LESSON 2

Assembling a Space Mission

Quick Write

Read the vignette about astronaut Leland Melvin. Now, consider the importance of being prepared for an alternative career path. What career paths and options have you identified for your future?

Learn About

- the essential components of a space mission
- the selection and training of astronauts

Leland Melvin, NASA Associate Administrator for Education (2007)

Mark Sowa/JSC NASA

Imagine, you spend years of blood, sweat, and tears training for the big leagues. Then, while playing for the National Football League (NFL), you suffer a hamstring injury that ends your football career forever. For many, it ends any career plans altogether. For others, it presents new professional opportunities in other areas. For Leland Melvin, it meant a bigger, better, and literally out-of-this-world endeavor. He joined the National Aeronautics and Space Administration (NASA)!

After his football injury in the NFL, Melvin went back to school to build on his undergraduate education in chemistry. In graduate school, he received a Master of Science degree in materials science engineering. In 1998, thanks to a persistent recruiter and NASA's efforts to diversify, Melvin began training with the NASA Astronaut Corps.

Melvin suffered hearing loss during underwater training that grounded him from going to space. Eventually, his hearing returned, and in 2008 and 2009, Melvin flew two missions on the space shuttle Atlantis. Both missions involved construction on the International Space Station. The International Space Station (ISS) *is a large spacecraft in orbit around Earth*. It houses astronauts and cosmonauts from around the world and acts as a science laboratory. Cosmonauts refer to *individuals trained and certified by the Russian Space Agency*.

After Melvin left the astronaut corps, he became NASA's associate administrator for the Office of Education until his retirement in 2014. His experience as an astronaut, athlete, and scholar has inspired NASA's education programs. It has also raised public awareness about NASA strategic goals.

The Essential Components of a Space Mission

NASA's Mission

Since 1958, NASA has been leading the United States in space exploration and has experienced amazing results. As you read in the previous lesson, NASA has been joined by commercial space exploration organizations that will help the US lead the way in exploring the vast space beyond Earth. NASA's vision is to discover and expand knowledge for the benefit of humanity.

NASA strives to discover new information about scientific principles in our solar system, and beyond—and to apply those facts to make space exploration safer and more convenient. We use much of our knowledge about space to create new products here on Earth, especially in the transportation industry. Automobiles and passenger planes are more comfortable, safer, and more fuel efficient than ever before.

To continue forward progress, we need deeper exploration of the regions of space that have already been studied, such as the Moon and Mars. We also need to gain more information about other places that might benefit us on Earth. We have put humans on the Moon and brought them back home safely. New explorations may enable us to build permanent laboratories, or even normal living spaces, there and beyond. Those explorations would begin with long-term studies of the Moon and Mars to gather more detailed information, instead of just short-term visits.

Vocabulary

- International Space Station (ISS)
- cosmonauts
- mission directorates
- heliophysics
- astrophysics
- aeronautics
- launch vehicle
- Tracking and Data Relay Satellite System (TDRSS)
- microgravity
- underwater training
- flight simulators
- g-force

Astronaut on lunar (moon) landing mission. Elements of this image furnished by NASA.

Courtesy of Castleski/Shutterstock

NASA's Langley Research Center has been providing NASA with aeronautical research for over 100 years.
Courtesy of NASA/Sandie Gibbs

We use the data gathered from our studies in space to develop new technology for space travel. We also use it to create new and better products in our everyday lives. Consider the fields of transportation, communications, construction, and food processing. Many of the new products we enjoy today resulted from NASA research. For example, we have memory foam, freeze-dried food, and parachute systems on aircraft. We benefit from this technology across the globe. It helps to bring us all together as one large, human society.

NASA aims to improve and continue beneficial space operations. For example, we rely on the ISS for ongoing studies on human safety in space as we advance our explorations. Remember the early pioneers in our own country? These settlers gradually moved forward from the eastern settlements to the far western regions. Our space travelers of today are truly pioneers in their own right! As we continue to explore space, we enable greater advances in engineering, design, and construction of products at home.

