, you are ready to design your very own Space Launch System (SLS).
- Cut the plastic milk bottle into shapes that you think would make good fins for your SLS.
- The top of the bottle will become the bottom of the SLS. Use the duct tape to attach the fins to the sides of the bottle near the bottle top. The fins will help you to balance it on the ground.
- Fill the bottle about 1/3 full with water and put the stopper in.
- Insert the bike pump into the hole in the stopper.
- Grab your goggles and go outside to a clear area so that the SLS has plenty of room to land. If your friends want to watch, they have to stand way, way back.
- Start pumping! "Ten, nine, eight, seven…"
- Watch the SLS flight path. How can you change the thrust power or the way it flies to send it higher into the air?



About Orbiting

Anything that is in orbit – the Moon, the Space Shuttle, the International Space Station (ISS) – is held there by gravity. The Shuttle and ISS are held in place by the Earth's gravity. The Earth and other planets are held in place by the Sun's gravity.

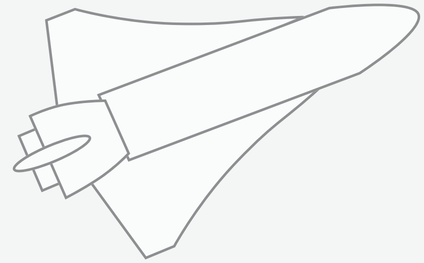
In activity #2, when you spin the tray in a circle, the tray is held in its orbit by the string. If you stop pulling on the string, the tray takes off in a straight line. The force you apply to the tray through the string is called centripetal force.

When the Space Shuttle is in orbit around the Earth, it is the Earth's gravity that exerts a centripetal force on it that prevents it from flying off into Space. The Earth's gravity pulls on the Shuttle like you pull on the string to keep the tray traveling in circular motion.

An orbit is a regular, repeating path that one object takes around another one. All orbits are elliptical, meaning that they take on the shape of an ellipse or oval. Based on Newton's First Law of Motion, an object in motion will stay in motion unless something pushes or pulls on it. Without gravity, an object orbiting the Earth would go off into space along a straight line. With gravity, the orbiting object is pulled back towards Earth. There is a constant state of tug-of-war happening between the orbiting object's tendency to move in a straight line and the tug of gravity pulling it back. The motion of an object and the force of gravity have to be balanced in order for an orbit to happen. The tricky part is trying to gain this balance. If the momentum is too small, the object will be pulled down and will likely crash into the Earth. If the momentum is too great, the object will speed past and not enter orbit at all. Orbital velocity is the precise speed needed to stay in orbit. When trying to get a Space Shuttle into orbit at an altitude of 150 miles above Earth, orbital velocity needs to exceed 17,500 miles per hour.

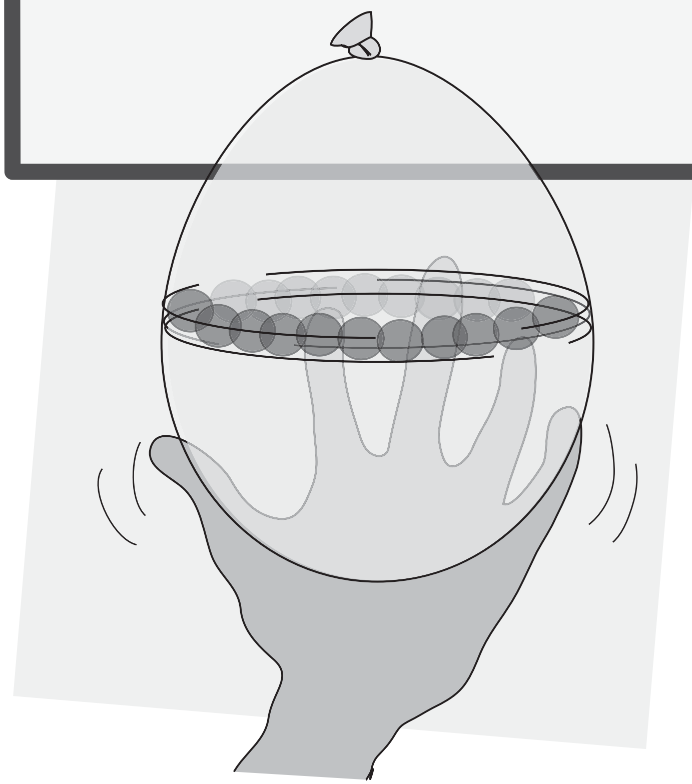
2

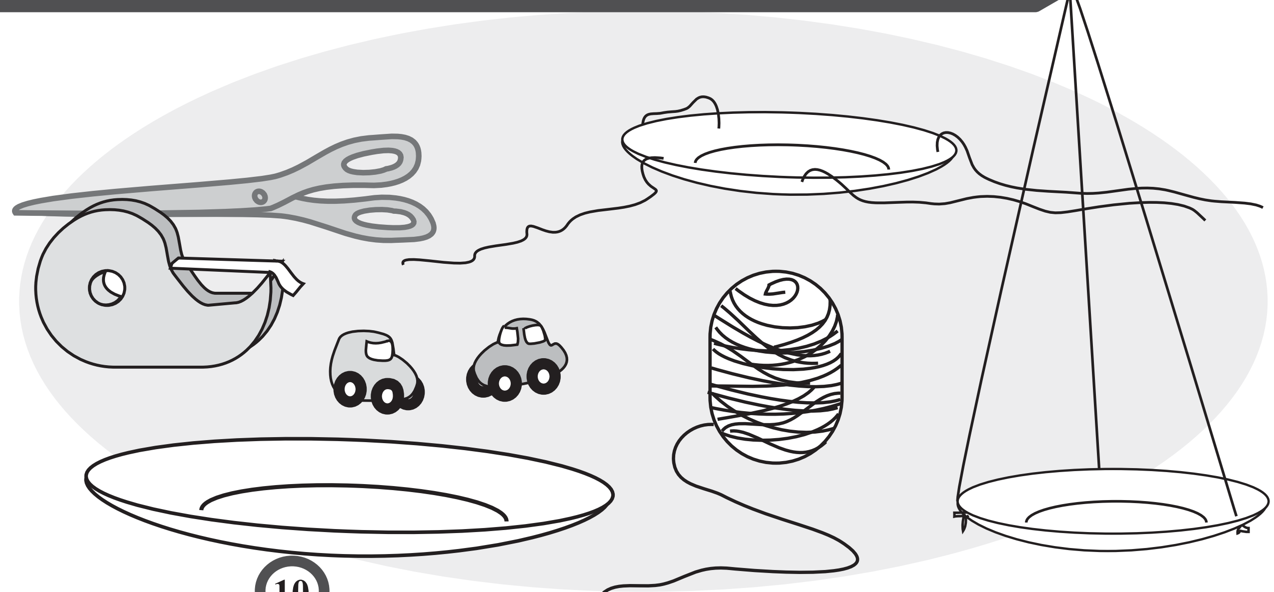
How did the Space Shuttle stay in orbit? (grades 4-8)



You will need: balloon, marble, sturdy paper plate, string, scissors, tape, micro-mini vehicle

- Put the marble inside the balloon and blow up the balloon, tying it closed.
- Spin the balloon so that the marble travels around the wall of the balloon.
- Centripetal force keeps the marble moving in a circle, pushing against the sides of the balloon. That's the same force that acts on the Space Shuttle.
- You can simulate the Shuttle's orbit by designing a swinging tray.
- Cut strings of different lengths and attach them to the paper plate so that, while holding the strings, you can spin the plate around in a full circle.
- Arrange the strings to create the design that works best to keep the tray steady when you spin it.
- Place the micro-mini vehicle in the center of the tray. How can you keep the vehicle on the tray while spinning it around in a circle? Make adjustments to improve your design.
- What happens if you let go of the string while you're swinging the tray?
- Can you achieve 30 revolutions (full circles) per minute without your Shuttle falling out of orbit?





About Landing the Space Shuttle and the Orion Spacecraft

In 1961, Yuri Gagarin and Alan Shepard used parachutes to return to Earth. In 2014, the Orion spacecraft used parachutes too. Why do parachutes work so well?

