Mars...

Just Imagine

Your future in space

Bruce Irving

Mars... Just Imagine

Your Future in Space

by Bruce Irving

Graphics by Bruce Irving
using Stellarium & Orbiter freeware
with various Orbiter add-ons (3D models)
and some NASA images
Cover and additional graphics by Jason Archer

Dear Readers, Parents, and Teachers,

Please see the background information section starting on page 18 for more detailed information on the pictures and text for each page, including credits and references for the free software and 3D models used to create most of the illustrations.

Bruce Irving

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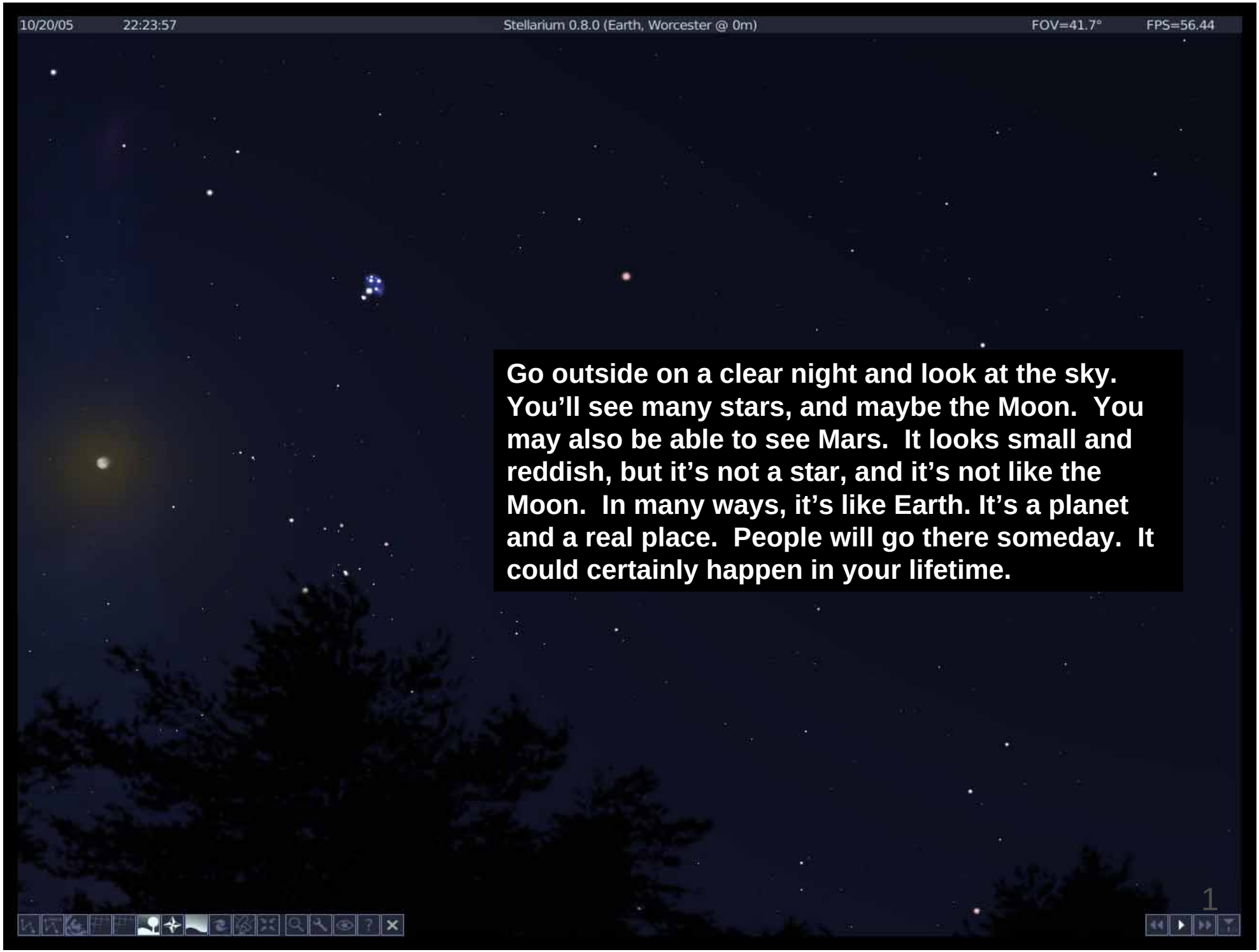
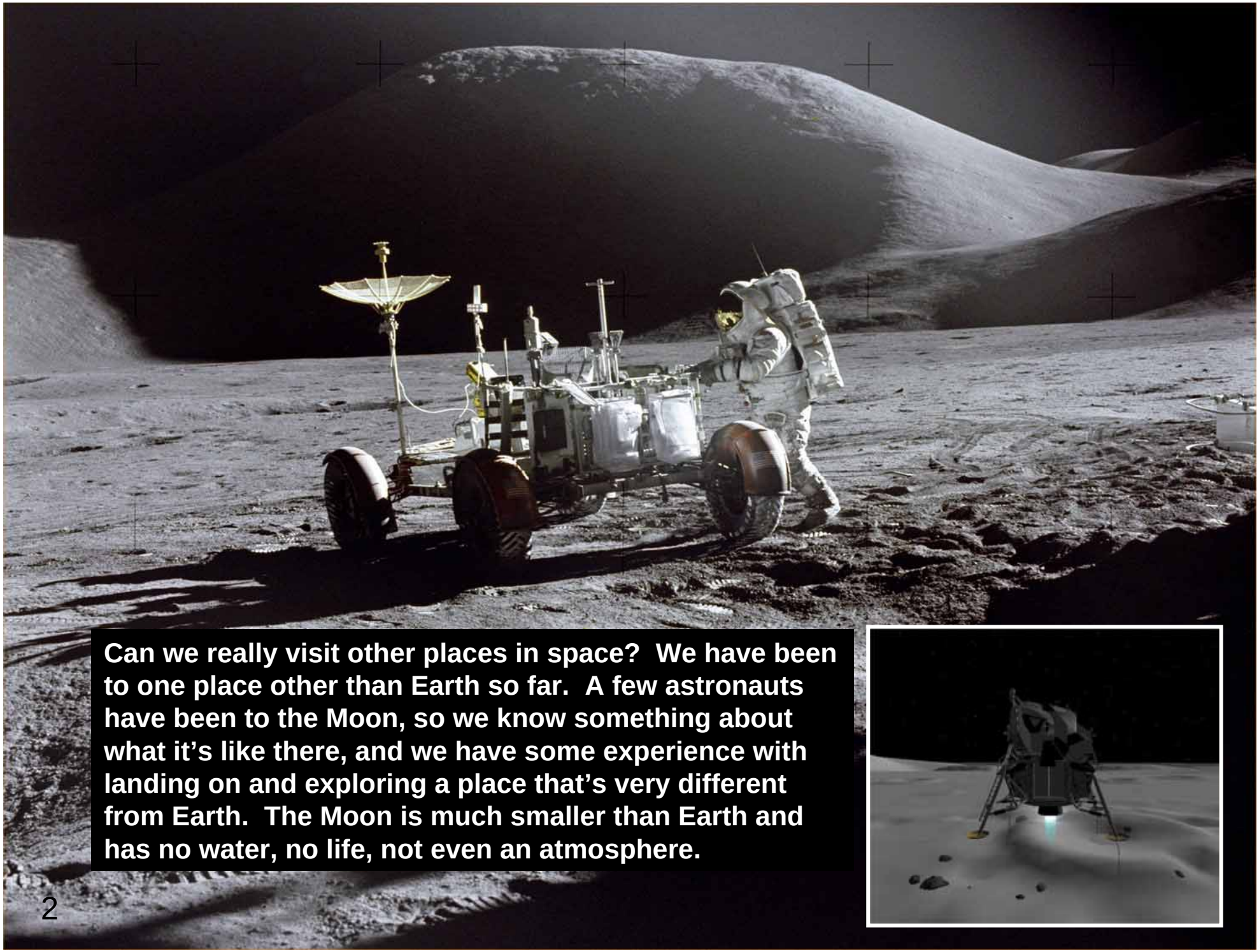
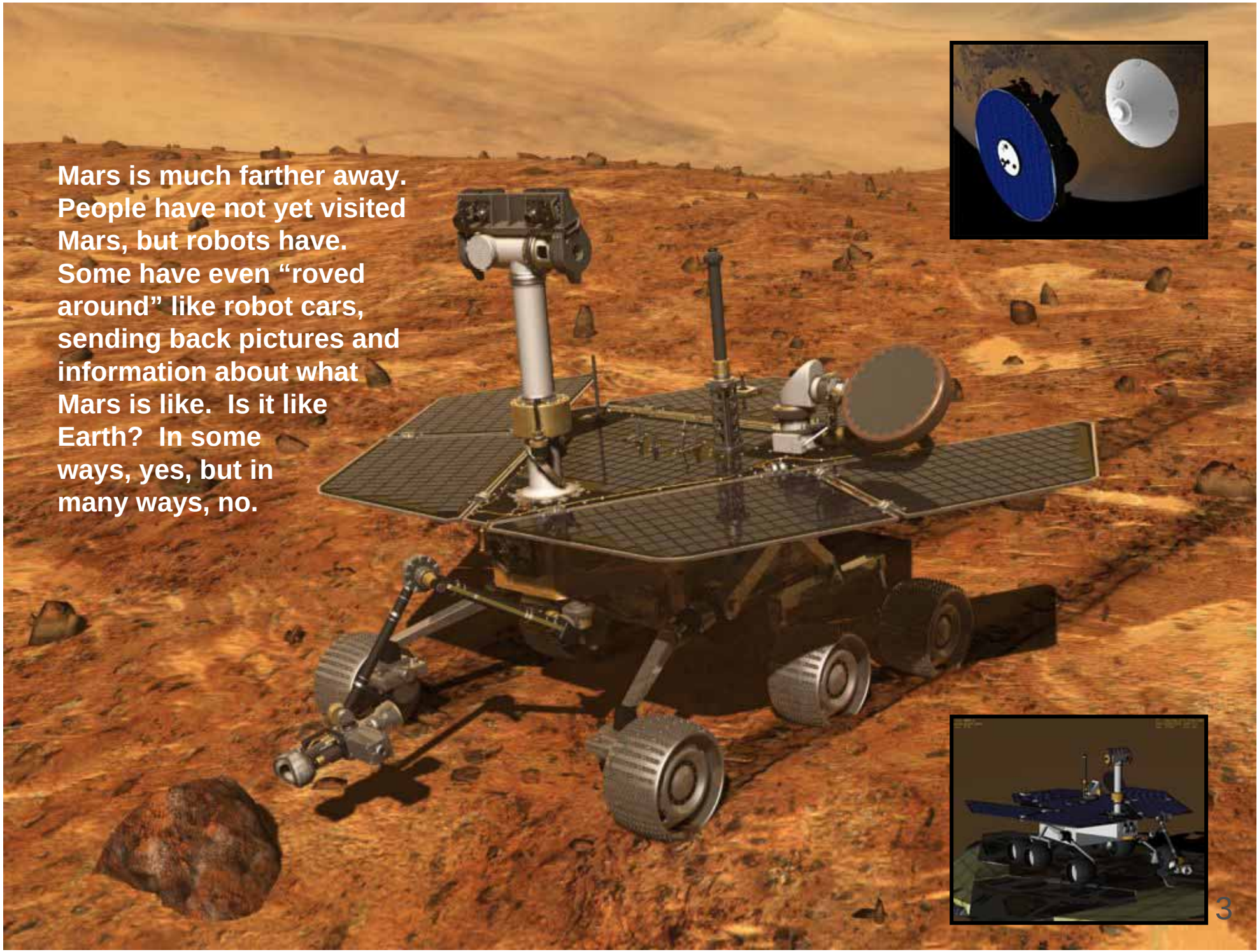


