CHAPTER 3

This artist rendering shows an aerial view of the liftoff of the 70-metric-ton (77-ton) lift capacity configuration Space Launch System (SLS) from the launch pad.

Image courtesy of NASA.gov.

Space Exploration

Chapter Outline

LESSON 1
Why Explore Space?

LESSON 2
Assembling a Space Mission

LESSON 3
The Hazards for Spacecraft

"We are at the dawn of a golden age of space exploration which will transform our relationship with the Earth and with the cosmos."

Sir Richard Branson

LESSON 1

Why Explore Space?

Quick Write

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The Humanity Star was sent to space to help humans look to the stars and reflect on our place in the universe. If you had the opportunity, what would you send into space that would generate interest in space exploration?

Learn About

- the benefits of space exploration
- NASA's plan to explore space
- private industry in space

On January 21st, 2018, Rocket Lab, a commercial space company, launched its Electron rocket into orbit. Unbeknownst to the world, Electron carried a surprise for humankind: the Humanity Star The Humanity Star was a highly reflective satellite that blinked across the night sky and could be seen with the naked eye! Think of a disco ball in space! Every 90 minutes the Humanity Star orbited Earth and could be seen anywhere in the world. Rocket Lab founder and CEO, Peter Beck created the Humanity Star as a bright symbol to remind us that we have a fragile place in this universe The Star also encouraged us to look up into the stars to be inspired to explore the universe.

The Humanity Star was designed to orbit Earth for a few short months; however, it only lasted a few weeks. Due to the small mass of the satellite, it deorbited faster than expected. In March 2018, it descended back to Earth and burned up during re-entry. No evidence of the Humanity Star survived the descent.

The company has no plans to send another Humanity Star to space. This was a one-time experience.

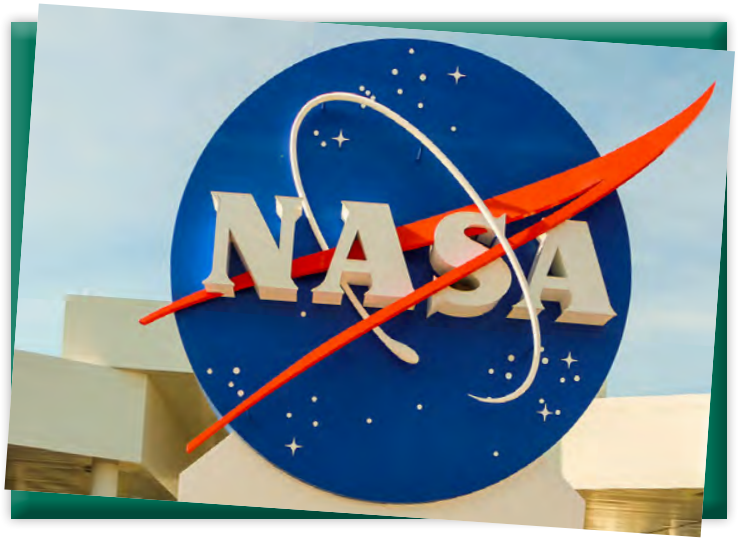
The Benefits of Space Exploration

Vocabulary

- low earth orbit (LEO)

Mankind has an immense amount of curiosity and a desire to explore the unknown. Space is no different. Mankind is compelled to explore unknown worlds and expand their scientific and technical knowledge. By exploring space, humans can gain further understanding about our solar system and universe. Through this exploration, we can discover our place in the universe.

For more than 60 years, NASA (National Aeronautics and Space Administration) has been the premiere organization for space travel in the United States. The knowledge gained from the research, space missions, and experiments conducted at NASA have provided many benefits to the human race.



The NASA logo in front of the Kennedy Space Center in Cape Canaveral, Florida.
Alexanderphoto7/Shutterstock

Knowledge

The greatest benefit that can be achieved by space travel is knowledge. The technical knowledge gained by space travel has provided many benefits to the public. For example, communications satellites, which are possible because of space travel, provide the means to make cell phones possible. As new products and services are developed, the economy is positively impacted for those countries investing in space travel.