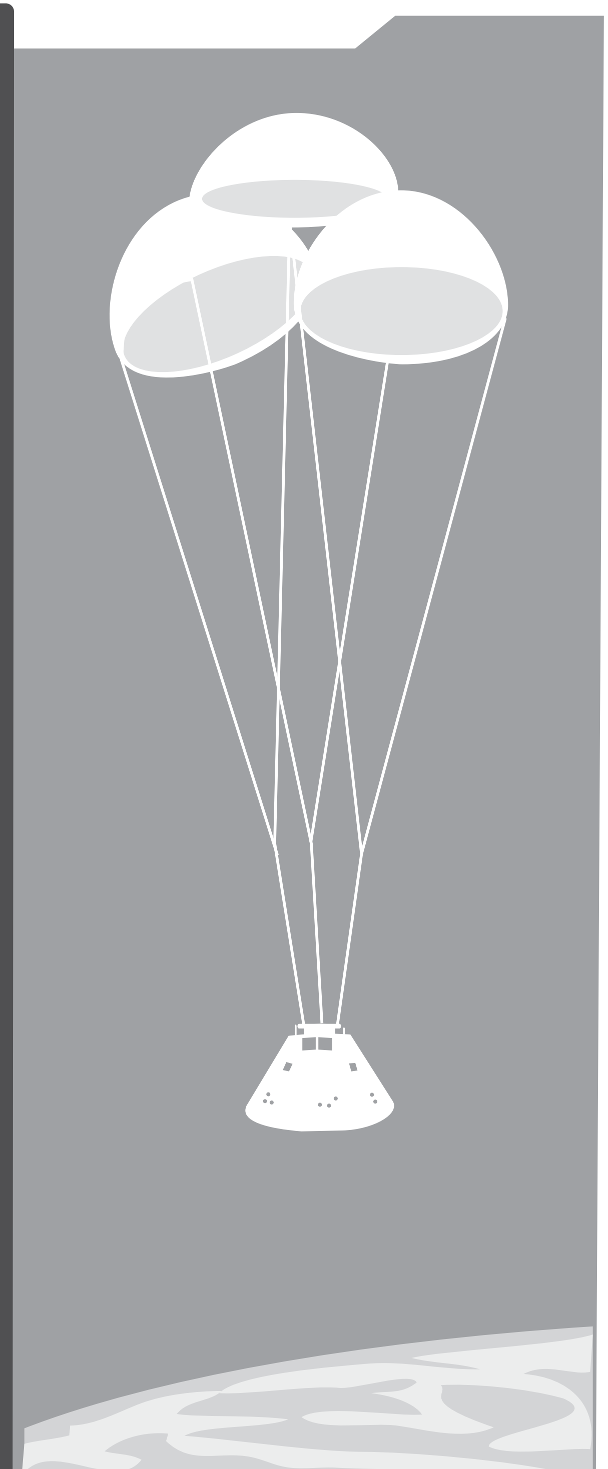
A parachute is an umbrella-shaped device of light fabric often used for making a safe jump from an aircraft. Parachutes are made primarily from nylon, which has a high air resistance. Due to the resistance of the air, a drag force acts on the parachute to slow down its motion. Because of its design, a parachute successfully creates a drag effect in the air. Drag means that parachutes act in the opposite direction of the oncoming velocity in this case, gravity. Without air resistance or drag, objects would continue to increase speed until the object hit the ground. The larger the object, the greater its air resistance. Parachutes use a large canopy to increase air resistance. This gives a slow fall and a soft landing.

Although the Space Shuttle launches with the help of solid rocket boosters and an external fuel tank, when the orbiter lands, it does so without the help of any engines. It essentially just falls back to Earth, with the help of scientists, of course. The parachute is deployed once the orbiter touches down on the runway. Parts of the orbiter have been carefully designed to make the descent and landing as graceful as possible, so that minimal damage is done to the orbiter upon reentry. The goal of the Space Shuttle program was to get the Shuttle and crew back to Earth safely, in part so that the Shuttle could be reused for future missions.

The landing of Space Shuttle Endeavour on the 15,000-foot concrete runway at Edwards Air Force Base, California, to conclude shuttle mission STS49 in 1992 demonstrated a new capability for the shuttle fleet. A 39-foot-diameter braking parachute was used to slow the vehicle, relieving stress on the brakes and tires and reducing the landing rollout by as much as 2,000 feet. Endeavour was the first orbiter to be built with the drag chute and soon after, the drag chute became a standard feature on the shuttle fleet.

In its December 2014 flight test, Orion was traveling at just under 20,000 mph when it returned to Earth's atmosphere. At that speed, it takes 10 minutes to reach the Pacific Ocean for splashdown. Orion's heat shield protects it from the high temperatures generated from the friction of the atmosphere. When the atmosphere slows Orion down to 300 mph, the first 2 of its 8 parachutes are released. In one minute, those 2 parachutes slow Orion down to 100 mph. When all 8 parachutes have been released, they slow Orion down to less that 17 mph, lowering it to the surface of the Ocean.

Excerpt from: nasa.gov/sites/default/files/files/orion_flight_test_press_kit.pdf

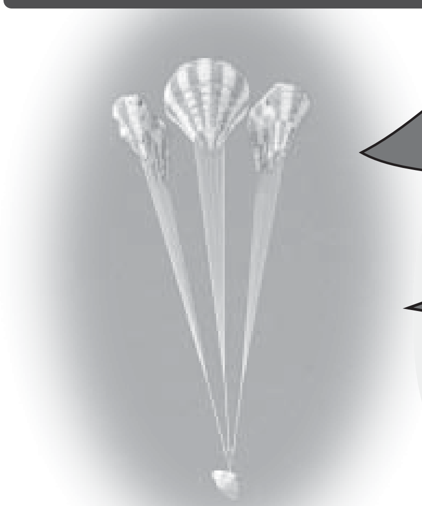


3

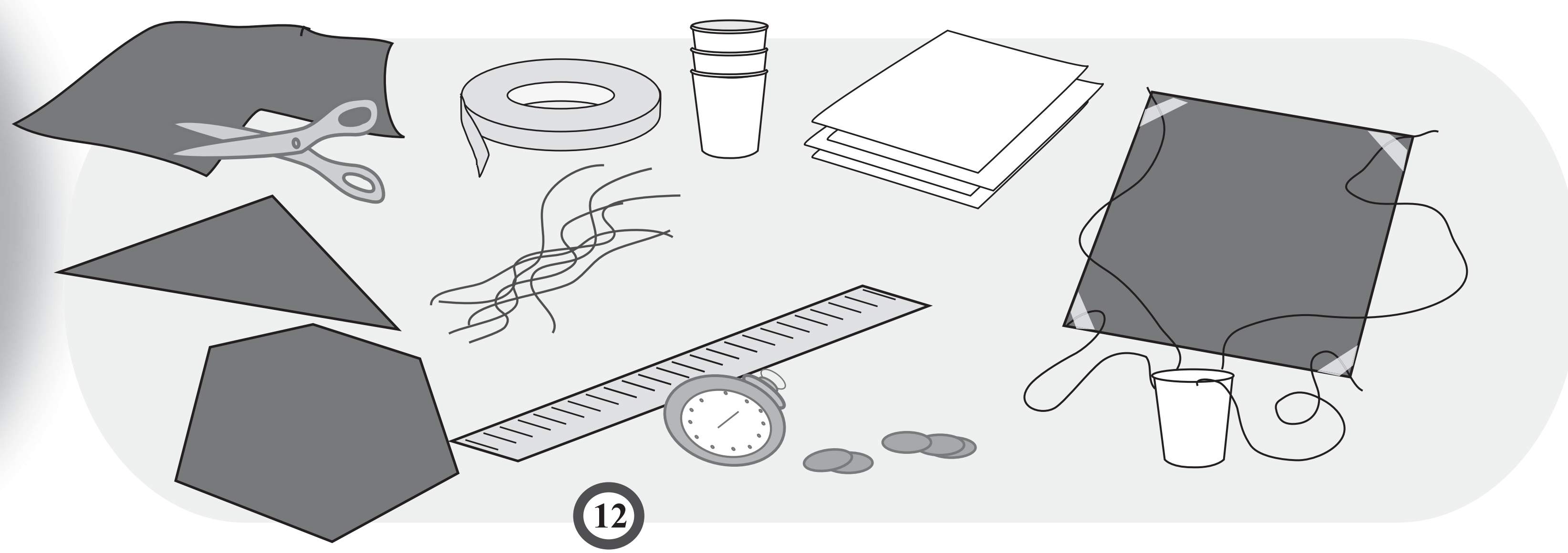
How did they land the Space Shuttle and Orion Spacecraft? (grades 4-8)

You will need: plastic garbage bag, scissors, ruler, paper, tape, string, 1 small paper cup per parachute, stopwatch, a partner, pennies, toy car

- Cut different sizes and shapes from the plastic garbage bag. Each shape will be used to create its own parachute.
- Cut as many different pieces of string as you would like to use to attach the parachute to the cup.
- Tape one end of each piece of string to the parachute and one end to a spot around the edge of the cup.
- Have your partner get ready with the stopwatch and find a high spot to launch the parachutes.
- What is your hypothesis? Which will land more quickly, the larger parachutes or the smaller ones? Drop each parachute from the same height and time how long it takes to land. Record your data.
- Experiment with adding weight to your parachutes by putting pennies in the cups. How would you need to adjust a parachute when it is carrying a heavy load?
- Does the shape of the plastic affect the parachute's fall? Do the locations of the strings on the cup make a difference? Modify your parachute to improve the design.
- You can re-design this activity using the toy car to represent the very heavy, speeding Shuttle when it is landing. What adjustments do you need to make?



Orion with its parachutes



The Space Shuttle on Earth

About Newton's Laws of Motion, Wheels and Axles and a Truck

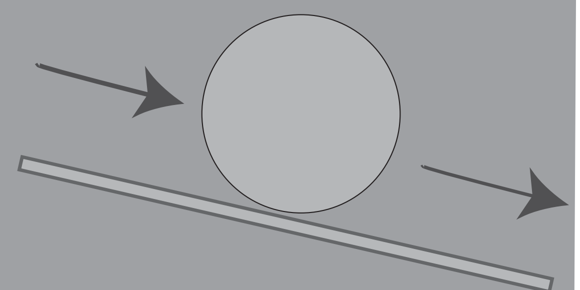
Two of the biggest challenges for a Toyota Tundra truck to be able to move the Space Shuttle down the street were controlling rolling resistance and avoiding going up and down hills. Rolling resistance is the energy that was lost from the tires on the SPMT (the Self-Propelled Modular Transporter which carried the Shuttle) as they experienced friction and gravity as they moved down the street. The truck didn't really have to pull the Space Shuttle once it overcame rolling resistance and got moving. The Space Shuttle has so much mass and is so heavy that it builds up a tremendous amount of momentum when going downhill, which makes it very difficult to stop. Momentum = mass x velocity. Nobody wants a runaway Space Shuttle. So the route was planned very carefully. The best speed for the Space Shuttle to travel was determined to be only 2 miles per hour.