Go outside on a clear night and look at the sky. You'll see many stars, and maybe the Moon. You may also be able to see Mars. It looks small and reddish, but it's not a star, and it's not like the Moon. In many ways, it's like Earth. It's a planet and a real place. People will go there someday. It could certainly happen in your lifetime.



Can we really visit other places in space? We have been to one place other than Earth so far. A few astronauts have been to the Moon, so we know something about what it's like there, and we have some experience with landing on and exploring a place that's very different from Earth. The Moon is much smaller than Earth and has no water, no life, not even an atmosphere.


Mars is much farther away. People have not yet visited Mars, but robots have. Some have even “roved around” like robot cars, sending back pictures and information about what Mars is like. Is it like Earth? In some ways, yes, but in many ways, no.

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Mode target-relative
Dist 19.45M

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MJD 53542.6709
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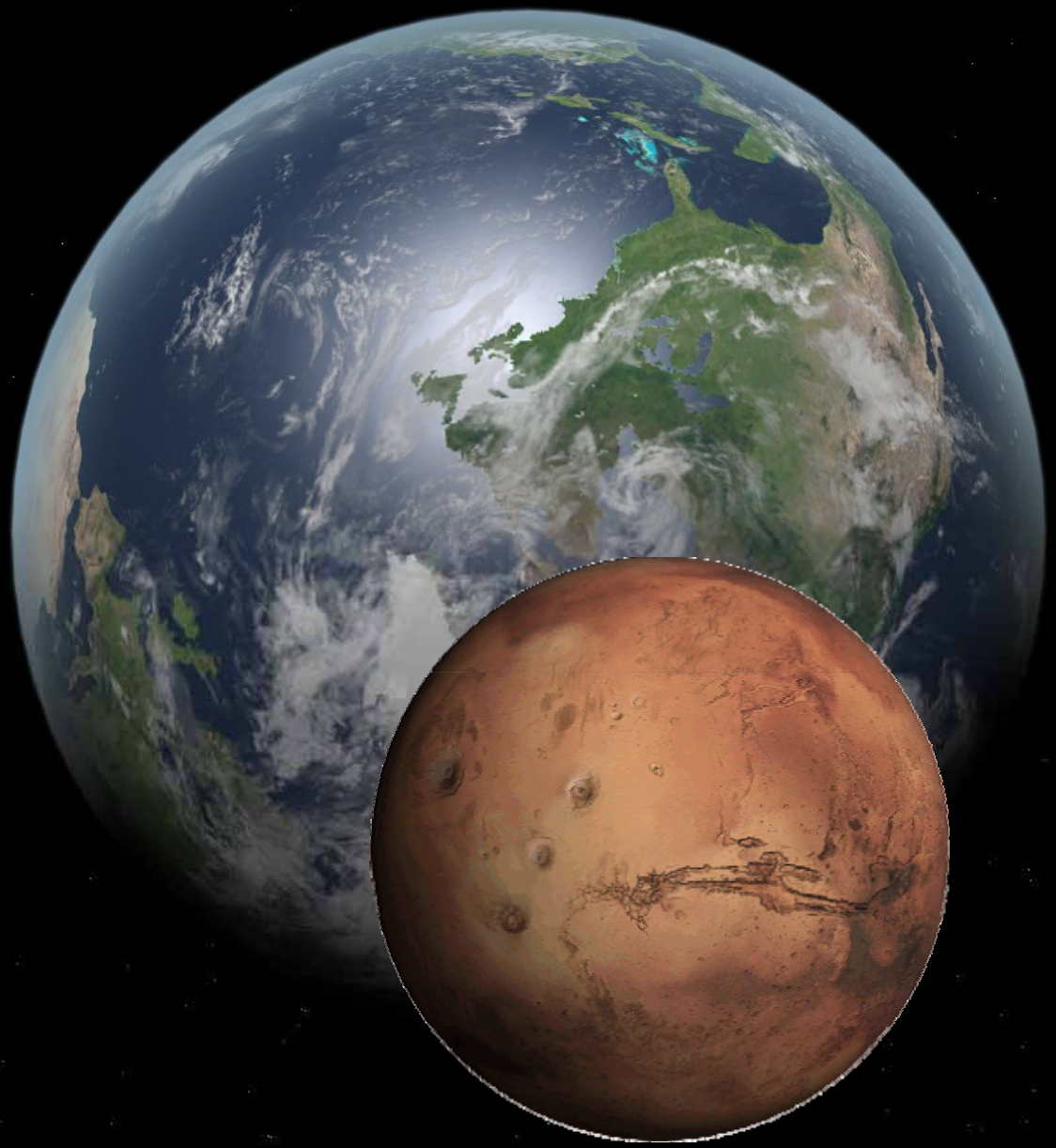
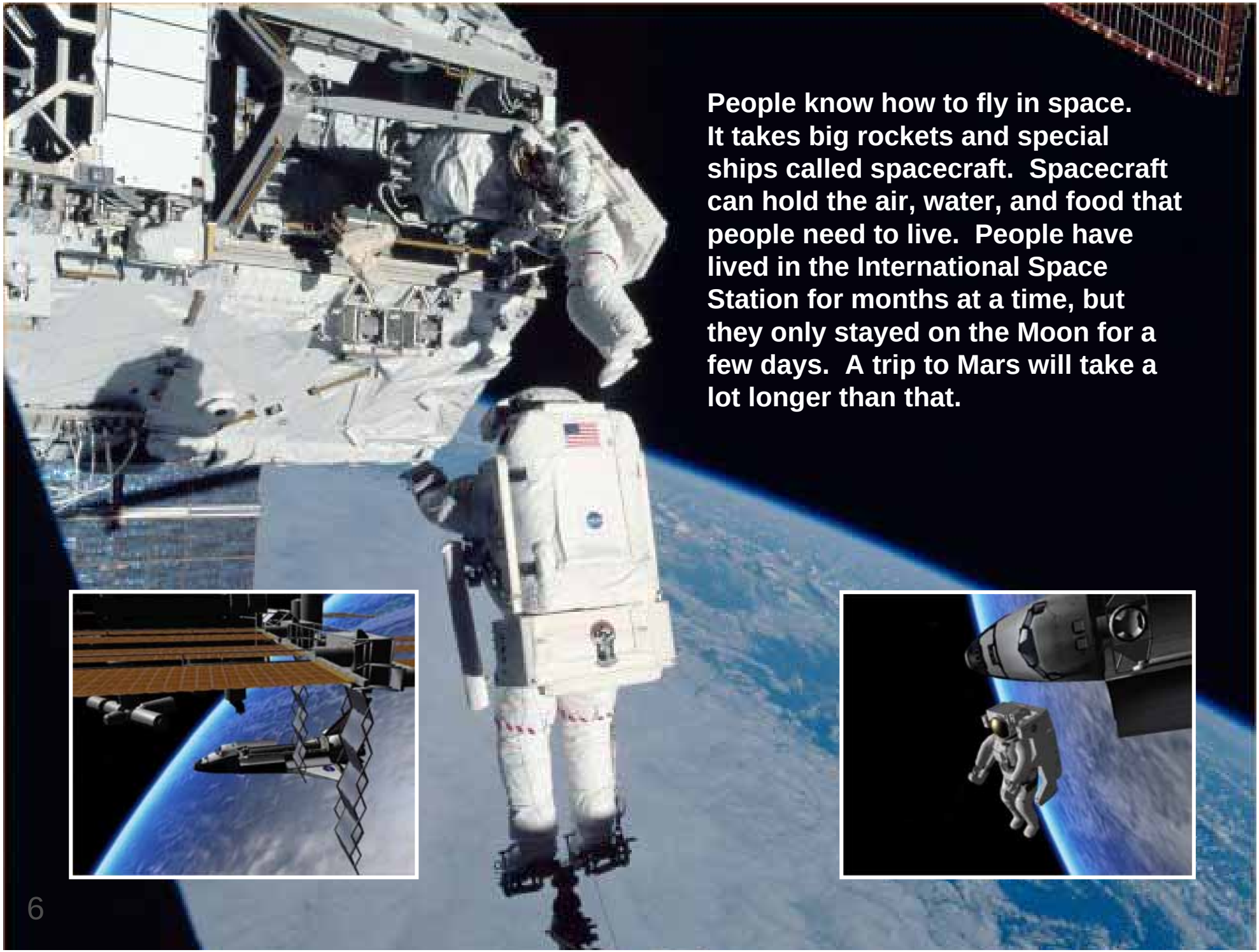
Mars is smaller than Earth, making its gravity weaker than Earth's gravity, so you would weigh less on Mars. It has a solid surface with rocks and dirt. Mars has an atmosphere, but it's thin and we can't breathe it. Mars has water, but it's so cold there, the water is mostly ice frozen in the soil. There are most likely no Mars plants or animals (and no people yet).