Space travel provides direct and indirect benefits for society. Direct benefits are benefits that you can see immediately, like scientific knowledge or creation of new products. Indirect benefits are benefits that take time to develop and include items such as economic prosperity and health benefits. See Figure 3.1 for a list of direct and indirect benefits of space travel, as outlined by NASA.

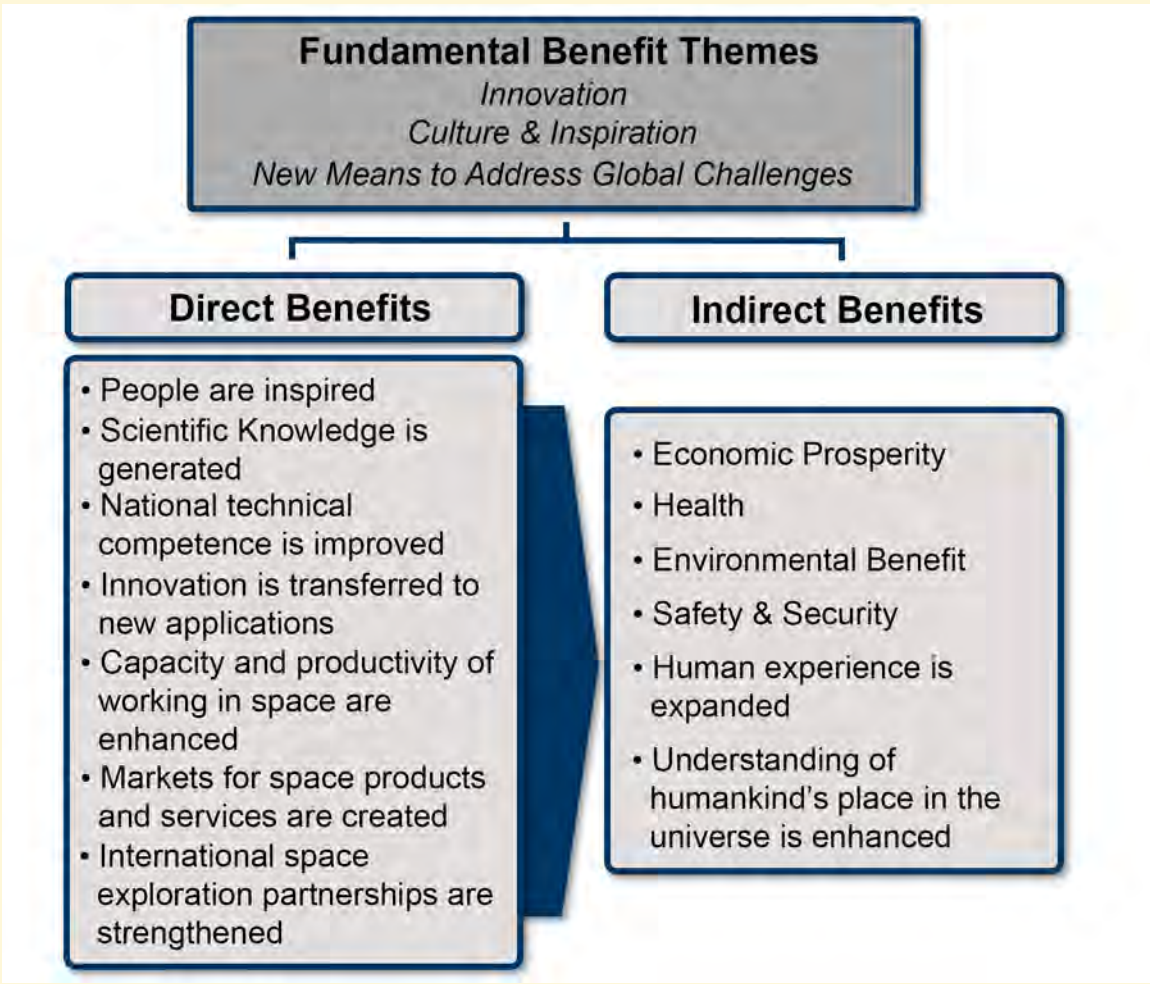


FIGURE 3.1

The direct and indirect benefits of space travel.
Courtesy of NASA.