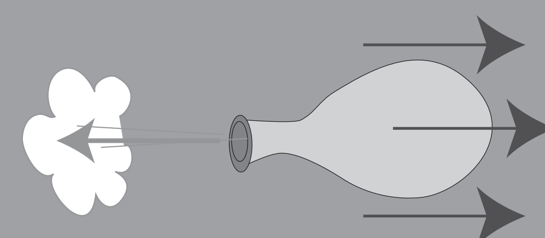
If you put wheels and axles on a vehicle, each wheel only touches the ground at one spot while it's turning, so it creates less friction to slow you down. Imagine trying to drag the Space Shuttle down the street. That would never work. The more wheels and axles you have, the more you distribute the weight. In activity #5, if you use more pencils, the weight of the brick is spread out, so it is easier to move. The SPMT has 160 wheels to distribute the weight of the Shuttle. Larger wheels require more energy to get moving but they are better at reducing friction than small wheels, so once you are moving, they go faster. Newton's Laws explain the forces that acted on the Shuttle.

Newton's First Law describes how an object moves when no force is acting on it. An object that is stationary (not moving) will remain at rest until a force is applied to it. Once you set an object in motion, the object continues to move at a constant speed until another force acts upon it, such as friction or collision with another object. Isaac Newton called his first law inertia, from the **Latin for idle or lazy.**

Newton's Second Law introduces mass, one of the most fundamental concepts in science. The word mass, as described by Newton, is a synonym for "quantity of matter." The more mass an object has, the more difficult it is to change its state of motion. The Second Law tells us that a net force will change the velocity (the speed of something in a given direction) of an object by changing either its speed or its direction. Such a change in velocity is called acceleration. So, we can say that a net force gives rise to acceleration.

Newton's Third Law deals with actions and reactions. The law states that "for every action, there is an equal and opposite reaction." The key to grasping this law correctly is to understand action/reaction pairs. Action is the result of a force. Release air from an inflated balloon. The air shoots out the nozzle. That is an action. When the air rushes out of the balloon, the balloon shoots the other way—reaction! The action and reaction in Newton's Third Law are forces. A force is a push or pull on an object.





4

How did a pick-up truck (Toyota Tundra) pull a gigantic Space Shuttle through the streets of Los Angeles? (grades 4-8)

You will need: toy trucks big enough to load with books, box about the same size as the trucks, heavy books, scale, string, scissors, duct tape, piece of plywood wide enough for two trucks

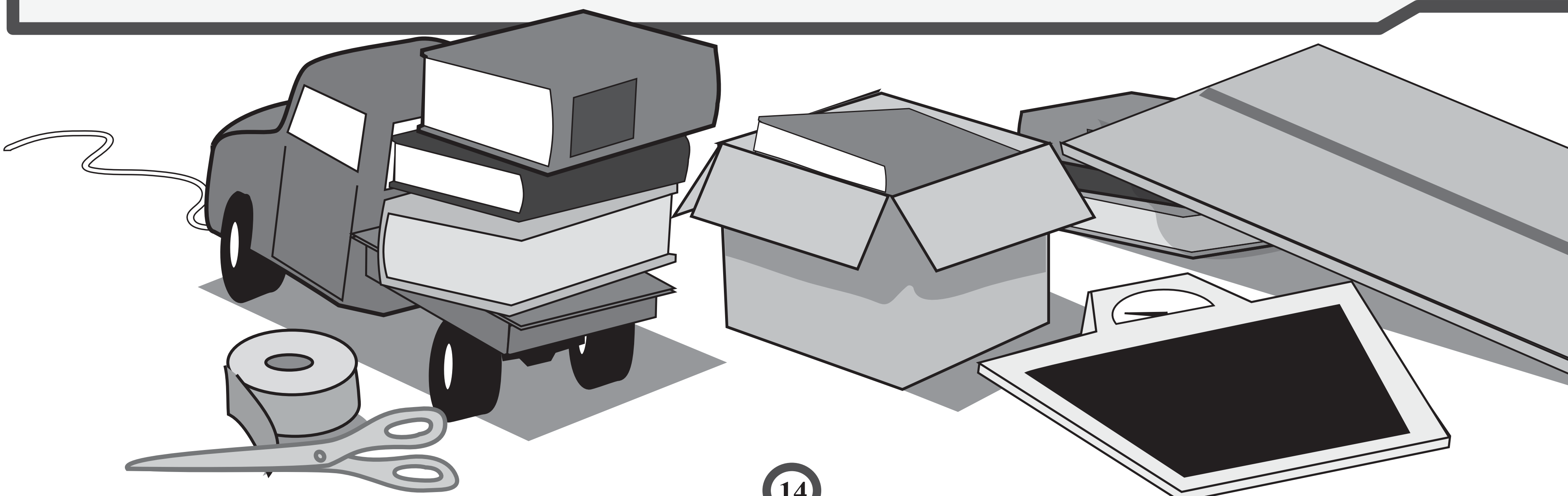
- Load one of the trucks with so many books that it's very hard to move.
- Weigh the truck filled with books and record its weight.
- Load the box with books so that it is the same weight.
- Attach one piece of string to the truck and one to the box.
- Pull on each string to test how difficult it is to move the box or the truck. Remove some of the books and try again. How are your results different?
- Using the string to tow the truck or box, design an experiment to analyze the variables to be considered when moving the Space Shuttle (the heavy truck or box). You can create a ramp with the plywood to simulate going up or downhill.
- Here are a few questions you might study, but feel free to think of your own:

  What difference does it make if the Shuttle is moving quickly or slowly?

  How does the design of the truck or box make it easier or more difficult to tow?

  Once you get it started, why doesn't the truck keep moving on its own?

  How do these variables change if you change the weight of the truck?



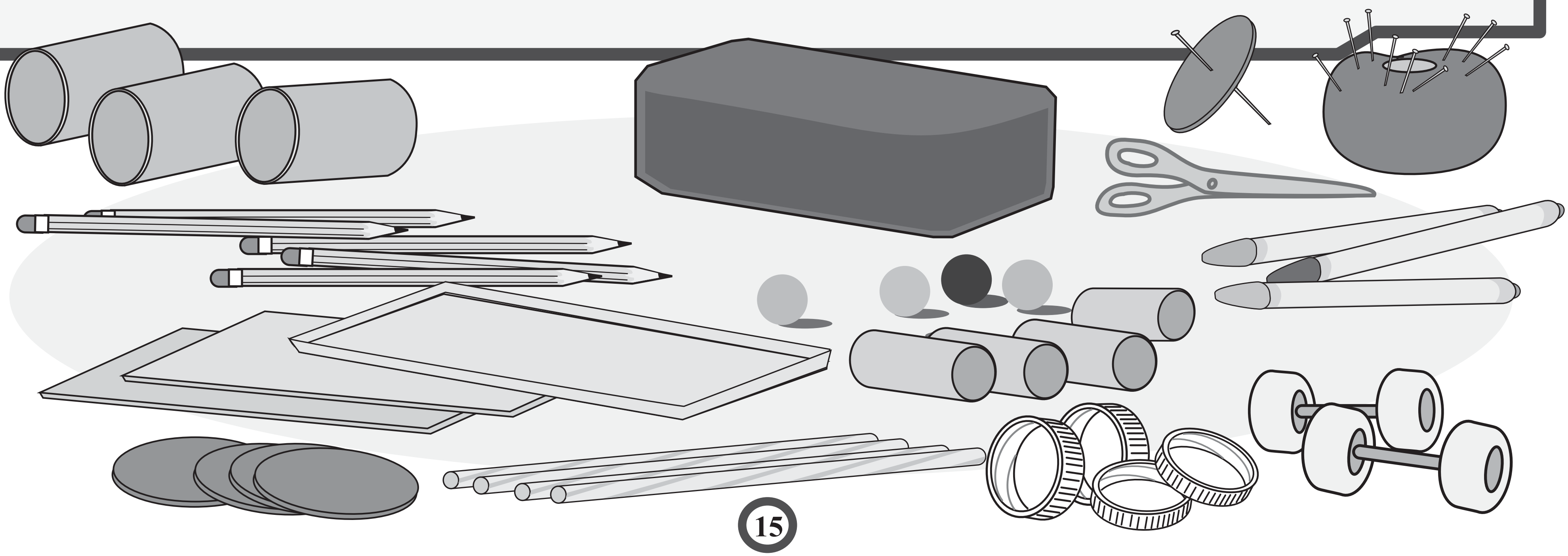
5

How does a Self-Propelled Modular Transporter (SPMT) work? (grades 1-5)

You will need: pencils, heavy brick, small cans, Styrofoam trays, something round you can trace to make wheels, marker, straight pins to use as axles, scissors, straws

Can an engineer make a heavy brick roll? How many wheels and axles does it take to make an SPMT (self-propelled modular transporter) that can transport the Space Shuttle? If you can answer one question, you'll be pretty close to understanding the other.

- Here is your challenge: Using only pencils and/or cans, design a system for rolling the brick. Study the advantages and disadvantages of pencils vs. cans.
- Now go on a wheel and axle hunt. Here are a couple of examples to get you started – a doorknob, a toy car. A wheel rotates around an axle.
- What's the advantage of a wheel over a ball? A small wheel over a large wheel?
- Based on your research, design a model of an SPMT for the Space Shuttle. We suggest cutting Styrofoam trays into the shapes you need, but feel free to choose your own materials.