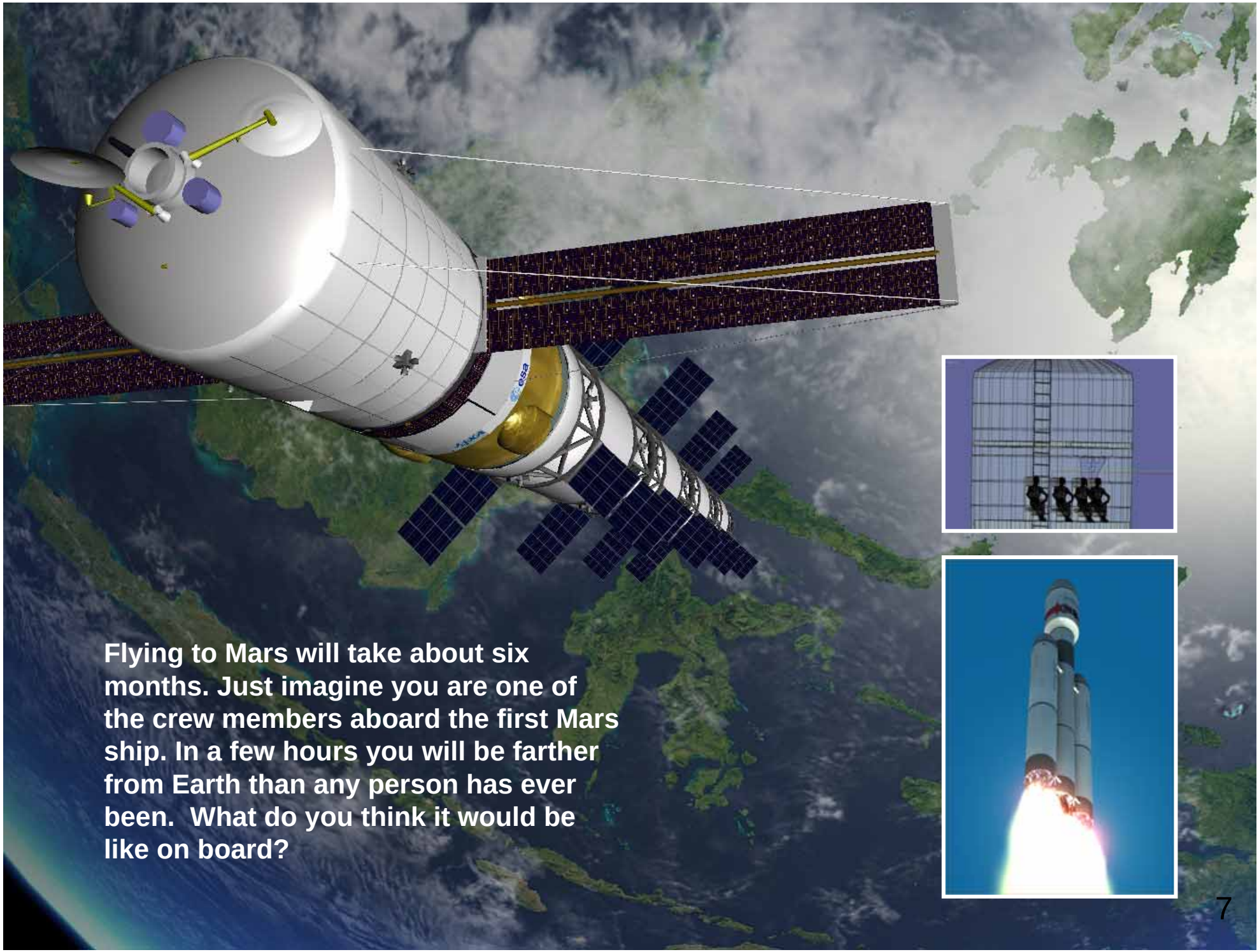
So does all that mean Mars is just like Earth? Not exactly! But there is enough useful stuff on Mars that with the help of machines and plants, people will be able to make good air, water, and rocket fuel, build shelters, and grow food. Even the first visitors to Mars will "live off the land" for some of the things they need.

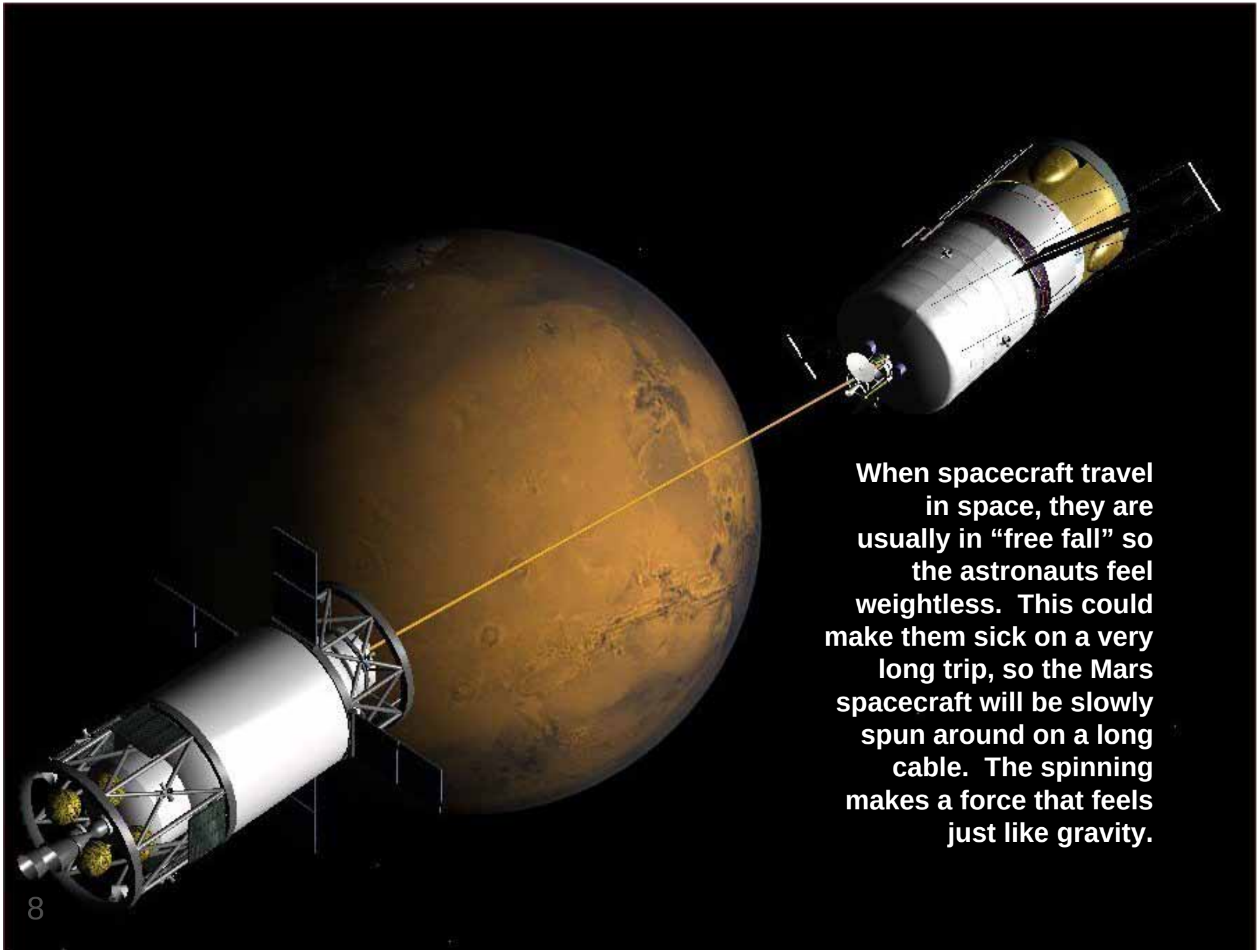
Even though it will be hard at first, before too long, people will go to Mars, to explore and eventually even to live there. We already have most of the necessary technology.

Just imagine what it would be like on Mars. Would you like to go? Of course it all begins with getting to space and learning how to live there, and we have a good start on that.



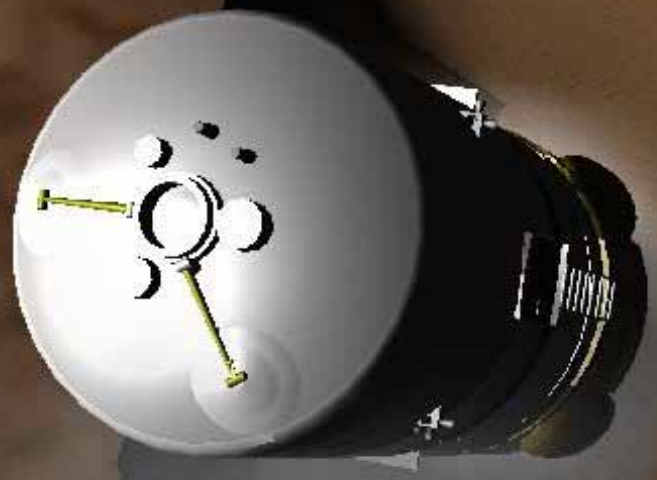
People know how to fly in space. It takes big rockets and special ships called spacecraft. Spacecraft can hold the air, water, and food that people need to live. People have lived in the International Space Station for months at a time, but they only stayed on the Moon for a few days. A trip to Mars will take a lot longer than that.

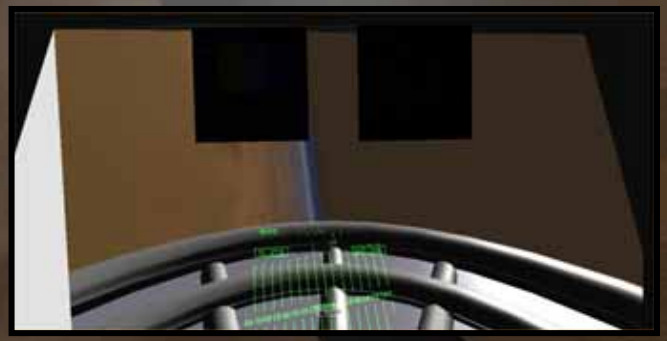

Flying to Mars will take about six months. Just imagine you are one of the crew members aboard the first Mars ship. In a few hours you will be farther from Earth than any person has ever been. What do you think it would be like on board?