Space exploration is a challenging feat that requires humans to develop innovative solutions to meet lofty space exploration goals. In addition, space travel stimulates the advancement of technology in areas outside of space exploration and throughout the scientific and technical community. For instance, innovations developed for space travel initiate progress in health care, robotics, automation, and many other industries.

Some specific examples of technological benefits of space travel include cordless tools, cameras in cell phones, biomedical technologies, implantable heart monitors, and solar panels. Scientific discoveries are ongoing with the use of the International Space Station (ISS). The ISS conducts experiments in space on human physiology, plant biology, materials science, and physics.

Education

Space travel and research also have a direct benefit on the education of youth in science and technology. As space travel continues to expand, a new generation is inspired to dream of ways to go farther into space. In the 1960s, the Apollo space mission to the Moon provided a large increase in the technical knowledge of US students at the time. The recent developments in commercial space travel are expected to provide the same benefits.

Mathematics and science scores in the US have been falling behind other nations. STEM (science, technology, engineering, and mathematics) is an initiative to provide science, technology, engineering, and mathematics knowledge to students throughout their learning. Toys for preschoolers are even being developed to help increase the STEM skills in youngsters. STEM education not only increases science knowledge, it also develops critical thinking skills and promotes innovation.

Teacher with students building robotic vehicle.
Monkey Business Images/Shutterstock

STEM education is growing in classrooms and will continue its upward trend. According to the U.S. Department of Commerce, STEM occupations are growing at a 17 percent rate annually. The average growth rate for other highly sought-after occupations is only 9.8 percent. In addition to the growth rate of STEM positions, students who hold STEM degrees achieve a higher pay rate. As you can see, STEM is a major factor in the growth of the US economy and also helps the US secure its future in STEM development.

Social Development

Space travel has a profound impact on a nation's cultural and social development. Space travel can help answer questions such as "Are we alone?" or "What lies beyond our solar system?" Space exploration has helped humans develop a new perspective of the Earth and space. Space travel and images from space allow us to understand the fragility of the Earth and the need to protect the Earth and its environment.

In addition, space travel has inspired movies, songs, books, photographs, and paintings. These cultural aspects further the social development of the human race.

International Partnerships

Space travel can also serve as a catalyst for international partnerships. Together, nations can advance their goals for space exploration, share knowledge gained during space travel, and conduct joint missions in space. The ISS is a partnership between 15 nations. Over the years, 68 nations have participated in ISS activities. This partnership allows us to invest in life in space, which would not be economically feasible as a single nation.

An illustration of the International Space Station (ISS) passing over Florida.
Courtesy of NASA.

NASA's Plan to Explore Space

NASA 2018 Strategic Plan Framework

Theme	Strategic Goal	Strategic Objective
DISCOVER	EXPAND HUMAN KNOWLEDGE THROUGH NEW SCIENTIFIC DISCOVERIES.	1.1: Understand the Sun, Earth, Solar System, and Universe. 1.2: Understand Responses of Physical and Biological Systems to Spaceflight.
EXPLORE	EXTEND HUMAN PRESENCE DEEPER INTO SPACE AND TO THE MOON FOR SUSTAINABLE LONG-TERM EXPLORATION AND UTILIZATION.	2.1: Lay the Foundation for America to Maintain a Constant Human Presence in Low Earth Orbit Enabled by a Commercial Market. 2.2: Conduct Exploration in Deep Space, Including to the Surface of the Moon.
DEVELOP	ADDRESS NATIONAL CHALLENGES AND CATALYZE ECONOMIC GROWTH.	3.1: Develop and Transfer Revolutionary Technologies to Enable Exploration Capabilities for NASA and the Nation. 3.2: Transform Aviation Through Revolutionary Technology Research, Development, and Transfer. 3.3: Inspire and Engage the Public in Aeronautics, Space, and Science.
ENABLE	OPTIMIZE CAPABILITIES AND OPERATIONS.	4.1: Engage in Partnership Strategies. 4.2: Enable Space Access and Services. 4.3: Assure Safety and Mission Success. 4.4: Manage Human Capital. 4.5: Ensure Enterprise Protection. 4.6: Sustain Infrastructure Capabilities and Operations.