NASA's Mission Directorates

Several organizations work together to achieve the mission and goals that NASA has set forth. NASA's organizational structure is built on mission directorates. *These are groups that study space from Earth, and in space*. Each group serves a specific purpose in contributing to the knowledge base of understanding air and space. The directorates include the following:

- Science Mission Directorate (SMD)
- Aeronautics Research Mission Directorate (ARMD)
- Space Technology Mission Directorate (STMD)
- Human Exploration and Operations Mission Directorate (HEOMD)
- The Mission Support Directorate (MSD)

The Science Mission Directorate (SMD) develops the knowledge base of Earth science, heliophysics (*the study of the Sun and its effects on space*), planetary science, and astrophysics. Astrophysics is *science that applies the laws of physics and chemistry to explain the birth, life, and death of stars, planets, galaxies, and nebulae*. The SMD seeks to answer some of the most important questions about our changing Earth. It uses advanced scientific methods and the latest Earth-based technologies. It also uses space technologies, such as satellites and probes. The SMD determines the needs of the space mission, including research needs and technology.

Did you know that every U.S. commercial aircraft and U.S. air traffic control tower has NASA-developed technology to help improve efficiency and safety? This is due to the efforts of the next directorate of NASA, the Aeronautics Research Mission Directorate (ARMD). The ARMD's primary goal is to use advanced aviation tools and technologies to improve flight operations and aviation safety, and to contribute to aeronautical research. We define aeronautics as *the study of the science of flight*. The ARMD also aims to reduce the overall environmental impact of flight on Earth.

The ARMD's Ikhana aircraft is the agency's first large-scale, remotely-piloted aircraft flight in the national airspace without a safety chase aircraft.

Courtesy of Ken Ulbrich/ NASA

The next directorate is the Space Technology Mission Directorate (STMD). The STMD exists to maintain important space-based technological gains. It also serves to counteract technologies that could endanger future missions or US national security. This mission directorate also provides technical and flight support for the rest of NASA.

The Human Exploration and Operations Mission Directorate (HEOMD) is most vital, as it provides NASA with leadership and oversight for operations related to human exploration in and beyond low-Earth orbit. The ISS is an example of space operations in and beyond low-Earth orbit. HEOMD manages operations related to launch services, space transportation, space communications, and human research programs.

The Human Research Program (HRP) was developed as a result of NASA refocusing the space program on exploration in early 2004. The program uses research findings to develop procedures to lessen the effects of a space environment on the health and performance of humans working in that setting. With the goal of traveling to Mars and beyond, the program is using ground research facilities and the International Space Station to develop these procedures and to further research areas that are unique to Mars.

The Mission Support Directorate (MSD) manages institutional services and capabilities. It oversees mission processes and operations to ensure efficiency, consistency, and standardization.

Components of a Space Mission

For NASA, a space mission looks a lot like a research project. Starting with a research goal, the MSD forms a scientific plan to accomplish that goal. Then, the appropriate research-gathering components are identified and assembled. These components include spacecraft, astronauts, advanced technology, ground support, and communications.

Artist concept of NASA's first Space Launch System (SLS), Block 1, on the launchpad. SLS is an advanced launch vehicle that provides the foundation for human exploration beyond Earth's orbit. It is the only rocket system that can send the Orion spacecraft, astronauts, and large cargo to the Moon on a single mission.

Courtesy of NASA/MSFC

The next important step involves building a spacecraft designed specifically to accomplish the goals of the mission. For example, manned spacecraft that go into deep space require specific features to ensure the safety of the spacecraft and the astronauts inside. The distance and duration of the mission also determine how the spacecraft is designed and built.

Along with the spacecraft, a launch vehicle is built. A launch vehicle is *a rocket that is used to propel the spacecraft into orbit*. The launch vehicle design and construction are also based on the goals of the mission. The weight of the spacecraft and the payload are careful considerations of the plan too. Before the launch vehicle propels the spacecraft into orbit, the spacecraft is tested and retested on the ground.