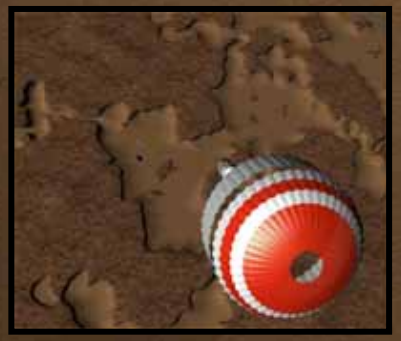


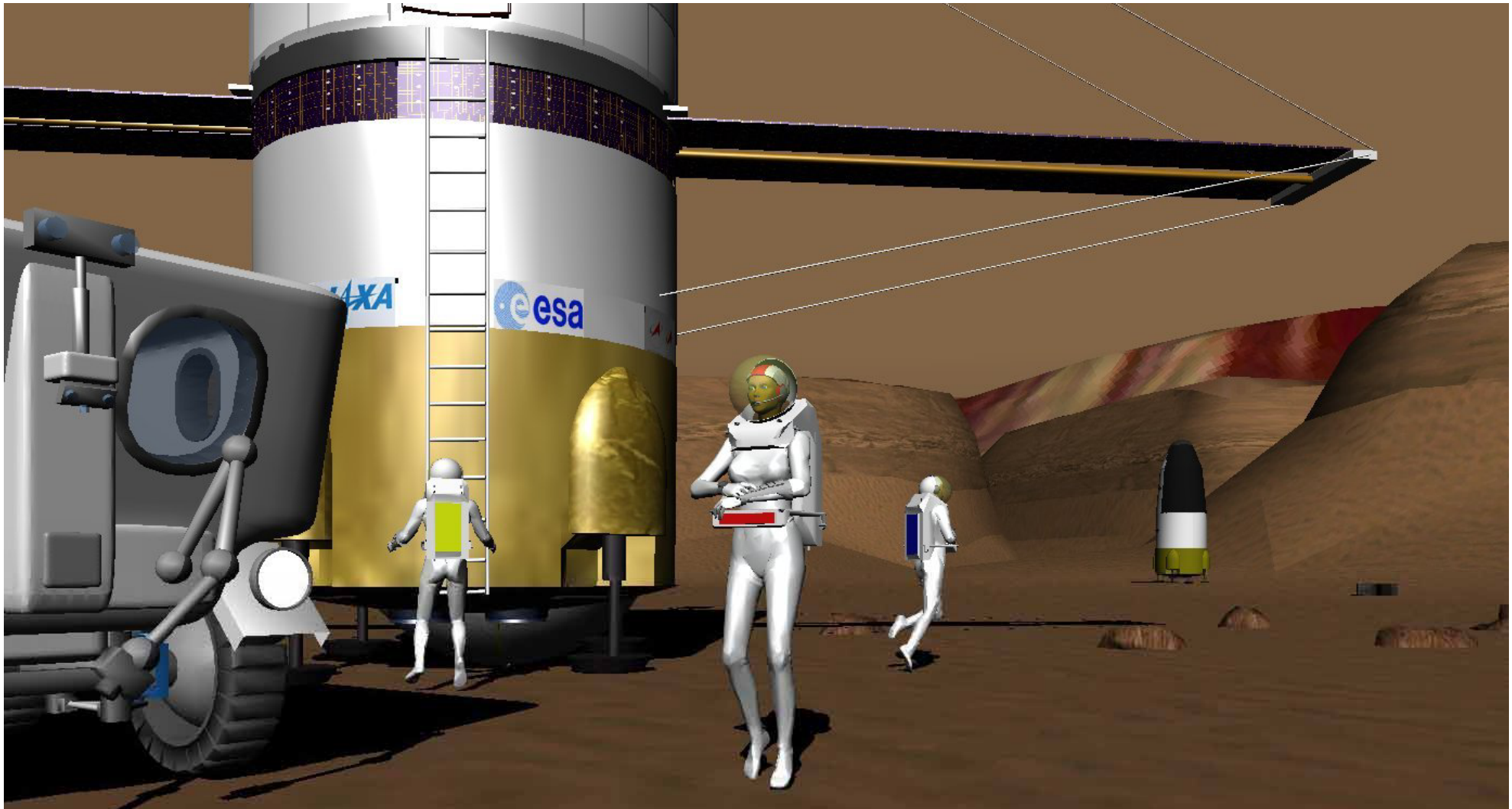
When spacecraft travel in space, they are usually in “free fall” so the astronauts feel weightless. This could make them sick on a very long trip, so the Mars spacecraft will be slowly spun around on a long cable. The spinning makes a force that feels just like gravity.

Landing on Mars will be exciting. The spacecraft is going very fast on its flight from Earth and needs to slow down to enter the atmosphere and land safely. The “aeroshield” starts the slowing down and protects the spacecraft from heat. Then parachutes and finally rockets are used to slow down more and land.





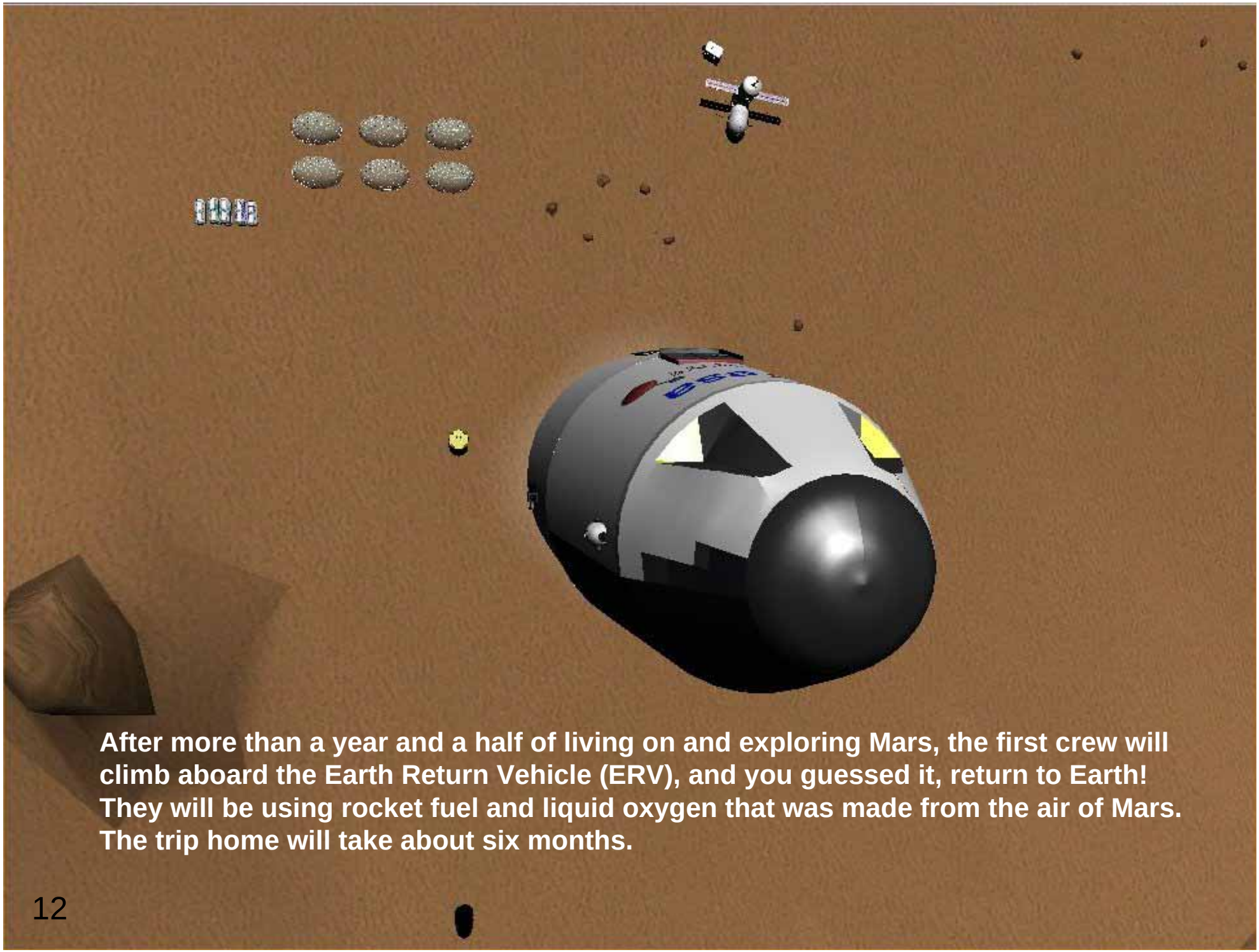




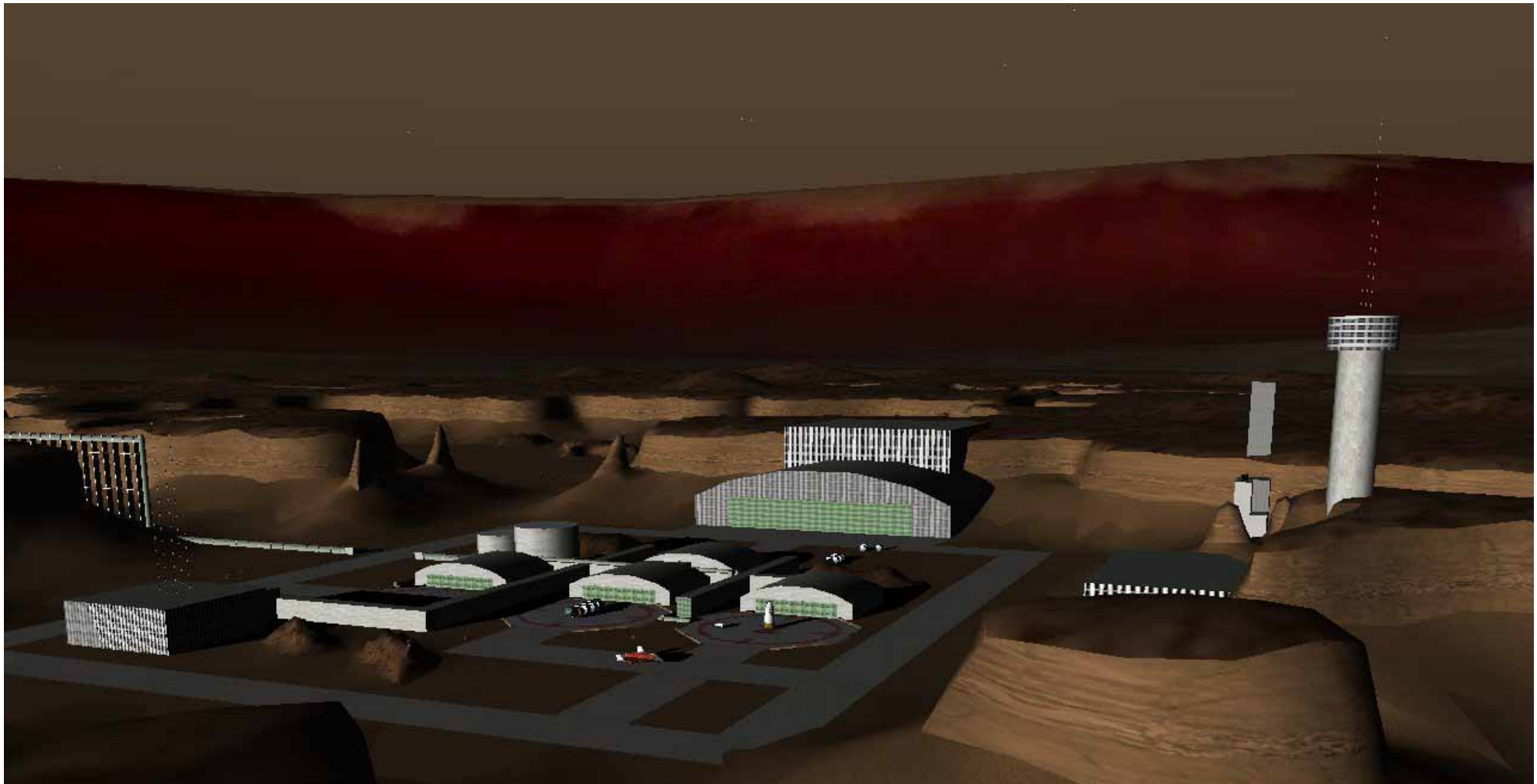
Mars has an atmosphere, but it's thin and it doesn't have enough oxygen to breathe, so people will have to wear space suits to go outside. Just imagine that you are the first astronaut to step onto the Martian surface. You would be making history.