Life on Earth

About Microgravity and Gravity

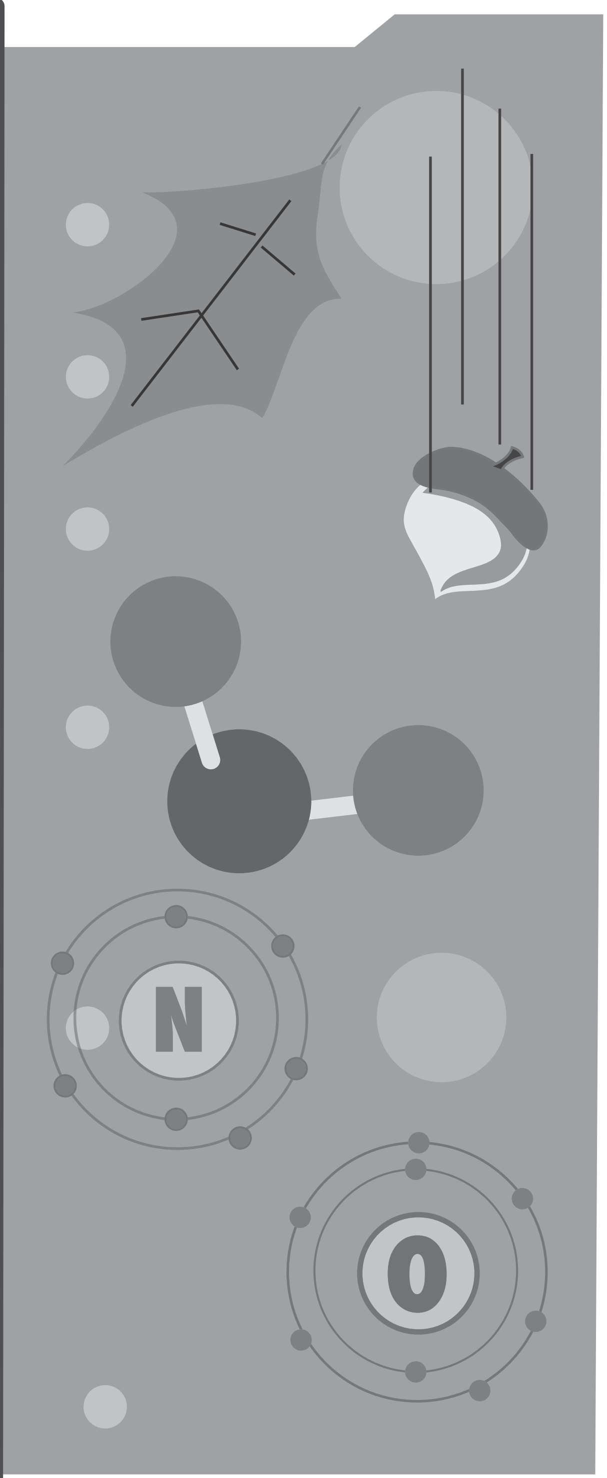
When we talk about weightlessness, what we really mean is microgravity. It's the free-fall feeling you get when you begin to speed down the hill on the roller coaster and it's what astronauts experience on the International Space Station. In activity #6, you (and the action figure in your shoebox) are in free fall after you jump into the air and are just starting to return to the ground, so, for a moment, the action figure – and even the rock – is floating. It's not surprising that NASA does a lot of testing for its missions underwater.

Gravity is a property of mass, however, the force of each object's gravity depends on its amount of mass. The less mass an object has, the weaker the effect of its gravity. Space is a microgravity environment, not zero gravity, because it is filled with mass such as planets, moons, astronauts and space capsules.

About Atmosphere

Air -- an atmospheric composition of nitrogen, oxygen, carbon dioxide, and water vapor -- is essential to Earth's atmosphere. The human body has developed on Earth and cannot survive without air. If there were living things on Mars, they would have to be adapted to its carbon dioxide atmosphere.

Carbon dioxide is an invisible gas that is heavier than air. In activity #7, when you create it from the chemical reaction of the vinegar and baking soda, it sinks to the bottom of the cup. When you pour the carbon dioxide from one cup into the other, it sinks down on top of the candle, putting out the fire. Fires cannot burn on Mars because there's very little oxygen. On Earth we use oxygen to breathe and to build fires that keep us warm and allow us to cook food.



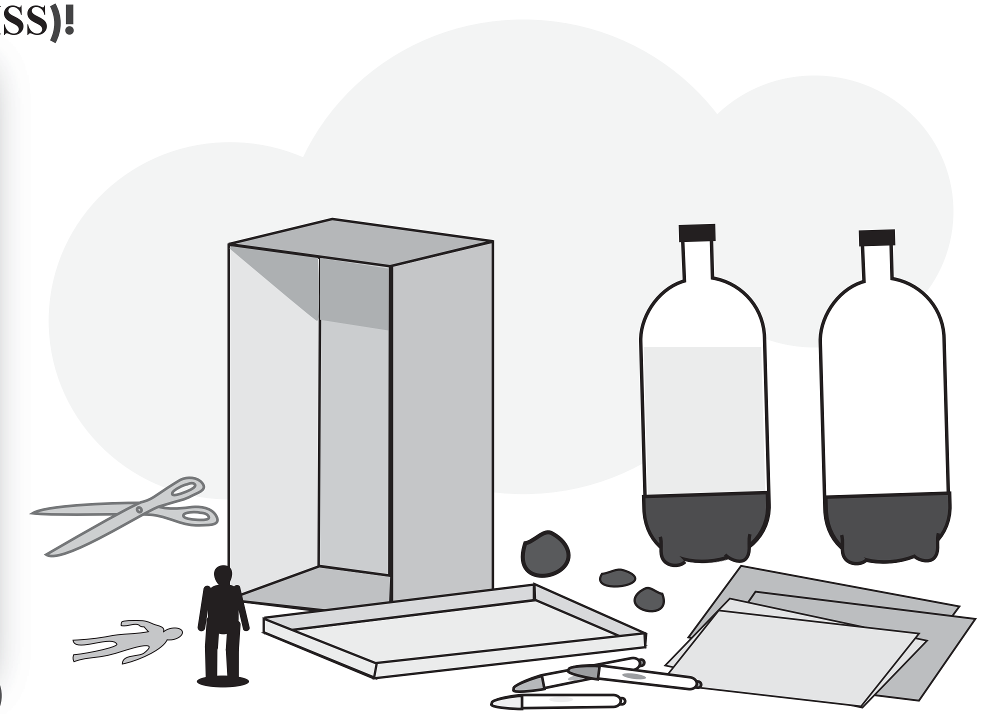
6

How is microgravity in Space different from gravity on Earth? (grades 1-5)

You will need: shoebox, markers, paper, cardboard, scissors, small action figures, rocks, empty 2-liter bottle, 2-liter bottle full of water

- Study the photo of Expedition 42 Commander Barry Wilmore and Flight Engineer Samantha Cristoforetti taken on the ISS. Look for all the clues that tell you it is a microgravity environment. How do you know they're not in a lab on Earth?
- Now, take your shoebox and recreate that ISS environment using the supplies above, or other recycled supplies you have at home. Make sure you design the box vertically, so that it is tall, not wide.
- Place the action figure astronauts in the box. Since you're on Earth, they just sit on the bottom of the box.
- Hold the box so that the opening faces you and you can watch the astronauts.
- When you jump, what do the astronauts do?
- Try the same thing with small and large rocks. What happens?
- Compare the difference between lifting the empty 2-liter bottle and the bottle full of water. What would happen if you did that in Space?

Happy New Year from the International Space Station (ISS)!

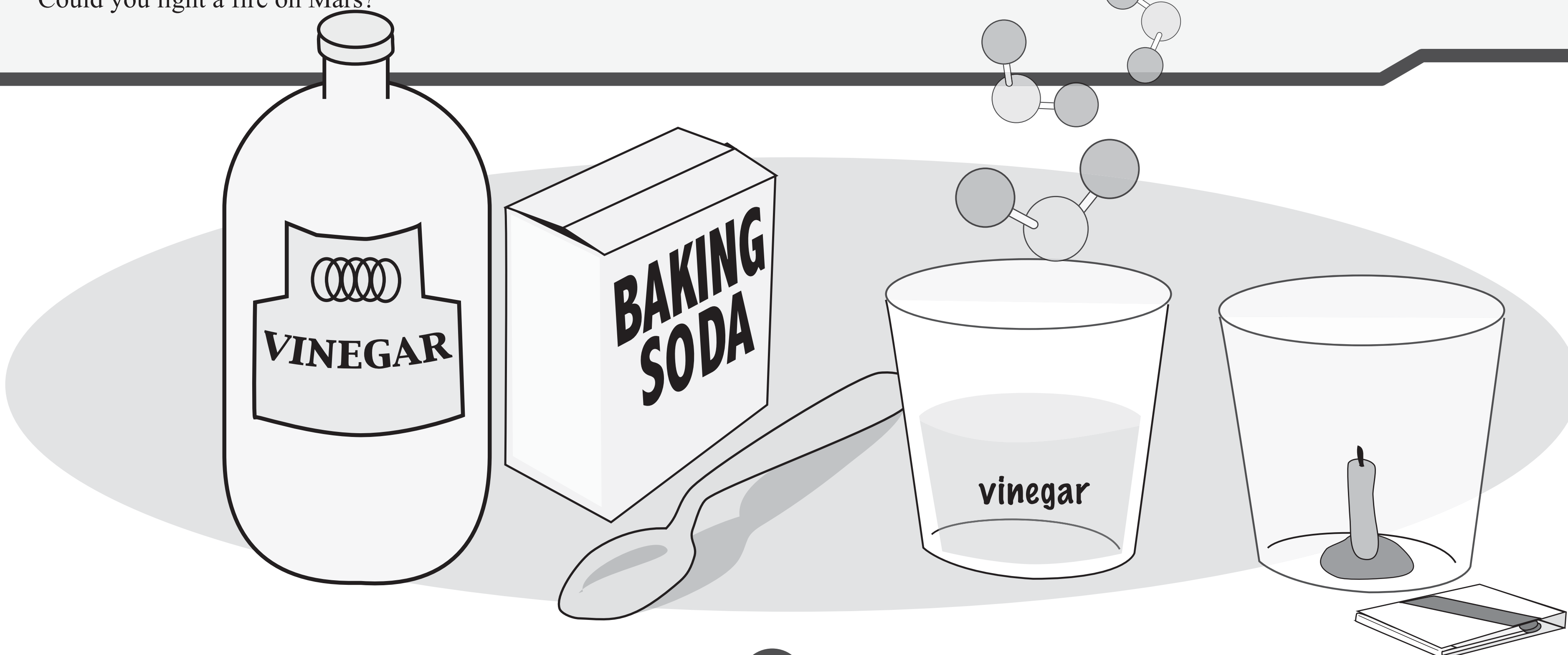


7

How is Earth's atmosphere different from Mars? (grades 4-8)