NASA 2018 Strategic Plan
Courtesy of NASA.

Every four years, NASA produces a strategic plan for space exploration. The most current plan was published in 2018. The 2018 Strategic Plan identifies four long-term goals and how they plan to achieve them:

- DISCOVER
- EXPLORE
- DEVELOP
- ENABLE

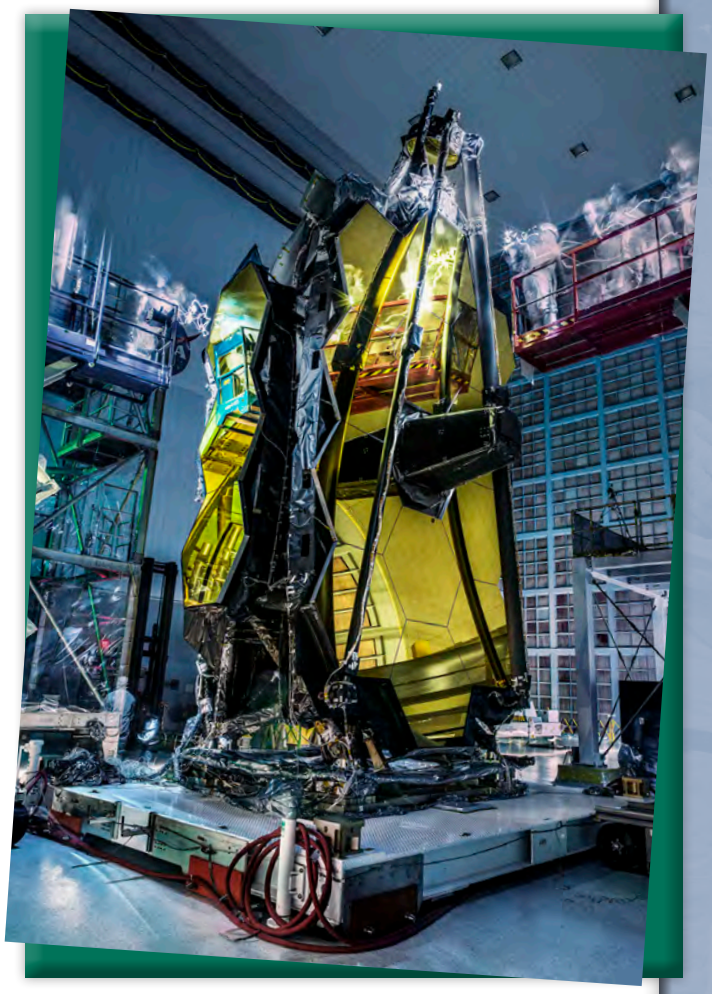
Strategic Goal #1: Discover

The "Discover" element of NASA's strategic goal is meant to expand human knowledge through new scientific discoveries. The specific aims of this goal are to better understand the Sun, Earth, solar system, and universe and learn more about the responses of physical and biological systems to spaceflight.

NASA's vision is to discover the secrets of the universe. They plan to accomplish this goal by studying the Sun, the Earth, other planets and solar systems, interplanetary environment, and the space between stars. One tool to help NASA enhance its knowledge is the James Webb Space Telescope.