What do you think your first words would be?

Driving their Mars rover, the first explorers will be able to visit a fairly large area around their landing site. They will probably be scientists who have trained to be astronauts. They will collect and study rock samples, drill holes to learn what's under the surface, and look for signs of possible past or present life. Compared to robots, humans learn quickly from experience and can easily change their plans based on what they see and learn.

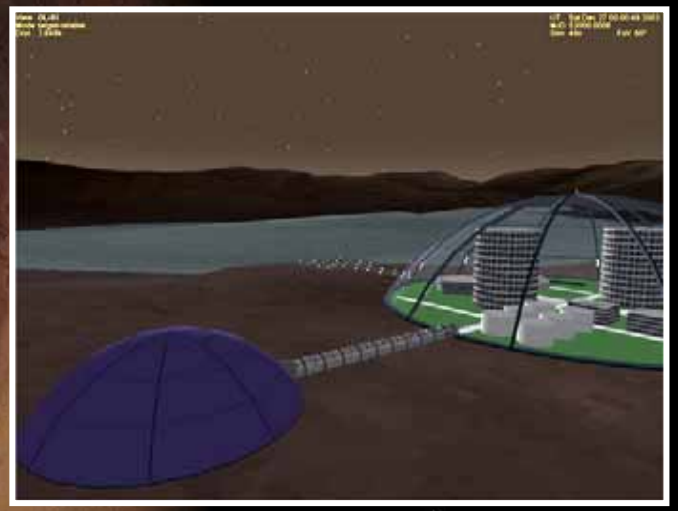


After more than a year and a half of living on and exploring Mars, the first crew will climb aboard the Earth Return Vehicle (ERV), and you guessed it, return to Earth! They will be using rocket fuel and liquid oxygen that was made from the air of Mars. The trip home will take about six months.



More crews will follow, exploring more of Mars. In a few years, people will begin to make permanent bases, and some of the explorers will stay on Mars to start to build a new world. Just imagine living in the first town on Mars. At some point, babies will be born on Mars, people just like you and me – but you could also call them the first true Martians. Mars will be a new branch of human civilization.

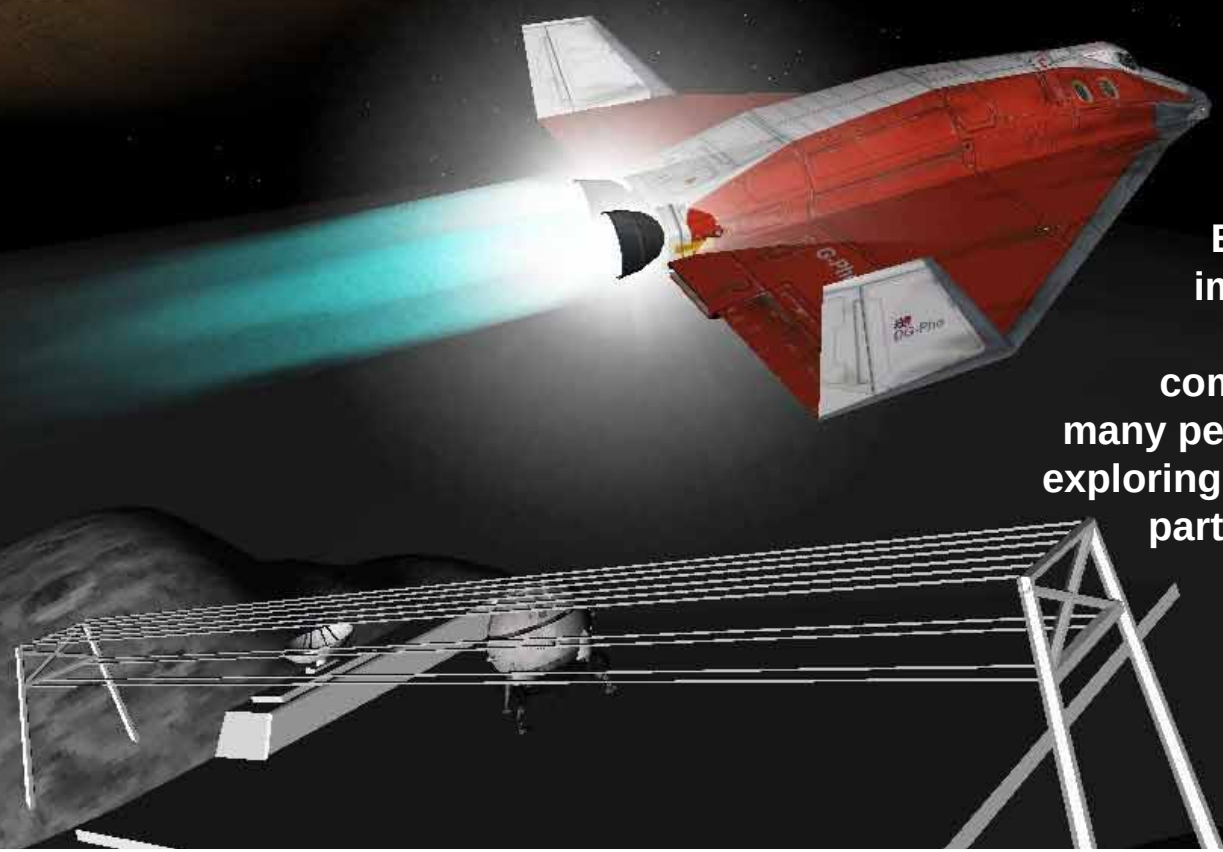
Once permanent bases are set up, more people may want to follow the explorers to Mars, and new technology should make possible large colony ships to carry hundreds of people at a time to Mars. These ships would use super advanced engines, allowing them to make the Earth-Mars trip in only a few weeks instead of six months or more.



Some people ask why we should go to Mars. Shouldn't we solve problems on Earth first? Of course we should work to solve Earth's problems, but we can and should go to Mars too. Here are a few reasons.

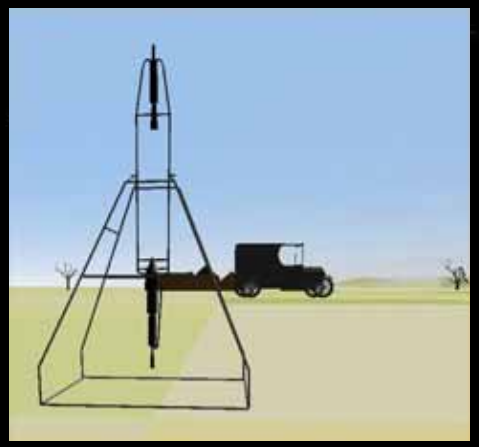
Whenever people in the past have gone to new places, they have found new resources and new ideas and have learned things that have been surprising and often useful. In learning to live on Mars, we may find better ways to live on Earth.

Exploring and living on Mars will be hard at first, and various countries will probably work together to do it. This common goal will help bring people together. All the work needed to do it will help create new jobs and new knowledge for everyone. Eventually we will get new materials and possibly solutions to energy and other problems from space, and the technology needed for Mars will help us with these things too.