You will need: 2 plastic cups, vinegar, baking soda, short candle, small lump of clay, matches

- Pour some vinegar into one of the cups and sprinkle in baking soda. Observe the chemical reaction that occurs.
- The vinegar and baking soda haven't disappeared, they have transformed into an invisible gas called carbon dioxide. As a scientist, you don't need to take our word for that. Test it yourself.
- Put a lump of clay in the bottom of the second cup. Stick the candle into the clay.
- Ask an adult to light the candle. Observe the flame in Earth's oxygen-filled atmosphere.
- What will happen if you tilt the vinegar/baking soda cup over the lit candle? Try it, being careful not to spill the vinegar.
- Have the adult try to light the candle again. Any problems?
- Could you light a fire on Mars?



Life in Space

About Space

For the next generation spacesuit, there's still a lot that we don't know about what it's going to be like to live and work on Mars every day. Once there, you'd be doing EVA probably, walking outside on the planet about every other day. Once we have the hardware in-house, we become the experts of how that hardware works, what it does and how it meets the needs for our next phase of our mission design. – Lindsay Aitchison, Spacesuit Project Engineer, NASA Johnson Space Center

There are five major hazards faced by people who travel in Space.

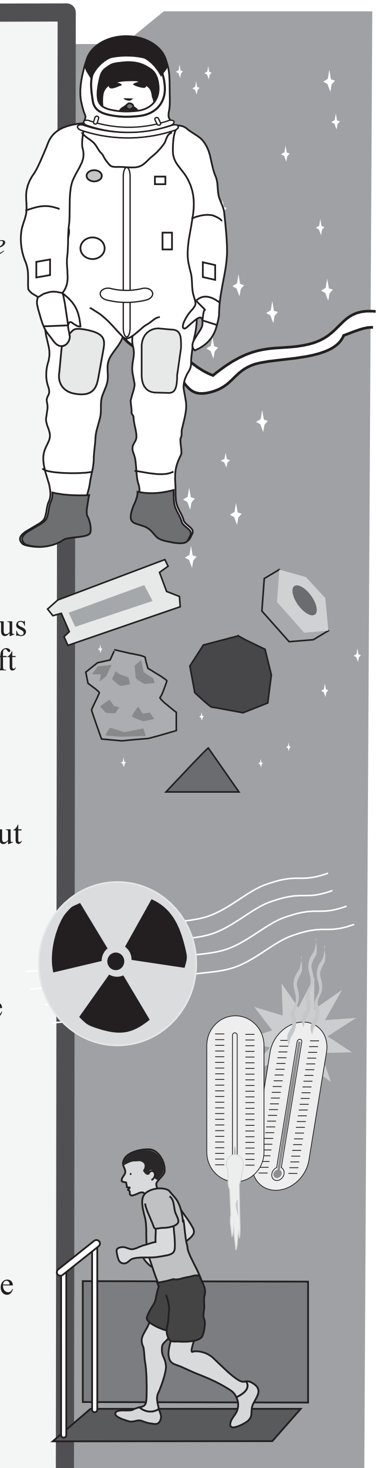
1. **Lack of Air.** The human body has developed within Earth's atmosphere and cannot survive without it. However, air does not exist in Space. The lack of air means that humans do not have any breathable oxygen and that there is no air pressure. Without a spacecraft and spacesuits to supply pressurized, breathable air, astronauts would suffocate and endure the effects of depressurization.

2. **Micrometeoroids**. Micrometeoroids are tiny bits of comets, asteroids, dust, and, sometimes, leftover junk from previous missions, all of which travel through Space at very high velocities. These fast-moving particles can puncture spacecraft and spacesuits, leading to loss of air and air pressure. They can kill astronauts by flying through them faster than a bullet. Strong spacecraft hulls and tough fabric layers in spacesuits protect against deadly micrometeoroids.

3. **Radiation.** Space contains many sources of radiation, including the Sun. Some radiation such as X-rays, gamma rays and high-energy particles can kill cells in the human body. On Earth, the atmosphere blocks most harmful radiation, but in Space, where there is no atmosphere, spacecraft and spacesuits must provide protection against this danger. In addition, to minimize the astronauts' exposure to radiation, spacewalks are kept short and crews stay in during sun storms that send out very intense radiation.

4. **Extreme Temperatures.** Space is a vacuum; it has no temperature and no air. In Space, heat cannot travel through the air like it does on Earth. When the astronauts are working outside the ISS, heating and cooling systems in their space suits protect them from, for example, bare metal that has been in the sunlight at 260°C or in the shade at -100°C.

5. **Microgravity.** Space is a microgravity environment, not zero gravity, because it is filled with mass such as planets, moons, astronauts and space capsules. The human body builds mass and strength of bone and muscle that overcome some resistance, such as the force of gravity on Earth. The resistive force sends signals to the body to build bone or muscle tissue. Because Space is a microgravity environment, the body does not have to do as much work and reacts by decreasing the mass and strength of bone and muscle. The longer an astronaut is in Space, the more bone and muscle are lost. Exercise in Space helps combat these effects.



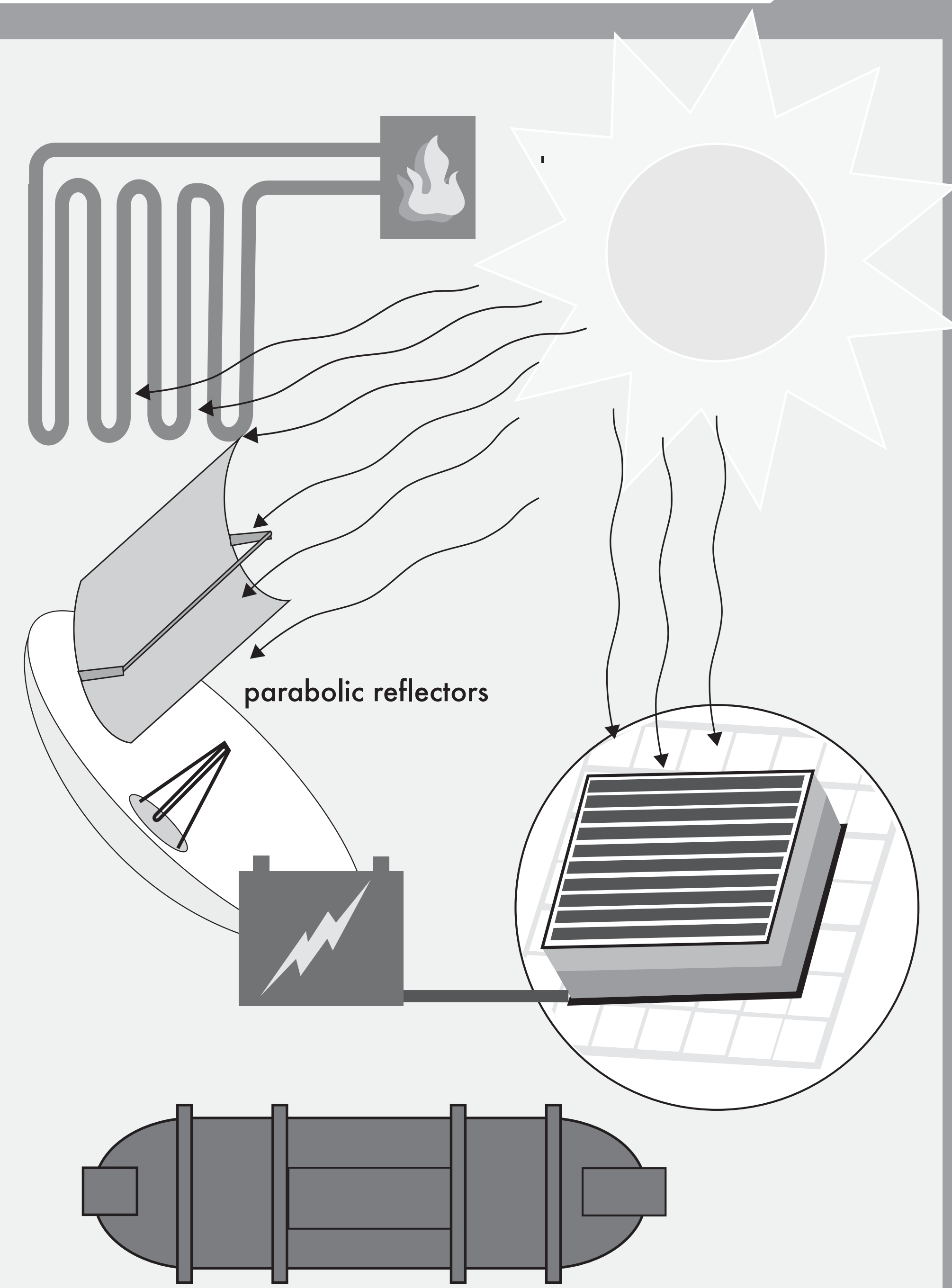
About Solar Energy

Solar energy – the energy we get from the Sun -- is used to create heat or electricity. In activity #10, your solar oven collects heat energy from the Sun and uses a parabolic reflector to gather sunlight and concentrate it in one place. In Space, large solar panels absorb enough energy from the Sun to run the International Space Station.