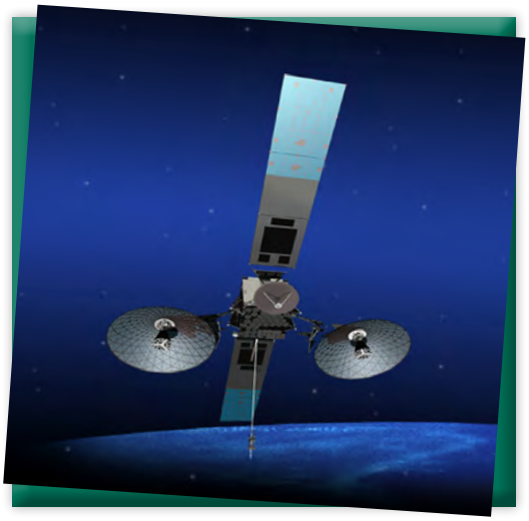
With a spacecraft and launch vehicle built and tested, it is time for lift off! Carefully planned communication systems, such as the Tracking and Data Relay Satellite System (TDRSS), and ground support operations, are essential components before, during, and after lift-off and landing. The Tracking and Data Relay Satellite System *provides near-constant communication links between the ground and the orbiting satellites*. On-ground support, often referred to as Mission Control, oversees the most important aspects of manned space missions. Its experts gather and analyze data from the spacecraft and launch sites to direct the mission and make time-sensitive decisions when needed.

Tracking and Data Relay Satellite-7 (TDRS-7) is placed in orbit by the Space Transportation System 70 (STS-70) Space Shuttle mission.

Courtesy of Thuy Mail/ NASA

Did You Know?

"There are thousands of people all around the country supporting the astronauts. Mission Control is the visible part, but it's less than one percent of the support team..." – William Foster (NASA Mission Control Center Ground Controller)



An illustration of the third generation Tracking and Data Relay Satellite in orbit.
Courtesy of NASA

Funding of Space Missions

As one of many government agencies, NASA submits a yearly budget request to the federal government for operating funds needed in the following year. They send their request to the US President's office, where it is included with those received from other government agencies. The President, along with staff and advisors, put that information together and decide on an itemized list for the total federal budget. They submit that document to the US Congress for adjustments and approval. Congress has the power to increase or decrease any of those requests. In some years, Congress has cut the amount requested by NASA; on other occasions, it has added more to NASA's requests.

The 2019 budget for NASA is expected to be approximately $19.9 billion. Although that seems like a very high figure, it usually represents less than one percent of the total federal budget.

NASA needs these funds for the construction of launching sites and rockets for space exploration and manned missions. In addition, NASA uses the funds for research, technology, offices, employees, and for joint projects with other public and private agencies.

NASA passes on much of the information gained by research and explorations to benefit our military, weather research, and communications companies and their satellites. In turn, large companies assist smaller companies that have contracts with them.

Directly or indirectly, NASA's projects affect each of the 50 states in a positive way. For this reason, members of Congress from all states usually support funding to NASA.

Did You Know?

Before their first mission, astronauts typically train for a combined total of 300 hours in flight simulators.

The Selection and Training of Astronauts

When asked, "What do you want to be when you grow up?" most young people will respond with, "a firefighter," "a nurse," or "an astronaut." Space travel makes the bucket list for many adults too. How many other jobs allow you to float around the office all day with a view of the entire Earth? The path to becoming an astronaut, however, is challenging. The selection process itself is strict, with a very tiny group of astronaut candidates chosen for nearly two years of extensive training. Training to be an astronaut is also hard work. Not only is there intensive classroom training, but also microgravity and survival training (in water and on land). Microgravity *is the condition in which people or objects appear to be weightless.*

Qualifications

NASA's astronaut program began in 1959 with seven astronauts selected from the military. At the time, required qualifications included flight experience in jet aircraft, a background in engineering, and knowledge and understanding of science. Because of the small space inside the first vehicles, astronauts were limited to a height of 5'11" or less. The height requirement has been changed to 5'2" up to 6'3," and applicants must complete advanced studies in science.

The education requirements today include having a bachelor's degree in engineering, biological science, physical science, chemistry, computer science, math, or medicine. A doctorate in one of those fields is considered valuable.

Applicants must have three or more years of professional experience beyond their bachelor's degree, or 1,000 hours or more of pilot-in-command experience in jet aircraft. They must also pass a long-duration astronaut physical and have near and distant vision correctable to 20/20 in each eye and a blood pressure of 140/90 in a sitting position. They must be US citizens or have dual citizenships and must complete a thorough background check and military water survival training. The first seven astronauts were all men. Today, NASA does not select astronauts based on gender or race.

Most importantly, NASA expects all applicants to have strong skills in leadership, teamwork, and communication.