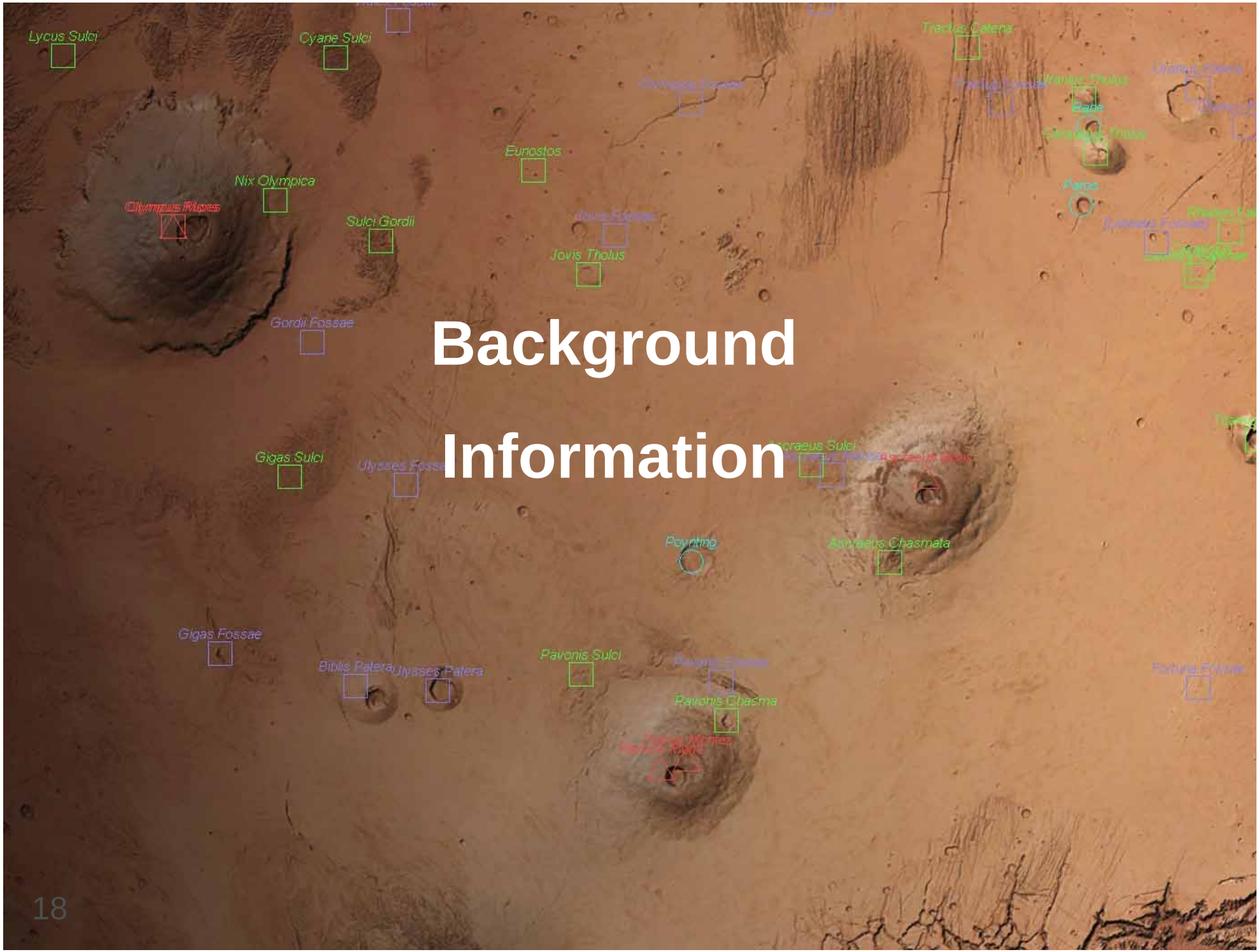
Exploring also inspires the imagination, and the idea of exploring and living on a completely new world excites many people. It won't be easy, but exploring and facing challenges are parts of what make us human.

Farther in the future, Mars may no longer even be the Red Planet. People living on Mars may figure out how to melt its hidden ice into rivers, lakes, and seas, and how to thicken and warm its thin, cold air. Plants would turn it into a Green Mars.



In the late 1800's, young Robert Goddard dreamed of flying beyond Earth's atmosphere. In 1926, he built and flew the first liquid-fuel rocket. It was small and didn't fly very high, and even his later rockets would never get anywhere near space. But they did show others the way to modern rockets, to rockets that took astronauts to the Moon just 43 years later. Goddard was a dreamer and a practical problem solver, a powerful combination. Your dreams can be powerful too. Powerful enough to reach Mars? Maybe so.

Just imagine…



Background Information

Motivation and Background

Although nominally aimed at children age 8 and up, this “picture book” is intended for anyone who is a bit curious about our future as a spacefaring civilization, which might be stated more simply as “our future.”

Its goal is to stimulate thinking about going to Mars and beyond as a serious and worthwhile calling for humanity; as a peaceful and productive international activity that can unite us, employ us, and teach our children that dreaming and problem solving are both essential parts of the human experience; and perhaps someday provide us with a lifeboat in case our recent luck with a one-planet strategy should run out.

There is a bit of scientific and technical information in the picture pages (and more in this section), but my real goal, however short I may fall, is to inspire. Aviator/author Antoine de St. Exupéry once said:

“If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.”

The sea is small potatoes compared to space, the final and essentially infinite frontier. Start working on the longing. We’ll get the wood later.

Bruce Irving

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Page 1 (Go outside…) Background picture from Stellarium, an excellent and free PC planetarium program you can download and install (see credits page). This picture is magnified a bit, more like the view through binoculars. It happens to show the sky from Worcester, Massachusetts, USA on October 20, 2005 at 10:23 pm, looking east (you can set any position, date, and time).

Finding Mars: Of course Mars moves around the Sun so depending on the time of year, time of night, and your location, it may or may not be visible in the night sky. There are some web sites that can help you find whether and where Mars can be seen in the night sky for your location, date, and time of night. Try these web sites (or search Google for "how to find Mars")

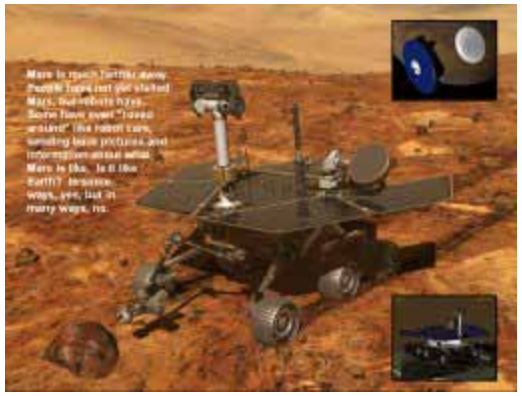
http://skytonight.com/observing/ataglance (see Planet Roundup at bottom)

http://www-mgcm.arc.nasa.gov/ (where Mars is in its orbit and more)

You can also use Stellarium to find Mars or any other common sky object (stars, planets, etc.). Just click the Search icon in the tool panel in the lower left and type **Mars**. The view will go to it, but it may be hidden behind the "ground" and thus invisible to you. You can turn off the ground with another icon in the program, but unfortunately not in real life!

Page 2 (Moon) Background picture of Apollo Moon Rover and astronaut Jim Irwin from Apollo 15 Moon landing, 1971, courtesy NASA. Inset picture shows the Apollo Lunar Module (LM) as modeled in Orbiter, with the free Apollo program add-on package that simulates the Apollo missions in great detail (quite complex, with lots to learn). See page 28 for more information on the free Orbiter space flight simulator.

Future of the Moon: Although the Moon has no air and little or no water, it has some potentially valuable materials and may serve as a base for some future space missions. Though it is not really needed as a base for Mars missions, it will be a good place to test some of the spacecraft and systems needed for Mars missions. NASA has plans to return to the Moon by around 2018. Other countries and even private companies also have plans for Moon flights in the next few years.



Page 3 (Mars Exploration Rover) Background image courtesy NASA/JPL-Caltech artist's concept of what the unmanned Mars Exploration Rovers (MER) *Spirit* and *Opportunity* look like on Mars (they landed far apart on Mars in January 2004 and can't take their own or each other's pictures). Inset pictures from Orbiter, showing the MER spacecraft preparing to enter Mars' atmosphere (upper right) and emerging from its landing pod (lower right), using an add-on by Bradley Hodges and others.

Roving Mars: The Mars Exploration Rovers *Spirit* and *Opportunity* were only expected to survive for around 90 Sols from when they touched down on Mars in January 2004. But as of this writing, both rovers have survived for more than 900 "Sols" (a Sol is the time it takes for Mars to revolve on its axis, about 24 hours and 40 minutes, just a little longer than an Earth day), over 2.5 Earth years! They have roved over much longer distances than originally planned and have made a lot of discoveries about the Martian surface and its sometimes wet history. For more information and activities related to the Mars Rovers, search the web for "Mars rover kids" or see:

http://marsrovers.nasa.gov/home/
http://athena.cornell.edu/kids/index.html

Page 4 (Earth/Mars comparison) Pictures captured from the Orbiter space flight simulator and superimposed for comparison of size and appearance. Here is a table comparing various aspects of Earth and Mars:

http://www.space.com/scienceastronomy/mars_tape_030819.html

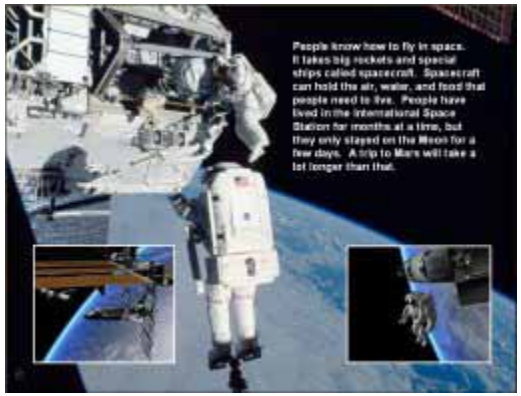
This NASA page has more information including some great animations:

http://www.nasa.gov/vision/earth/environment/Sibling_Rivalry.html

Comparing Planets: One of the benefits of space exploration (robotic as well as human) is the chance to study other planets up close for comparison with Earth. Comparison of systems that are similar in some ways and different in others can really help us to understand those systems better. We are lucky that there are three fairly similar planets in the Solar System, Venus, Earth, and Mars. All three are fairly close to the Sun, fairly similar in size (Venus and Earth are almost exactly the same size, and Mars is about half the diameter of Earth), and are solid "rocky" planets with atmospheres. Studying the atmosphere of super-hot Venus helped scientists to understand the greenhouse effect which is causing global warming on Earth. Mars also has weather, including giant dust storms. As we study Mars in more detail, we will learn more things that will help us to better understand the Earth. For more information, web search for "compare Earth Mars".

Page 5 (Early Mars Base) Background picture of an early Mars exploration base simulated in Orbiter, using the following add-ons: *Mars for Less* project for Orbiter, Vallis Dao 3D Mars terrain, inflatable module add-on, and astronauts and greenhouse 3D objects by Greg Burch.

Mars for Less: The spacecraft shown here and on pages 7-12 are from a proposed human Mars mission called *Mars for Less*, designed by Grant Bonin (a Canadian aerospace engineer) and simulated for Orbiter by a team consisting of Andy McSorley, Mark Paton, and Bruce Irving (the present author). *Mars for Less* is similar to an earlier mission proposal called *Mars Direct* by Robert Zubrin, using his basic idea of "living off the land" by using the Mars atmosphere to make rocket fuel and oxygen for the return flight. *Mars for Less* adds the idea of using some existing "medium" rockets to launch the mission in sections or "modules" instead of using giant rockets that are planned for development by NASA. We don't really know how people will first get to Mars, and which country or group of countries and/or companies will do it, but the first missions will probably use many of these general ideas. It could be as early as 2018 or perhaps 2033 or even later depending on when someone decides to develop the hardware and go. Most of the needed technology already exists today.