The James Webb Space Telescope (Webb) will be launched in 2021. The Webb will be a premiere observatory in space available to astronomers across the world. The telescope is designed to study the history of the universe, which includes the first light after the Big Bang, formation of solar systems that can support life, and the evolution of our solar system. Webb is an international collaboration between NASA, ESA (European Space Agency), and the CSA (Canadian Space Agency).

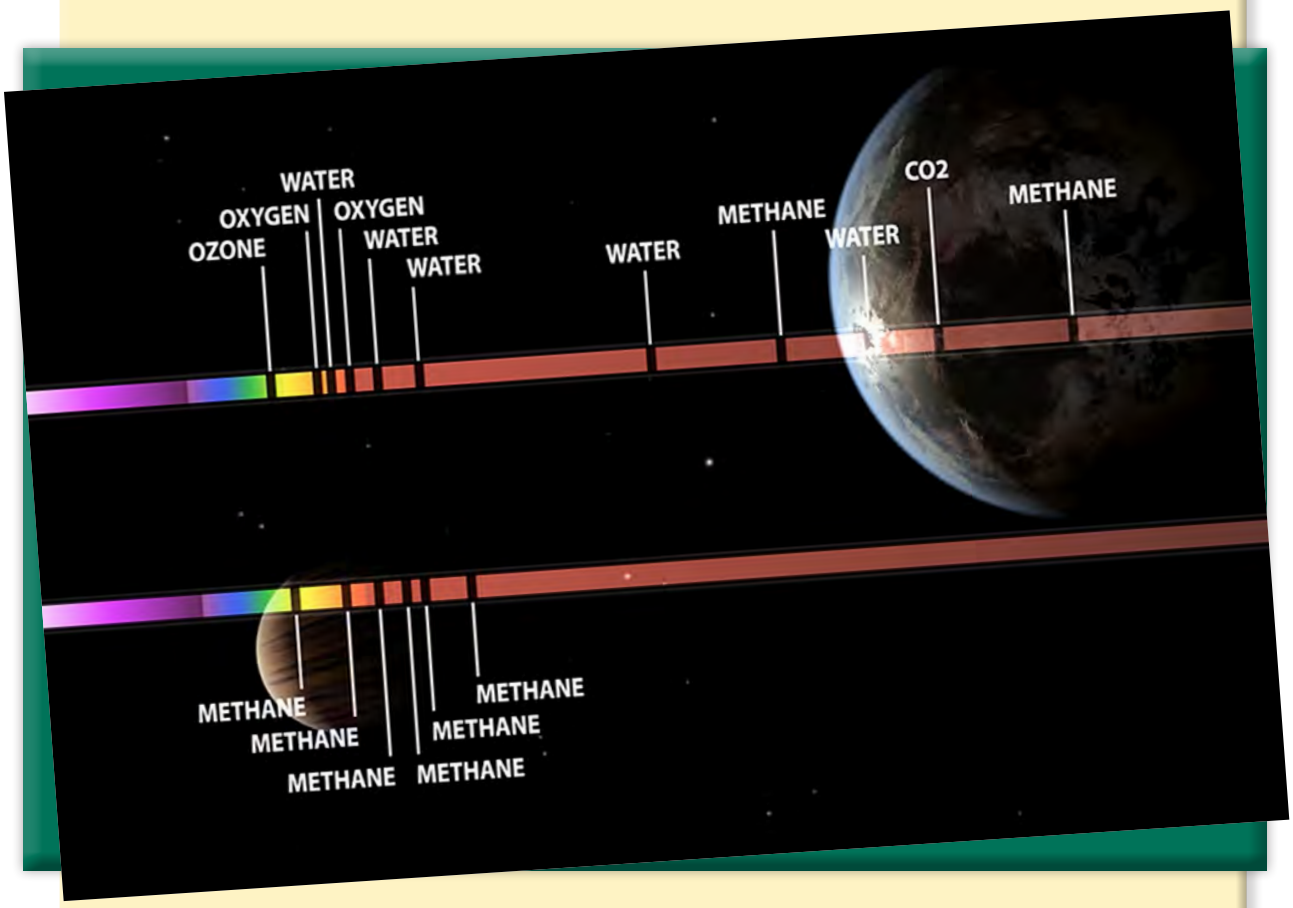
In addition, as part of its "Discover" goal, NASA would like to explore the fundamental question, "Are we alone?" Such exploration would involve searching for habitable zones both in our solar system (Mars, moons, etc.) and outside of it.