Solar energy is used to create heat or electricity. Energy from the Sun can be converted into solar power in two ways. The first way involves the use of solar thermal applications that use the Sun's energy to provide direct heat to air or liquid. Solar thermal panels can be used for both residential and larger- scale applications.

The second method of obtaining solar power involves the use of photoelectric applications. These applications use photovoltaic cells to convert energy from the Sun into electricity. The cells are considered low-maintenance and well-suited to remote applications using semiconductors like silicon to convert energy from the Sun into electricity. Silicon is an abundant nonmetallic element found throughout the universe and is probably best known for its use in computer chips.

NASA has been examining solar energy/photovoltaic cells as a possible fuel for space travel. All spacecraft require electrical power in order to accomplish their missions. Power is provided either by a photovoltaic array with batteries or by radioisotope thermoelectric generators (RTG). RTGs have been used as power sources in satellites, space probes and robotic missions. NASA's Curiosity Rover uses RTG power to carry out its mission on Mars.



8

How can people survive in Space? (grades 4-8)

As a medical doctor with a specialty in aerospace medicine. I am interested in keeping astronauts healthy as we head into deep space. – Astronaut Serena Auñón

It's surprising that an inflatable habitat can protect its crew against micrometeorites and radiation, but that's what tests have shown. – Astronaut Chris Ferguson

You will need: computer, access to the internet and library

- Study the photo of Expedition 42 Commander Barry Wilmore and Flight Engineer Samantha Cristoforetti taken on the ISS. Look for all the clues that tell you it is a microgravity environment. How do you know they're not in a lab on Earth?
- Now, take your shoebox and recreate that ISS environment using the supplies above, or other recycled supplies you have at home. Make sure you design the box vertically, so that it is tall, not wide.
- Place the action figure astronauts in the box. Since you're on Earth, they just sit on the bottom of the box.
- Hold the box so that the opening faces you and you can watch the astronauts.
- When you jump, what do the astronauts do?
- Try the same thing with small and large rocks. What happens?
- Compare the difference between lifting the empty 2-liter bottle and the bottle full of water. What would happen if you did that in Space?
- Imagine that you are an engineer focusing on the hazards astronauts face when they leave the safety of Earth's atmosphere. Their lives depend on you. How will you design elements of the International Space Station (ISS) to protect them?
- Choose one of the following hazards: lack of air, micrometeoroids, radiation, extreme temperatures, or microgravity. Study the ISS inside and out to understand the problem and see how it has been addressed.
- Write a report, advising NASA about the hazard and your proposed solution. Include details about how you would conduct tests on Earth.
- What materials are used to make the components that address your hazard?
- Draw a design of a section of the inside and outside of the ISS, featuring your protective system, labeling the most significant elements.
- Here are some quotes and websites to get you started:

"We can't take most of the materials with us for a long-term shelter because of the weight consideration. So one thing we're working on is how to make radiation-shielding materials from the elements that we find there (on Mars)," says Sheila Thibeault, a scientist at Langley Research Center specializing in radiation shielding.

Johnson Space Center named the NBL (Netural Buoyancy Lab) training facility in 1995 in honor of the late astronaut M. L. "Sonny" Carter, who was instrumental in developing many of the current space-walking techniques used by the astronauts.

On October 24, 2014, Alan Eustace was lifted to his peak altitude by a helium-filled scientific balloon while wearing a custom-made pressurized spacesuit. At over 135,000 feet, he began his dive, remaining in free fall for approximately 4.5 minutes.

"Within the U.S., NASA is the principal source of orbital debris expertise and is the only organization which actually characterizes the orbital debris population from the smallest debris — microns — to the largest, which can be tens-of-meters." Nicholas Johnson, Former NASA Chief Scientist for Orbital Debris

Excerpts from: nasa.gov/vision/space/gettingtospace/16sep_rightstuff; nasa.gov/directorates/spacetech/niac/thibeault_radiation_shielding.html; dx12.jsc.nasa.gov/site/index.shtml; ilcdover.com/news-and-events; and orbitaldebris.jsc.nasa.gov/index.html.

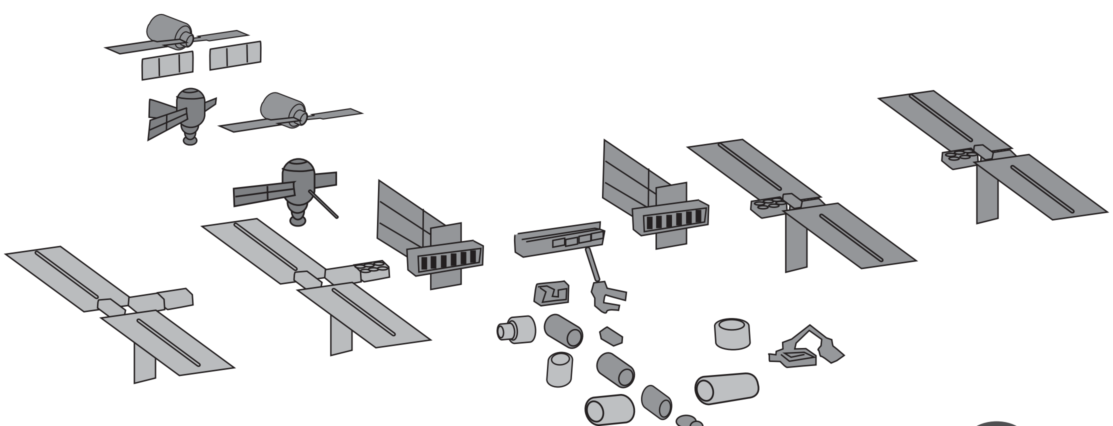
9

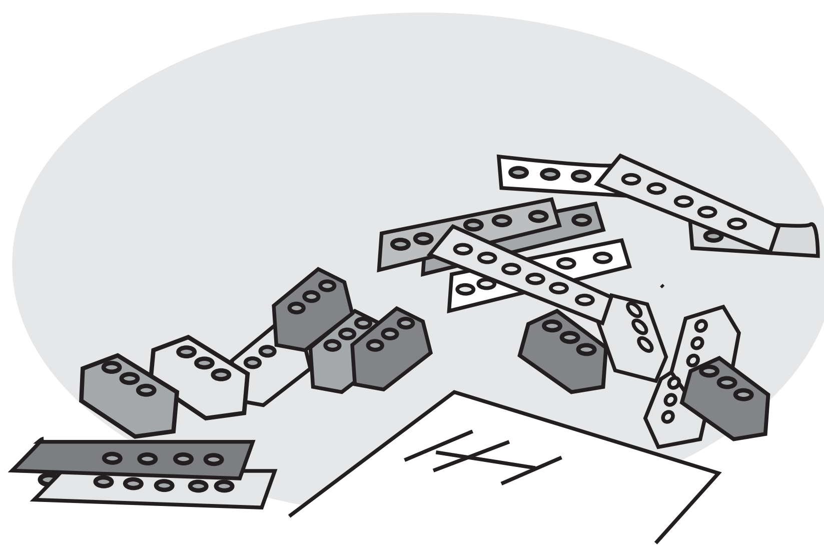
How do you build a Space Station? (grades 1-5)

You will need: plastic interlocking bricks, the drawing below, your imagination, paper, markers

- The United States, Russia, Canada, Japan and Europe all worked together to make the International Space Station (ISS).
- The ISS is put together from many different modules, brought into Space at different times. Components include docking stations, solar arrays, a robot arm, laboratories and much more.
- If assembling the ISS was your job, how would you do it? Use the plastic bricks to create your design.
- If you were going to be in Space for a long time, what would you bring with you? What would you need to survive?
- Write and/or draw your explanation for what you have included.