Selection

When you apply for most any job, you are likely part of a pool of applicants with a variety of skills and backgrounds. The pool may be relatively small, consisting of only a few candidates, or the pool may be the size of a hundred or more. Similarly, NASA's astronaut selection process starts with applicants, but the pool of want-to-be astronauts is typically in the tens of thousands. Astronaut applicants represent a variety of backgrounds—ranging from teachers to scientists, and, yes, even former NFL players!

From the thousands of astronaut applicants, human resources personnel screen out those without the basic qualifications discussed earlier. After that, applicants are grouped by field of study and interviewed by review boards. From there, the pool shrinks to a few hundred individuals.

After first and second interviews, medical testing, and meetings with current astronauts, a very small group of astronaut candidates are selected for NASA's two-year spaceflight training.

Did You Know?

NASA selects fewer than 0.08 percent of applicants to become astronauts. In 2017, NASA selected 12 new astronauts to begin training out of 18,300 applicants.

The new astronauts will train for deep space missions on NASA's new Orion spacecraft and SLS rocket.
Courtesy of NASA/Rob Markowitz

Training to Become an Astronaut

Ask most any astronaut what it takes to fly in space and they will tell you: years of training—training before being selected for training; astronaut candidate training; and advanced on-going training. The first phase of NASA's two-year spaceflight training involves general instruction on science, space technology, foreign languages, and public speaking. Astronaut candidates also go through challenging survival training (in water and on land), along with microgravity and medical training.

Underwater Training

Candidates train underwater in a deep tank called the Neutral Buoyancy Laboratory (NBL) at NASA's Johnson Space Center in Houston, TX to prepare for space walks. Underwater training *simulates conditions similar to the weightlessness in space*. One of the first training tests for astronaut candidates is a swimming test where they swim 75 meters and tread water nonstop for 10 minutes in a flight suit and tennis shoes.

NASA astronaut Peggy Whitson trains underwater for a spacewalk at the Neutral Buoyancy Laboratory (NBL) at Johnson Space Center in Houston. Whitson launched to the International Space Station in late 2016 as part of Expedition 50/51.
Courtesy of NASA

Did You Know?

Established in 1995, the Neutral Buoyancy Laboratory (NBL) holds 6.2 million gallons of water and contains a model of the ISS underwater.

Underwater training also occurs at the Aquarius Reef Base that is located six miles off the coast of Florida. The Aquarius Reef Base is 62 feet underwater and is operated by Florida International University. Astronauts spend 10 to 14 days at the facility with an average of nine hours a day diving outside the facility to simulate the experience of living in space.

Flight Simulation

Besides underwater training, astronaut candidates experience the microgravity of space by using flight simulators. Flight simulators are *safe and cost-effective alternatives to actual flights to gather data, and provide facilities for practice and training*. Pilot astronauts maintain flying proficiency by flying 15 hours per month in NASA's fleet of T-38 training aircraft. Mission specialist astronauts fly a minimum of four hours per month.

Centrifuge Training

Astronauts also travel to NASA's Ames Research Center in Silicon Valley, CA to experience the 20-G Centrifuge. Most astronauts are not a fan of this portion of the training. Centrifuge training helps astronauts prepare for the g-forces they will experience during launch and re-entry. G-force is *the gravitational force that is put on a body during acceleration*. For example, 1 g is the force of gravity at Earth's surface. This is what we all experience every day. During launch, astronauts will experience 3 g, which is about three times the normal acceleration. Think of your body weighing three times more and the pressure of that weight being pushed into your seat. During re-entry, the g-forces are much more extreme. Astronauts experience 8 g for 30 to 60 seconds during re-entry.