The James Webb Space Telescope during the construction process.
Courtesy of NASA/Chris Gunn.

Did You Know?

How will we know if we find life? Can you believe a rainbow may be the answer? Sir Isaac Newton discovered that white light shot through a prism (or through curtains of mist seen with the sun at your back) is exposed for what it really is: a band of color, spanning from violet to red, and characterized by "wavelength." Chemicals and gases in the atmospheres of planets can absorb certain slices of this band, called a spectrum, and leave behind a narrow black gap. As light from a star is analyzed it looks almost like a bar code. The pattern of black gaps on the bar code can identify the gases present in the atmosphere, like oxygen or methane. The bar code we see may help identify life on other planets.



Different colors correspond to different wavelengths of light. Missing colors show up as black lines, indicating specific gases are present, because each gas absorbs light in a specific wavelength (or color).

Courtesy of NASA.gov

Finally, NASA aims to safeguard and improve life on Earth by investigating the hazards to life from the solar system, Sun, and Earth itself. NASA works to predict the paths of asteroids and comets that could harm life on Earth. They study severe weather events to help create more predictability, so that humans can prepare when a weather event is going to hit. To safeguard life on Earth, NASA works with NOAA (National Oceanic and Atmospheric Administration), the US Geological Survey, and the Environmental Protection Agency.

Astronaut Sunita L. Williams, Expedition 15 flight engineer, exercises on the Cycle Ergometer with Vibration Isolation and Stabilization (CEVIS) system (CEVIS) during a Periodic Fitness Evaluation with Oxygen Uptake Measurement (PFE-OUM) on the International Space Station.

Image courtesy of NASA.gov/ Rodney Grubbs.

NASA's exploration does not end with Earth itself. One of the objectives of the "Discover" goal is to research the physical and biological responses to spaceflight. The human body, and other organisms, react differently when living in space. NASA will continue its experiments and research in the ISS with long-duration missions to study the effects of space life.

Strategic Goal #2: Explore

When you think of space travel, you most likely think of the exploration aspect. NASA's second strategic goal focuses on exploration and, specifically, human presence in space and on the Moon for long-term exploration. So, what does this mean?

Currently, NASA is laying the foundation for the US to sustain a commercial, human presence in space. Plans are in the works to return humans to the Moon. Space travel to the Moon is seen as a stepping stone to reaching Mars. By creating a lunar space community that can be used for training, and developing the space program on the Moon, humans are setting the stage for deep space travel. It may sound like a scene from a movie, but the reality is that future generations could choose to live on the Moon, if NASA accomplishes its goals.

NASA does not plan to accomplish this mission alone. The US will seek international partnerships and rely on the US private sector for assistance. This will be discussed further in a later lesson.

Astronauts in space suits viewing the Milky Way galaxy.
Gorodenkoff/Shutterstock

Strategic Goal #3: Develop

NASA's third goal strives to develop aeronautical advancements that secure the US's status as a forerunner in space travel. The planned demonstrations and research are designed to advance flight well into the 21st century. It could mean the return of supersonic flight, new airliners that use less fuel, or "self-driving" airplanes. To achieve this goal, NASA is dedicated to recruiting students in STEM fields, with hopes of inspiring future generations to pursue STEM degrees, as well. Public interest in NASA is growing, and missions are attracting not only potential scientific minds but interested observers. In 2015, NASA's mission to Pluto prompted 10 million views of the NASA page.