ISS Configuration



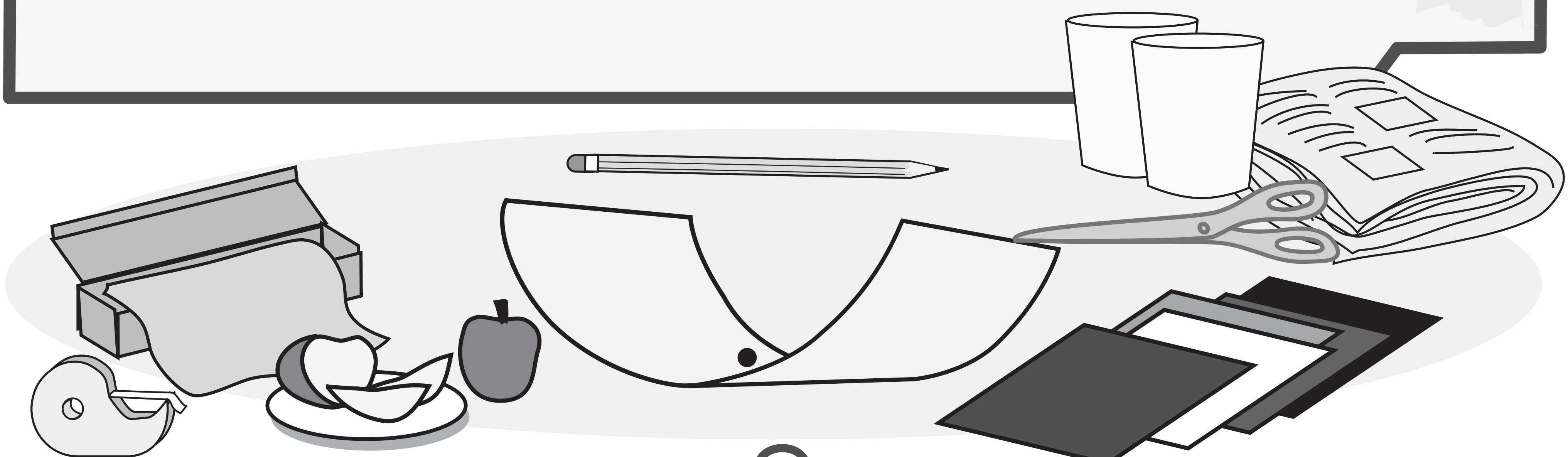


10

How do they use solar power in Space? (grades 4-8)

You will need: poster board, scissors, tape, marble, pencil, paper cups, black, white and colored construction paper, foil, newspaper, small pieces of apple

- Take your supplies outside on a sunny day.
- Curve the poster board so that it focuses the sunlight in one spot.
- Roll the marble back and forth across the curved poster board and mark the spot where it settles. That spot is called the focal point.
- Now you can use the curved poster board and other supplies to make a solar cooker.
- Design an experiment to find out what color paper or foil absorbs the most heat from the Sun. What would make the best lining for your solar cooker?
- Line your solar cooker with the paper you have chosen.
- Spread out a newspaper in a sunny spot.
- Put apple pieces in the focal point of your solar cooker and place it on the newspaper.
- Put other apple pieces on the newspaper next to your cooker. Compare what happens.
- Adjust your solar cooker to make it more powerful, based on your experiments. What changes did you make to your design?



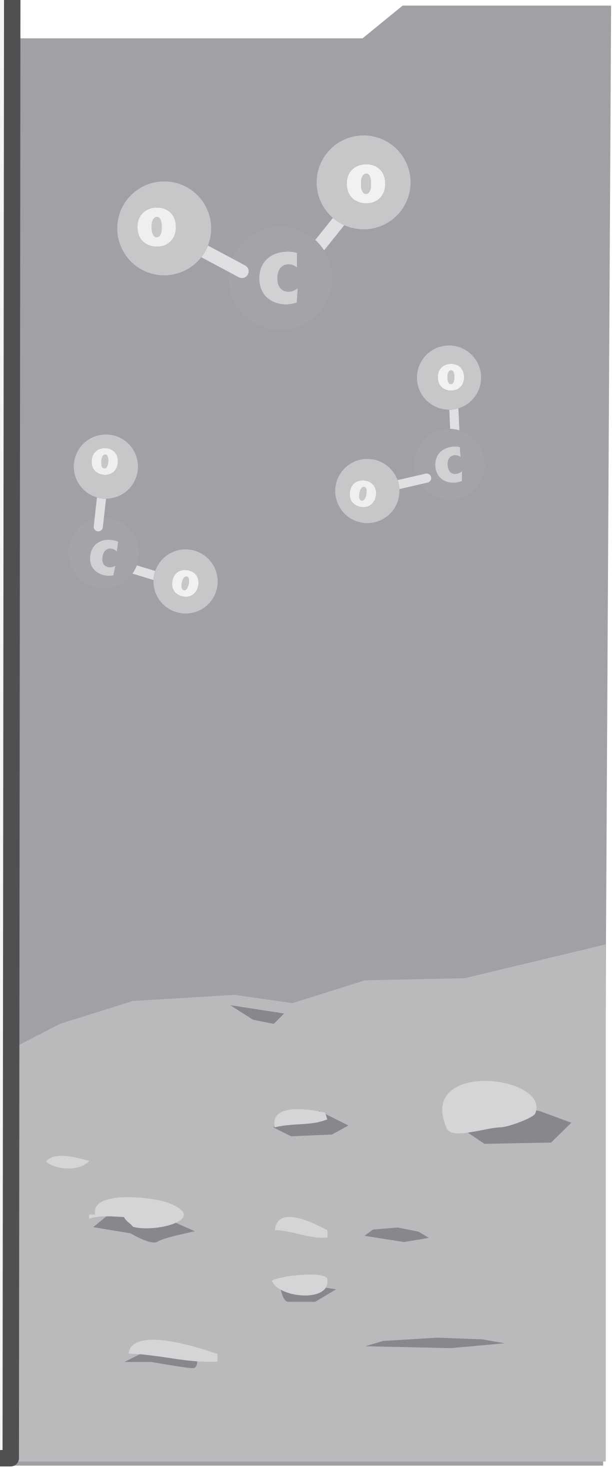
Life on Mars

About Mars

The average temperature of Mars is about -60°C and can range from -125°C to 20°C. Temperature is an important factor in determining if life can exist on a planet. Different types of living beings have different adaptations for survival in varying temperatures. The temperature range tolerable for single-celled microorganisms is remarkable. Survival in extreme temperatures is much more difficult for multicellular organisms. Plants are not specifically adapted to the cold and suffer fatal frost damage by one night's exposure to below-zero temperatures. In fact, in order for seeds to germinate into plants, the optimal temperature is between 10-40°C. This temperature range is similar for animal life. Humans cope better with temperature variations because of our clothing. The average temperature range for human habitability is 0-30°C.

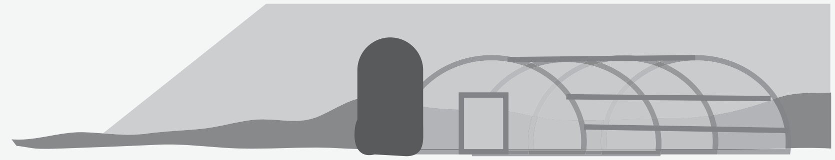
The atmosphere of Mars is very thin and is composed mostly of carbon dioxide. Atmospheric composition is another important factor in determining if life can exist on a planet. Humans are adapted to live in an atmospheric composition of nitrogen, oxygen, carbon dioxide, and water vapor that makes up the atmosphere of planet Earth. Some bacteria have demonstrated the ability to tolerate and metabolize gaseous compounds, such as hydrogen, ammonia, methane, and hydrogen sulfide, that would be dangerous in higher-level organisms.

The environmental conditions on Mars are extreme. The planet is terrestrially rocky and the soil is full of iron. Strong winds and dust storms blow across much of the planet. Liquid water is nonexistent on Mars, although water can be found frozen in polar ice caps. On Earth, organisms display a wide array of adaptations to extreme environmental conditions. Given enough time, it might be possible for life forms to evolve to withstand and even flourish with the conditions that exist on Mars.



Excerpts from *Greenhouses for Mars*

science.nasa.gov/science-news/science-at-nasa/2004/25feb_greenhouses/



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. No greenhouses exist there yet, of course. But long-term explorers, on Mars or 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. But in some ways, it turns out, they're probably going to like it better! Some parts of it, anyway.

"When you get to the idea of growing plants on the Moon or on Mars," explains molecular biologist Rob Ferl, director of Space Agriculture Biotechnology Research and Education at the University of Florida, "then you have to consider the idea of growing plants in as reduced an atmospheric pressure as possible."

There are two reasons. First, it'll help reduce the weight of the supplies that need to be lifted off the Earth. Even air has mass. Second, Martian and lunar greenhouses must hold up in places where the atmospheric pressures are, at best, less than one percent of Earth-normal. Those greenhouses will be easier to construct and operate if their interior pressure is also very low -- perhaps only one-sixteenth of Earth-normal.

The problem is, in such extreme low pressures, plants have to work hard to survive. "Remember, plants have no evolutionary preadaption to hypobaria," says Ferl. There's no reason for them to have learned to interpret the biochemical signals induced by low pressure. And, in fact, they don't. They misinterpret them. Low pressure makes plants act as if they're drying out.

In recent experiments, supported by NASA's Office of Biological and Physical Research, Ferl's group exposed young growing plants to pressures of one-tenth Earth-normal for about twenty-four hours. In such a low-pressure environment, water is pulled out through the leaves very quickly, and so extra water is needed to replenish it.