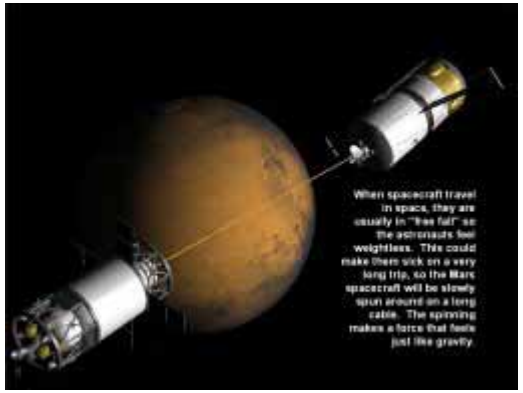


Page 6 (Astronauts at work) Background picture of astronauts working on the International Space Station (ISS), courtesy of NASA. Inset pictures are from the Orbiter space flight simulator, showing the ISS (left), and the space shuttle *Atlantis* with an astronaut flying in space with the MMU (Manned Maneuvering Unit).

Living & Working in Space: The International Space Station (ISS) is a cooperative program with a number of partners, including the USA, Russia, Japan, Canada, and Europe. It is considered the most expensive construction project in history and was started in 1998. Flights by US space shuttles and Russian Soyuz and Progress spacecraft have expanded the ISS and carried crew members, supplies, food, etc. back and forth. The international crews who have lived on the ISS for months at a time have learned a lot about living, working, and cooperating in space. This experience will be very valuable when Mars missions are started, since those missions will probably take nearly 3 years (6 months travel each way, 18 months or more on the surface).

Page 7 (Leaving for Mars) Background picture shows the assembled *Mars for Less* spacecraft ready to leave Earth orbit for Mars. The part in the foreground is the two-story crew compartment, the size of a very small apartment (top inset). Below the crew compartment is a "stack" of four rocket modules (each with four solar panels in a cross shape). You can see clouds, ocean, and islands (Indonesia area) on the Earth, about 200 kilometers below. The lower inset is an artist's concept by Jason Archer of the SpaceX company's *Falcon 9* medium rocket launcher, launching one of the *Mars for Less* modules. The privately built Falcon 9 is planned for first launch in 2007 or 2008 and is expected to be cheaper to operate than many other space launchers.

Mars for Less Launch & Assembly: The spacecraft in *Mars for Less* are launched in sections or modules, using "medium" (but still quite big!) rockets as shown in the lower right inset. The parts would be assembled in Earth orbit by docking, something that astronauts know very well how to do (you can even try simulated docking yourself in Orbiter). There are two spacecraft that go to Mars. The empty Earth Return Vehicle (ERV) goes first to make fuel for the astronauts to use years later when they return to Earth, and the "hab" ("habitat") vehicle carries the crew there about two years later.



Page 8 (Spinning in Space) Background picture of *Mars for Less* spacecraft from Orbiter approaching Mars. The crew spacecraft (right) is attached to the empty final stage of the rocket booster (left) by a strong cable or "tether." Small rockets in the spacecraft can make the tethered pair of spacecraft spin slowly in space, generating "artificial gravity" for the astronauts.

Artificial Gravity: One problem with living in space for long periods is "zero G." The human body developed in Earth-normal gravity (1G) and when people stay in zero G for long periods, their bones and muscles start to get weak (this and other symptoms are what I meant by "could make them sick"). Exercise and special medicines can help this, but many people feel that a better solution is to create artificial gravity by spinning the spacecraft as shown. Note that Mars' gravity is weaker than Earth's (0.38 or about one-third of Earth's gravity). This still might be too little for people to live normally in, so tests of this "partial G" need to be done with spinning spacecraft in Earth orbit, before we first send people to Mars.

Page 9 (Landing on Mars) Background picture of *Mars for Less* spacecraft in Orbiter shows the crew vehicle firing its landing rockets in the final seconds of its landing at Vallis Dao on Mars (Orbiter add-on by "jtiberius"). Inset pictures show earlier stages of the landing process – the aeroshield, a cockpit view, and the second of two parachutes that use Mars' thin atmosphere to slow the spacecraft for landing.

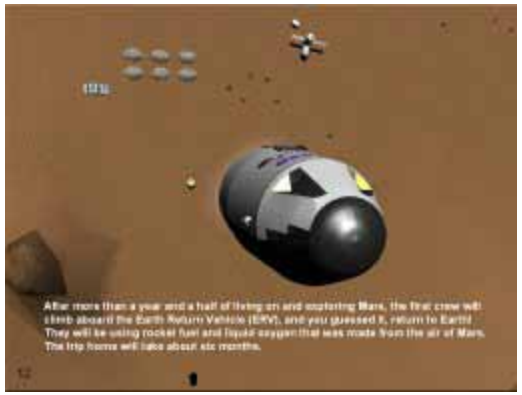
Challenges of Landing: Landing on Mars is not easy to do. Small robotic spacecraft have been landed a few times, and aerospace engineers have gotten better at it over time. But landing a large spacecraft with humans on board is tougher, because humans are more "delicate" than robots, so the forces from entering the atmosphere, opening parachutes, and landing on the surface must be kept within a certain range. Computer simulations can be used to figure out the best way to do it, and computer autopilots can accurately control the spacecraft's rockets to make sure everything is done exactly right for a safe landing (of course the pilot can take over if necessary to avoid a last-minute obstacle). We even simulated different landing cases in our *Mars for Less* add-on for Orbiter, but aerospace agencies and companies will create more complex and accurate simulations that will include all effects.

Page 10 (First Words on Mars) Orbiter picture of *Mars for Less* spacecraft, rover, and astronauts at Vallis Dao on Mars. The Mars crews will probably include both men and women, probably from several different countries. The first person on Mars could be a woman or a man, or they may figure out a way to have several people step onto Mars at the same time, so there is not a single "first man" or "first woman" on Mars.

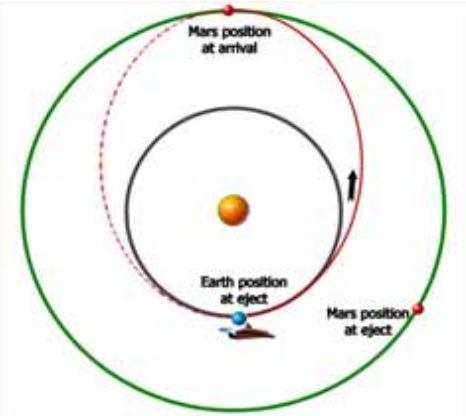
Space Suits for Mars: Space suits will be different on Mars. The bulky air-filled space suits used by Apollo and by space-walking Shuttle and Space Station astronauts will be replaced by less bulky suits using super-strong modern materials (though they may not be as thin as shown here!). They will still need to carry their own breathable air (oxygen and other gases) since the Mars atmosphere is too thin and cold and has almost no free oxygen (it's mostly carbon dioxide, a gas we exhale when we breathe on Earth).

Page 11 (Exploring Mars) This background picture is a composite of a real Mars Exploration Rover (MER) image (courtesy NASA/JPL) overlaid with the simulated human Mars rover (by Andy McSorley) and astronaut figure (by Greg Burch) from the *Mars for Less* add-on package for Orbiter. The inset picture is also from MER, showing its robot arm and a close-up of the Mars surface.

Human Roles in Exploration: Although robot spacecraft have done a great job in surveying the planets, and even wandered around to look closely at a small area of Mars' surface, robots are not yet as smart and flexible as human explorers and scientists. Robots can be directed to do certain tasks, or even programmed to "look for" certain things in some cases. But a robot doesn't know what is "interesting" to a human expert. Human experts in geology, weather, biology, or other subjects can be looking for one thing and then realize that something new and different has happened. They can change their plans, quickly moving to another area or choosing a different instrument or tool in response to the changing events. Robots will get smarter, but tests on Earth show that when only robots are used to explore a certain area, they often miss things that human scientists easily notice and find. Humans really do make the best explorers.



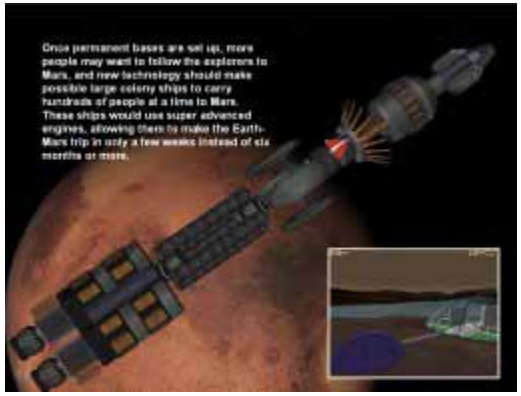
Page 12 (Leaving Mars) Background picture of the *Mars for Less* Earth Return Vehicle (ERV) seconds after its launch back to Earth. You can see the "hab" and the Mars rover as well as six greenhouses that have been left behind for the next crew to visit this base.



Long Trip Home: Like the flight to Mars, the trip back to Earth will take about six months. Why so long? There are two basic reasons. One is that the Solar System is big, and the orbits of Earth and Mars around the Sun are quite far apart (the Earth-Mars straight-line distance ranges from 34 to 234 million miles, or 54-374 million kilometers). But you can't go in a straight line between the planets because this would take more energy than rockets can provide. Remember everything is moving fast around the Sun! You have to "loop around" in a big orbit that connects Earth's orbit (gray circle) and Mars' orbit (green circle). The diagram shows what this means for the case of going from Earth to Mars. "Eject" means to leave Earth (blue dot) to head for Mars. Even though Mars is pretty close to Earth at "eject" (lower red dot), you can't shoot straight for it, you have to follow the solid red curve with the arrow to reach Mars at the top of the diagram (top red dot, "Mars position at arrival"). To go home to Earth, you would follow the red dotted curve on the left side (but you have to do this at just the right time so your ship and the Earth reach the same point at the same time).

Page 13 (Expanded Mars Base) This picture shows a pretty extensive Mars base with Earth-like buildings, fuel tanks, antennas, etc. This is the “Port Dao” add-on for Orbiter by Chad Overton, built dramatically into the canyons of the Vallis Dao 3D Mars terrain. If you look closely you may notice some next generation spacecraft.