The window in the sidewall of the 8-by-6 foot supersonic wind tunnel at NASA's Glenn Research Center shows a 1.79 percent scale model of a future concept supersonic aircraft built by The Boeing Company
NASA/Quentin Schwinn

In addition to expanding the potential science community, NASA seeks to develop revolutionary technologies that ensure the possibility of space exploration. Investments have been made in large-scale industrialization of space and projects to enable humans to live and work in space. These technologies will also focus on commercial aviation, including supersonic aircraft, efficient aircraft, real-time safety, and autonomy in aviation.

Strategic Goal #4: Enable

Finally, we have NASA's goal to focus on enablement. This goal means NASA will optimize its programming and resources (including people) to concentrate on activities and projects that push toward achievement of its long-term goals. To reach those goals, NASA must partner with private agencies and academic organizations to become the leader in space travel. NASA will continue using international and private partnerships to enhance the priorities of the nation. The agency also will use private and government resources to deliver people and goods to space. Later in this lesson, you will read about the boom of private organizations in space travel.

Cost of Space Travel

As you just read about NASA's strategic goals, you probably wondered, "How do we pay for this? Space exploration is expensive!" NASA does have lofty goals for sending humans back to space and ensuring a future space exploration program. But truth be told, our current space program fell behind for some time due to the exorbitant cost of space travel.

In 1972, when NASA's space shuttle program was announced, it was estimated to cost $20 million per flight. This estimate was massively under budget. In 2010, a single space mission cost $1.6 billion. In all, NASA spent $209 billion dollars on the shuttle program. The program came to an end on August 31, 2011.

NASA was not designed to make money, so cannot fund its budget on its own; instead, it is funded by the government. In recent years, NASA funding flatlined, and budget cuts led to delays in programs and new technology. NASA's 2019 budget provides $19.9 billion to lead an innovative space campaign and return humans to the Moon for long-term exploration.

Space Launch System (SLS) solid rocket booster prime contractor Grumman Innovation Systems (formerly known as Orbital ATK) recently completed work at its Utah facilities on the booster nozzles for Exploration Mission-1 (EM-1), the first flight of SLS and the Orion spacecraft.
NASA/Orbital ATK

Private Industry in Space

For decades, NASA has relied on private companies to supply components and equipment for space travel. In 1962, the Telstar 1, a communications satellite, became the first object built entirely by a private company.

In 1984, Congress passed a law that allowed private companies to launch rockets into space. Then, in 1990, Congress passed another law that required NASA to use private companies to launch supplies into space. The private space industry was born.

In 2004, Congress passed the Commercial Space Launch Amendments Act to make private space exploration legal. Until then, private organizations could launch satellites and supplies into space, but they could not actively explore space or send humans into space. With the shutdown of the NASA shuttle program in 2011, private companies have now entered the space exploration industry. NASA plans to use private space companies to launch humans and supplies into space.

Some of the businesses currently working on plans for space exploration are SpaceX, Rocket Lab, Blue Origin, Sierra Nevada Corporation, and Virgin Galactic.

Kennedy Space Center, Florida — February 19, 2017: A SpaceX rocket launches on the CRS-10 resupply mission to the International Space Station.

John Huntington /Shutterstock

SpaceX

SpaceX currently has the most advanced space travel plans. SpaceX was founded in 2002 by Elon Musk with the goal of revolutionizing space technology. Elon Musk is also the co-founder and CEO of Tesla. In addition, he co-founded PayPal. SpaceX designs, manufactures, and launches rockets and spacecraft. The ultimate goal of SpaceX is to provide the technology for humans to live on other planets.

SpaceX's Dragon spacecraft was the first commercial spacecraft to deliver supplies to the ISS in 2012. The Dragon spacecraft was designed to transport humans to space, and SpaceX is well on its way to making that a reality.

SpaceX is also responsible for designing and manufacturing the world's most powerful rocket, Falcon Heavy. The Falcon Heavy rocket can lift twice the payload of its competitors and will be used to launch satellites and spacecraft.