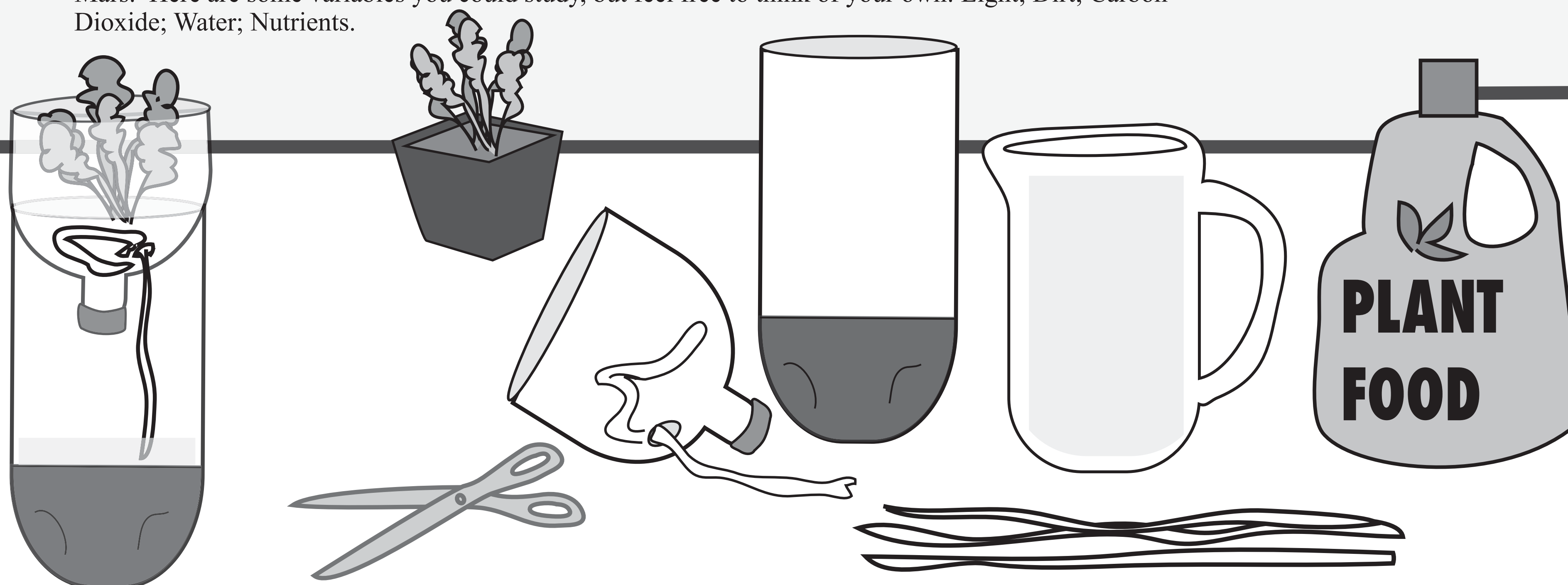
But, says Ferl, the plants were given all the water they needed. Even the relative humidity was kept at nearly 100 percent. Nevertheless, the plants' genes that sensed drought were still being activated. Apparently, says Ferl, the plants interpreted the accelerated water movement as drought stress, even though there was no drought at all.

Plants will play an extraordinarily important role in allowing humans to explore destinations like Mars and the Moon. They will provide food, oxygen and even good cheer to astronauts far from home. To make the best use of plants off-Earth, "we have to understand the limits for growing them at low pressure," says Ferl. "And then we have to understand why those limits exist."

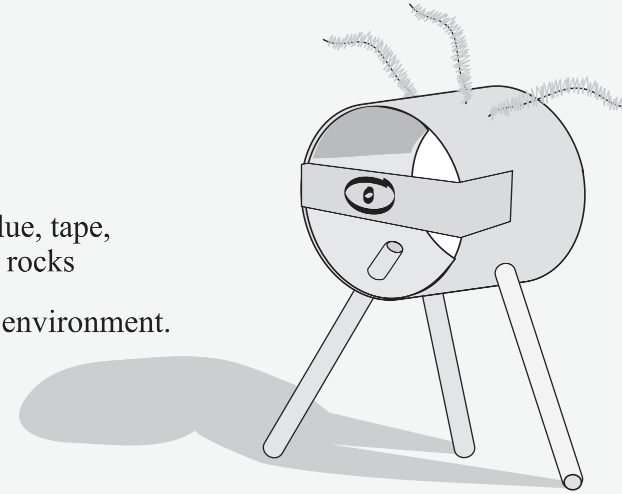
11 Can you grow plants on Mars? (grades 4-8)

You will need: two 2-liter plastic bottles with the tops cut off, scissors, strips of cotton t-shirt, liquid plant food, water, two small lettuce or swedish ivy plants

- Cut a small hole in the top half of the bottle, near the bottle cap.
- Thread the strip of t-shirt through the hole.
- Mix the plant food following the instructions on the container and pour some into the bottom of the bottle.
- Put the top of the bottle upside down inside the bottom part.
- Position the t-shirt strip so that the plant food solution can travel up the shirt to the top part of the bottle.
- Put the plant in the top of the bottle, without any dirt.
- Repeat these steps so that you have two identical set-ups – one for your control and one for you to change the conditions for your experiments.
- Create your own experiments to determine what you need and don't need to successfully grow lettuce on Mars. Here are some variables you could study, but feel free to think of your own: Light; Dirt; Carbon Dioxide; Water; Nutrients.



12 What would a Martian look like? (grades 1-5)

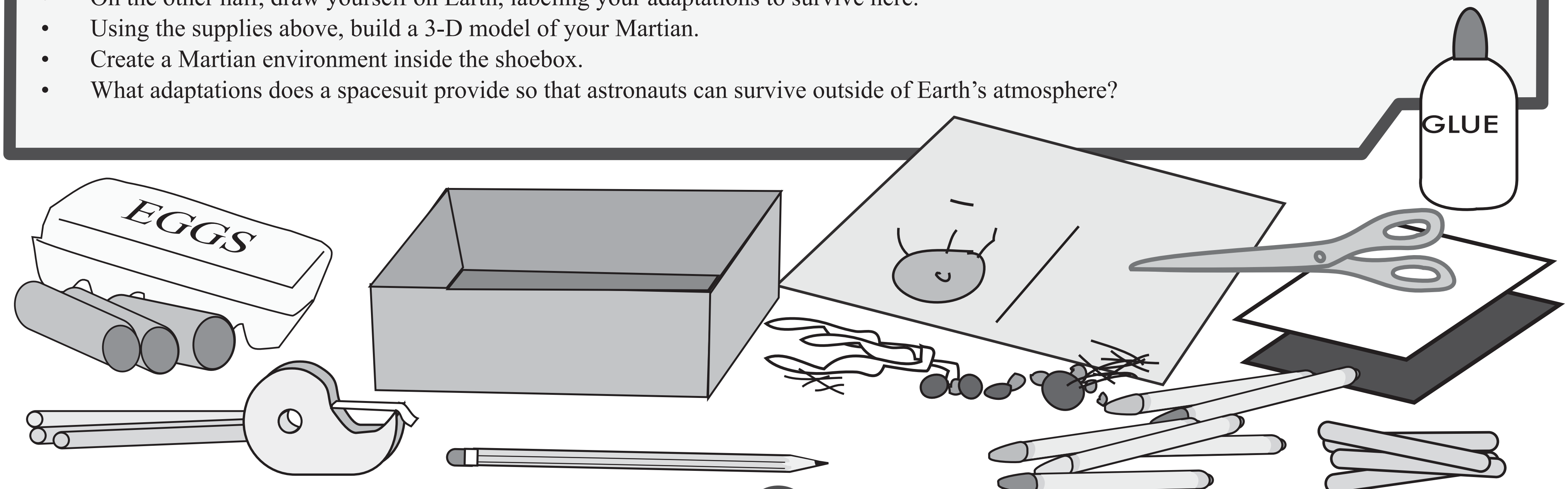


You will need: paper, markers, recycled cardboard and Styrofoam containers, egg cartons, glue, tape, scissors, paper clips, straws, toothpicks, pipe cleaners, tissue paper, shoebox, rocks

What would your body be like if you were a Martian? You would have adapted to survive in that environment. Here are five big differences between Mars and Earth.

1. Mars is very cold, windy, and dry.
2. There is no water in liquid form.
3. It is rocky and largely volcanic.
4. It has a very thin atmosphere that is mostly carbon dioxide.
5. The planet has a reddish hue due to the abundance of Iron in the soil.

- On one half of your paper, draw a picture of a Martian, labeling his or her adaptations to survive on that planet. Design adaptations for all five of the conditions above.
- On the other half, draw yourself on Earth, labeling your adaptations to survive here.
- Using the supplies above, build a 3-D model of your Martian.
- Create a Martian environment inside the shoebox.
- What adaptations does a spacesuit provide so that astronauts can survive outside of Earth's atmosphere?



I think to explore beyond what is known is simply at the core of our DNA. – Astronaut Serena Auñón

More to Explore: A Guide for Families

If you loved *Journey to Space* you'll love seeing the Space Shuttle.

Atlantis: Kennedy Space Center Visitor Complex, NASA, Cape Canaveral, FL
Discovery: National Air and Space Museum, Steven F. Udvar-Hazy Center, Chantilly, VA
Endeavour: California Science Center, Los Angeles, CA
Enterprise: Intrepid Sea, Air & Space Museum, New York City, NY
Full Fuselage Trainer: Museum of Flight, Seattle, WA (full-scale mockup without wings, used for training)

Visit astc.org or childrensmuseums.org to find other museums, planetariums and space exhibits near you.

The *Journey to Space* Educators Guide is full of fun, hands-on science you can do at home. Visit http://journeytospacefilm.com to download the activities and enjoy.

You can continue your "Journey to Space" with more complex, modular electronics activities on Satellites, Mars and more at http://littlebits.cc/education.

Meanwhile, quiz your family on some of the fun facts below!

How big is the International Space Station (ISS)? The ISS is the size of an American football field with the end zones included. It's roomier than a six-bedroom house.

How much does the ISS weigh? 924,739 pounds.

What are the five countries that built the ISS? United States, Russia, Canada, Europe, and Japan.

When the ISS celebrated its 10th anniversary in 2010, how many miles were on its odometer? 1.5 billion statute miles (the equivalent of eight round trips to the Sun).

In 10 years, how many people visited the Space Station? 215.

How long is the Space Shuttle Orbiter? 122 feet. That's longer than 3 school buses.

How much does it weigh? 178,000 pounds. That's 13.4 African Elephants.

How many total miles were flown by all of the Space Shuttles? 513.7 miles.

Excerpts from: nasa.gov/mission_pages/station/main/onthestation/facts_and_figures and nasa.gov/externalflash/the_shuttle/.