Living on Mars: Making the transition from visiting and exploring Mars to actually settling and living there will take a few years and a lot of imagination and work. This base was created from standard Orbiter parts, positioned to suggest that some of the structures are built into the valley walls, which is probably a good idea both for insulation from the cold Martian air and for protection from cosmic radiation (Mars’ atmosphere provides some protection but not as much as do the Earth’s thicker atmosphere and strong magnetic fields). Robots will surely be used to help with construction, and the buildings would likely look very different from Earth buildings, maybe more like the canyon walls themselves. But when it comes to problems, human imagination and technical skills will certainly come through, just as on Earth. People will make Mars their home.

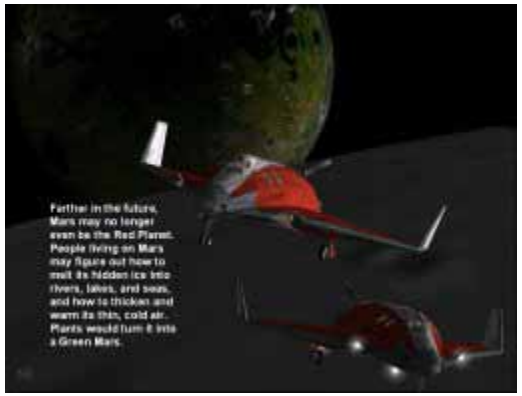


Page 14 (Mars Colony Spaceship) Background picture shows a large colony ship called the Vespucci orbiting Mars (Orbiter add-on). This spacecraft is so large, it is more like a space station, and it does not enter the atmosphere of Earth or Mars (it would be built in space). Note the small red and white spacecraft attached to the side of the ship (see next few pages for close-ups of these space planes, used for shuttling crew and supplies to and from the surface). The inset shows a Mars colony base (Orbiter add-on) built next to a frozen “lake” of water ice in a crater near the Martian North Pole. The buildings have been built under protective domes.

Advanced Propulsion: Rockets can be powerful, but the rockets used now (called “chemical rockets”) use up too much fuel for the thrust (pushing force) they provide. Space scientists and engineers are working on better ways to travel in space, with more efficient types of engines. Eventually these will make it much easier and faster to move around the Solar System.

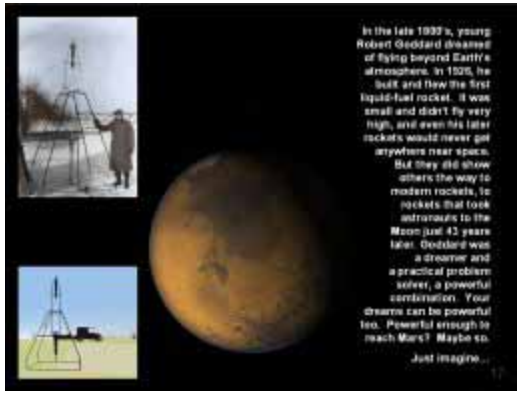
Page 15 (Why Mars?) Background picture is an Orbiter shot of a spacecraft base on Phobos, the closer of Mars' two small moons. A futuristic rocket plane fires its main engines above the base (this is actually Orbiter's standard "training" spacecraft, called the Delta Glider – powerful and futuristic but physically possible).

The Next Frontier? Nearly all of the Earth has been explored, and people live in nearly every imaginable place, from the hottest deserts to the coldest Arctic areas. Of course even the coldest, most barren part of Earth is friendlier to humans than any part of Mars, because we can breathe the air and find some water everywhere here, which is not true on Mars. But we do have technology to allow people to live even in space for months at a time, and Mars (with its 24 hour day/night cycle, solid ground, light but workable gravity, and thin but somewhat protective atmosphere) offers more advantages than any spot in the Solar System other than Earth. We do need to greatly improve technology for long-term life support (e.g., recycling everything, even water and air). It won't be easy and it won't be for everyone, but exploring and later living on Mars will be possible. To those who accept the challenges of the Next Frontier will come the rewards of knowing they have opened up a truly New World and a new branch of human civilization.



Page 16 (Green Mars) Picture of two space planes landing on Mars' second moon, Deimos, with a terraformed "green Mars" (Orbiter add-on) in the background.

Terraforming: To change the climate and terrain of an entire planet (this is what terraforming means) might seem to be impossible, but it may not always be so. One clue that it might be possible is the fact that most scientists believe that we are accidentally "terraforming" the Earth right now, because human technology (mostly burning fossil fuels) has increased the amount of carbon dioxide in Earth's atmosphere, leading to a change in climate called global warming. Although it might take a very long time, it might be possible to make intentional changes in Mars' atmosphere that would cause it to get warmer and thicker and eventually to support liquid (not only frozen) water on the surface and maybe even to support plant growth. Whether this is really possible and whether it's a good idea even if it *is* possible are big questions – but we have a few years to decide!



Page 17 (Robert Goddard & You) Background picture shows an Orbiter view of how Mars looks now. Top inset shows Dr. Robert Goddard standing next to his first liquid fuel rocket before its launch in Auburn, Massachusetts (USA) in 1926. The bottom inset shows this same simple rocket in an Orbiter "early rockets" add-on by Mark Paton.

Dreams and Actions: Robert Goddard grew up in Worcester, Massachusetts (very close to where I live). He studied physics but dreamed from an early age of space travel, a rather distant dream considering there were not even airplanes until 1903! He wrote about his dreams in journals, but studied physics and engineering and did experiments to figure out how to make liquid fuel rockets (solid fuel rockets had been used in fireworks and some weapons for hundreds of years, but for long flights, Goddard figured out that liquid fuels would have many advantages). Goddard's early rocket research was very influential, and even though other people developed the more advanced liquid fuel rockets that eventually made it to the Moon and beyond, Goddard is remembered as one who dreamed big, worked hard, and solved practical problems with inventive genius.

There are a number of books on Robert Goddard. One for young readers (grades 5-8) is ***Rocket Man: The Story of Robert Goddard*** (Trailblazer Biographies) (1995 Hardcover) by Thomas Streissguth. An excellent biography for older readers is ***Rocket Man: Robert H. Goddard and the Birth of the Space Age*** (2004) by David Clary.

About Orbiter - Orbiter is a freeware space flight simulator used to create many of the graphics in this book, simply by screen-capturing a scene from the simulator while it is running a scenario. Orbiter is sort of a cross between an astronomy program and a PC flight simulator, in which you are the pilot or astronaut flying the spacecraft (though you can also see various external views as shown in this book). Orbiter is based on realistic physics, so it is fairly detailed and complex and probably not suitable for younger children except for demonstrations by a teacher. But people as young as 11 or 12 who are interested in space flight have made simulated flights to dock with the ISS in Earth orbit, go to the Moon, and even fly to Mars. My free e-book (PDF) ***Go Play In Space*** is a detailed and step-by-step tutorial for learning to fly in (simulated) space with Orbiter. Note that many of the spacecraft in this book are free add-ons, not included in the basic Orbiter package.

Selected References

Books & Videos

Stikky Night Skies published by Laurence Holt Books (2003, book stores, Amazon.com, etc.)
Quickly and easily learn to identify prominent stars and constellations.

Kids to Space by Lonnie Jones Schorer (2006, Amazon.com, book stores, etc.)
Space questions asked by thousands of kids clearly answered by many experts.

Go Play In Space by Bruce Irving with Andy McSorley (2006, www.virtualspaceflight.com)
Free tutorial e-book (PDF download) on using the Orbiter space flight simulator.

I Want To Go To Mars by Tom Hill (2006, www.lulu.com)
A young child dreams of going to Mars (picture book for ages 3-7, initial inspiration for this book for older kids).

Home on the Moon: Living on a Space Frontier by Marianne J. Dyson (2003, book stores, Amazon.com, etc.)
All about what is involved in living on another world, with great explanations and pictures (grades 4-6).

Destination Mars by Alain Dupas (2004, book stores, Amazon.com, etc.)
Lavishly illustrated book on every aspect of Mars, including a different approach to a first Mars mission in 2033.

October Sky (1999 DVD/VHS, based on the book *Rocket Boys* by Homer Hickam, Jr.)
Inspiring true story of a boy who turned his dreams of rockets and space into a career as a NASA engineer.

Web Sites

A Family Guide to Mars – amazing resource! (http://www.marsquestonline.org/resources/familyguide/index.html)

Astronomy for Kids (www.dustbunny.com/afk/)

Kids4Mars (www.kids4mars.com)

4Frontiers Corp. (www.4frontierscorp.com, kids' pages: http://www.crazy4mars.com)

Imagine Mars (http://imaginemars.jpl.nasa.gov/about/)

NASA's Mars Exploration Program (http://marsprogram.jpl.nasa.gov/)

Orbiter Space Flight Simulator (www.orbitersim.com)

Credits

Art Work, Photographs, Mission Concepts/Design

Jason Archer - Cover illustration and Falcon 9 illustration (page 7 inset)

NASA (www.nasa.gov) – Photos pages 2, 6, 11, 17; art work page 3

Grant Bonin (gbonin@connect.carleton.ca) - *Mars for Less* concept and mission design, pages 5 and 7-12.

Software

Stellarium planetarium software for PC (freeware, www.stellarium.org)

Orbiter space flight simulator by Dr. Martin Schweiger (freeware, www.orbitersim.com)

Orbiter Add-ons

Apollo/NASSP project (page 2) by NASSP team, available at http://nassp.sourceforge.net

Mars for Less project by Andy McSorley, Mark Paton, and Bruce Irving (www.orbithangar.com, search **Mars for Less***)

Vallis Dao 3D Mars valley terrain (pp. 5, 9, 10, 12, 13) by "jtiberius" (www.orbithangar.com, search **vallis**)

Inflatable modules add-on (http://orbiter.mustard-fr.com/addons/inflatable.php)

EVA Pack and **Heinlein Moon Base** by Greg Burch (www.orbithangar.com, search for author **gregburch**)

Mars Exploration Rovers (page 3) by Bradley Hodges and others (www.orbithangar.com, search author **hodges**)

Port Dao (Vallis Dao Base, page 13) by Chad Overton (www.orbithangar.com, search for **Dao**)

Vespucci interplanetary space ship (page 14) by Christopher M Dittrick (www.orbithangar.com, search **vespucci**)

World of 2001 (page 15) by Erik Anderson and others (www.orbithangar.com, search **2001**)

Green Mars surface textures (page 16) by Christophe Chabot (www.avsim.com, search **green mars**)

Early Rockets (page 17) by Mark Paton (www.orbithangar.com, search for **early rockets**).

* available early 2007