The SpaceX Dragon is pictured from inside the seven-windowed cupola moments before ground controllers remotely commanded the Canadarm2 to release the resupply ship from its grips.
Mark Garcia/NASA

Did You Know?

Japanese billionaire Yusaku Maezawa, will be the first paying customer to travel around the moon on SpaceX's yet-to-be-developed Big Falcon Rocket (BFR). In a presentation at SpaceX headquarters in Hawthorne, CA, Maezawa — said that his flight will occur in 2023 and that he wants to invite six to eight artists to accompany him. He called his trip around the moon a "lifelong dream."

Rocket Lab

In January 2018, Rocket Lab became the second commercial company to achieve orbit. Its Electron rocket is one of the cheapest rockets that can be used to launch into space, due to its lightweight design; the rocket is made entirely of carbon fiber. Rocket Lab is now using the Electron to deliver small satellites into low Earth orbit (LEO), which means that the *objects orbit at between 99 to 1,200 miles above the Earth's surface*.

Blue Origin

Blue Origin was founded by Jeff Bezos. In case you have not heard of him, Jeff Bezos is also the founder and CEO of Amazon. Blue Origin was the first commercial organization to equip a space rocket with landing gear. The first rocket by Blue Origin, New Shepard, was launched into space, completed its orbit, and then landed back on Earth in an upright position, ready to take off again. And two months later it did! Bezos estimates that the largest cost of space travel is the unwanted waste or debris created by a rocket. He aims to reduce the cost of space travel with reusability. He estimates that a launch currently costs $60 to $100 million, but if reusable rockets were deployed, the cost would be just under $1 million per launch.

Blue Origin is currently working on a new reusable rocket, New Glenn, that is designed to deliver humans and payloads to space on a regular basis. Blue Origin's plan is to offer commercial trips to space for those willing to pay. Their test flights thus far have included human dummies. However, they estimate it will be 2019 before they can offer commercial service.

Virgin Galactic

Virgin Galactic was founded by Virgin Atlantic founder Sir Richard Branson. The company's reusable SpaceShipTwo is the first commercial spacecraft built to carry passengers. Yes, that's right! Virgin Galactic has a goal to offer space travel to all humans, not just astronauts. One of the first passengers into space will be Sir Richard Branson himself.

The futuristic Virgin Galactic reusable, suborbital spacecraft on static display at the Farnborough International Airshow, UK, on July 15, 2012.
Steve Mann /Shutterstock

Benefits of Private Space Travel

Private space travel provides an enormous benefit when it comes to cost. By using commercial launches, NASA can drop the per-launch cost to send satellites into space from $4 billion to less than $50 million. In addition to the cost benefits, the introduction of private space exploration brings innovation. When you bring multiple companies and organizations into the mix, they begin to challenge each other to develop new technologies.

Of course, with benefits, also comes the consequences of space travel. As with any private organization, profit is the bottom line. Space travel technology will only advance if space travel is profitable for these organizations.

Cost of Private Space Travel

Are you ready to go into space? Virgin Galactic and Blue Origin are both primed to offer commercial space travel, but you'd better start saving. A trip to space on a commercial company's spacecraft will cost approximately $250,000 per seat. That gets you a round-trip ride into space, during which you will experience a few minutes of weightlessness before the return trip to Earth. If you want to orbit the Earth during your time in space, it will cost you about $60 to $70 million. Believe it or not, there may come a day when your annual vacation could be a trip into space!

CHECKPOINTS

Lesson 1 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What is the greatest benefit that can be achieved by space travel?
2. What is STEM education?
3. What are the four 2018 strategic goals for NASA?
4. What are the goals of the James Webb Space Telescope?
5. What did a single space mission cost in 2010?
6. What was the first space object built entirely by a private company?
7. What does Blue Origin see as the key to commercial space travel?
8. What are the benefits of private space travel?

APPLYING YOUR LEARNING

9. Provide a brief description of why the benefits of commercial involvement in space exploration would outweigh any negative consequences.