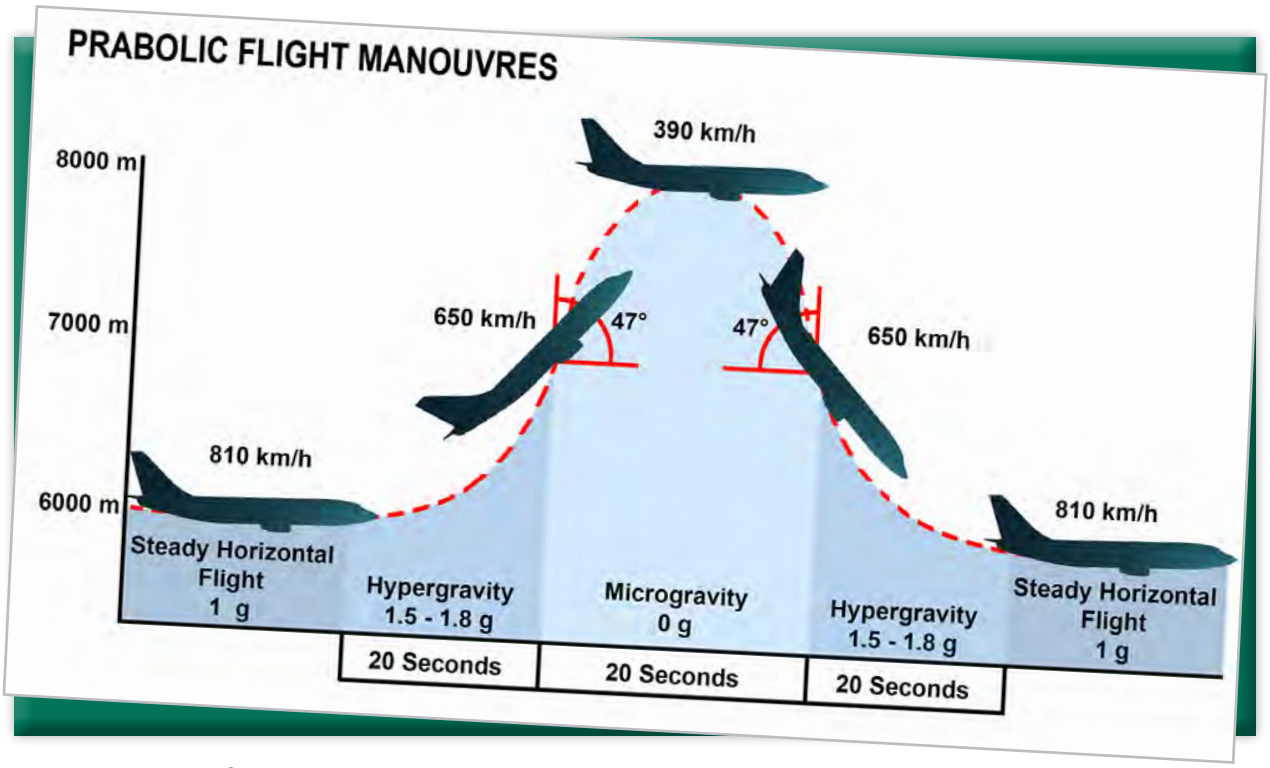
The 20-G Centrifuge helps astronauts prepare for the g-forces they will experience during space travel. The centrifuge is a large rotating arm that rotates up to 50 times per minute. It creates g-forces up to 12.5 g for astronauts.

The 20-G Centrifuge at NASA's Ames Research Center.

Courtesy of NASA

Vomit Comet

The nickname of this training makes it sound like a fun experience, right? The "Vomit Comet," as astronauts fondly call it, is a hollowed-out Boeing 727 that flies in parabolic arcs over Las Vegas, NV to simulate weightlessness. NASA began using the Boeing 727 owned by Zero Gravity Corporation after canceling its Reduced Gravity Research Program in July 2014. Parabolic arcs refer to the flight pattern of an aircraft that makes a steep incline, briefly levels out, and then makes a steep decline to create a brief period of weightlessness.



Parabolic Arcs in flight.

Astronauts take off and wait about 30 minutes to reach an altitude of 24,000 feet. The pilot then climbs to 32,000 feet at a sharp 47-degree angle. This allows astronauts to reach 1.8 g. The plane then levels out and astronauts experience 20-30 seconds of weightlessness before they dive back down to 24,000 feet. The flight repeats this pattern at least 15 times to give astronauts enough practice at 0 g. (0 g is the value for weightlessness.)

After the initial phase of spaceflight training, astronaut candidates go on to learn more about the finer details of the ISS, the experiments, special mission-specific activities, the transport vehicles, and the role of ground control. Part of training at this stage involves supporting current astronauts in space and astronauts from other training facilities.

Did You Know?

For $5,000, Zero G Corp. will provide you the same experience. You can take a ride on the Vomit Comet and experience weightlessness.

The Reduced Gravity Education Flight Program provides a unique academic experience for educators and undergraduate students to experience reduced-gravity experiments of their choice.
Courtesy of NASA

Duties

Astronauts hold several different titles and responsibilities on each space mission. As the person in charge, the mission commander handles everything from the vehicle itself to the crew and their safety. Successful completion of the mission is paramount. Commanding a space flight may also involve spacecraft deployment and retrieval of satellites, using payload equipment. "Payload" refers to cargo such as instruments and space equipment that is carried into space to accomplish a mission. Payload cargo even includes the astronauts themselves!

Just as a commercial flight captain has a first officer or co-pilot, every space mission commander has a supporting pilot, or next-in-command. Spacecraft support pilots assist the commander and have primary responsibility for operating the spacecraft. They perform many of the same duties as a commercial pilot and use a mechanical arm or other payload equipment to release and retrieve experiments conducted outside the spacecraft. Pilots may also be involved in scheduled spacewalks.

Working closely with commanders and pilots, mission specialists direct the daily activities. These activities include distribution of food and water to other crew members, monitoring of fuel, and carrying out experiments and payload activities. Mission specialists are experts who oversee the operation of all systems aboard the craft, including experiments, spacewalks, and payload-handling duties performed during a mission.

Dr. Ellen Ochoa became an astronaut in July 1991 and was the first Hispanic woman to go into space. She is a veteran of four space flights and has logged over 978 hours in space. She currently serves as director of the Lyndon B. Johnson Space Center in Houston, Texas.

Courtesy of NASA

One of the more recent astronaut roles is that of the payload specialist. Payload specialists are scientists or engineers selected for their expertise. They perform special functions during a mission, beyond the normal routine for standard flights. These functions may include operating unique spacecraft equipment or carrying out experiments based on their expertise. Unlike pilots and mission specialists, payload specialists do not appear on most missions.

With more missions by NASA planned for the future, the demand for the number of astronauts needed may increase. Missions include more studies in the International Space Station and a return to the Moon for additional research. Manned missions to Mars for short-term or even long-term projects may be possible. Depending on those results, we hope to see astronauts venture even farther into space than the Moon and Mars!

Do you have dreams of becoming an astronaut? Has completing this lesson sparked an interest in possibly becoming an astronaut? Although the path to becoming an astronaut is very competitive and challenging, the opportunities in fields of study related to astronomy, engineering, and medicine are endless. Find an interest in something that ignites your passion and plan a career path that will take you there. Plan for detours along the way, and the sky just may not be your limit!

The Right Stuff

Day in the Life of an Astronaut on the ISS

It's 6:00 in the morning, and it's time for breakfast and another day at the office--unless you are on a mission in the ISS. Astronauts in the ISS start their day a little differently. Getting showered, dressed, and ready in microgravity is a bit more challenging. For example, the shower is a soothing wake-up call for most of us. Showering aboard the ISS is more like a sponge bath with very little water and with rinseless shampoo. After toweling dry, an airflow system evaporates the rest of the water.

After a morning "shower," astronauts have the first of three daily meals. Space meals are much like MREs (Meals Ready to Eat) for soldiers. Without refrigeration on the ISS, space food must be spoil-proof. It must also be easy to prepare and store. You also need to consider microgravity. For example, salt and pepper are not something you find on the ISS. Imagine trying to sprinkle salt on your food, just to have it float away!

How astronaut Scott Kelly enjoys a snack aboard the ISS.

Courtesy of NASA/JSC

When astronauts are not working, they spend free time exercising, relaxing, or just having fun. Exercise is actually a requirement in space. Daily exercise, up to two and a half hours, helps to prevent bone and muscle loss. A major difference in working out in space, of course, is the amount of weight you are able to lift just to feel some resistance.

It's now 9:30 p.m. and time to strap into a sleeping bag for a good night's sleep without floating around and bumping into things. When the sun rises, it will not be time to wake up for another day, though. Keep in mind, the sun rises 16 times in a day aboard the ISS, so astronauts take special measures to avoid the light while sleeping.

CHECKPOINTS

Lesson 2 Review

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

1. What is NASA's vision for exploring space?
2. What are NASA's mission directorates?
3. What are the components of a space mission?
4. How is NASA funded?
5. What are the basic qualifications of astronauts?
6. How do astronaut candidates train for microgravity?
7. What is involved in centrifuge training?
8. What is a payload specialist responsible for?

APPLYING YOUR LEARNING

9. NASA plans to send astronauts to Mars by 2040. If you wanted to be an astronaut on that mission, what special skill do you think would be needed?