LESSON 2

US Manned Space Program

Quick Write

Read the vignette about the soccer ball survivor. Why do you think it was important for the soccer ball to finally complete its journey to space?

Learn About

- early US manned space program
- why develop a shuttle program
- space shuttle's main components
- lessons learned from Challenger and Columbia

It's another day of practice on the soccer field at Clear Lake High School in Texas in 1986. Young Janelle Onizuka has the thoughtful idea to have her teammates autograph the soccer ball for her father. Passing around a blue ink pen, each teammate autographs the ball and writes "Good Luck, Shuttle Crew." You see, Janelle Onizuka just happens to be the daughter of astronaut Ellison Onizuka. Her father is one of seven crew members who will go on the space shuttle Challenger's 10th mission in the days to come.

Although Ellison is supposed to be in quarantine to avoid sickness before the launch, he sneaks out to catch a soccer game. There, the team proudly presents him with the ball.

On January 28, 1986, Ellison Onizuka boards Challenger with a few personal items, including the soccer ball. Just over a minute into flight, Challenger breaks apart, creating a fiery ball in the sky. Debris is scattered over the area. The seven crew members are lost.

For weeks to follow, the US Coast Guard retrieves tons of debris from the Challenger accident. A most important item found floating in the Atlantic Ocean is Onizuka's soccer ball with blue-inked autographs still visible.

For decades, the soccer ball sits in a trophy case at Clear Lake High School. Thirty-one years after the Challenger accident, Clear Lake High School parent and astronaut, Shane Kimbrough offers to take a memento to space on the school's behalf. Principal Karen Engle has the idea to send the soccer ball into space, as its story was beginning to fade within the school. And so, Kimbrough took the soccer ball survivor into space.

The infamous soccer ball from the Challenger accident that finally made it to space more than 30 years later.

Courtesy of NASA/JSC

Vocabulary

- retrorocket
- space shuttle
- orbiter
- Remote Manipulator System (RMS)
- airlock
- extravehicular activity (EVA)
- aft
- Solid Rocket Boosters (SRBs)
- Space Shuttle Main Engines (SSMEs)
- O-ring
- max-Q

Early US Manned Space Program

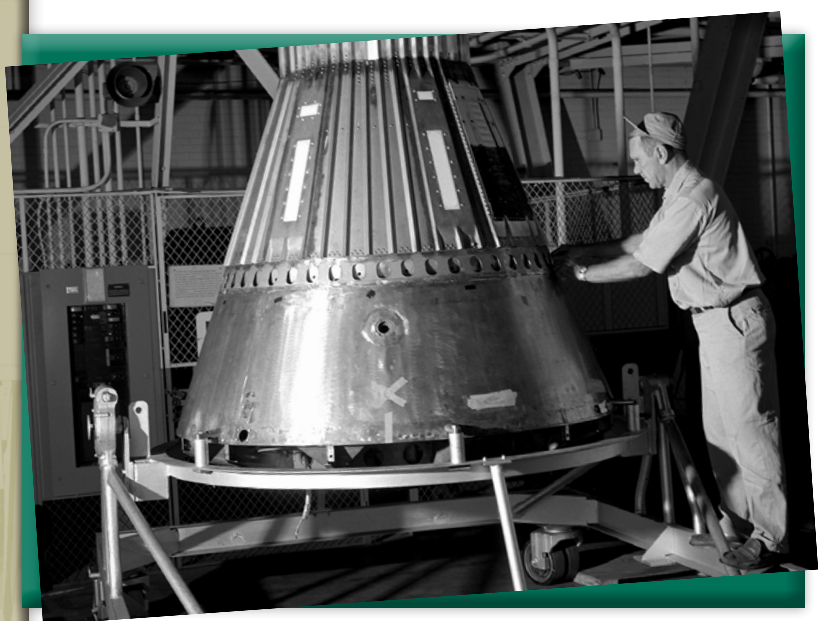
After NASA was established, the United States embarked on a mission to send a man into orbit. After each success, NASA pushed the limits and extended its goals for sending humans into space. The US manned space program led to scientific discoveries and technological advances in space travel and paved the way for future space travel.

Project Mercury

NASA answered the call from President Eisenhower to put a man into orbit around Earth. Project Mercury was the initial project of the US manned space program. Mercury was the winged messenger of the gods in ancient Roman and Greek mythology. The name was suggested by NASA's Director of Space Flight Development. Project Mercury consumed most of NASA's resources for the next five years until it succeeded in putting a man into orbit.

Project Mercury was a three-phase project that included six spaceflights. In Phase I, NASA selected and trained astronauts, while also developing safety systems to be used in the launch and re-entry of the space capsule. In Phase II, NASA adapted the Redstone ballistic missile for suborbital flights. A suborbital flight is a spaceflight in which your trajectory takes you in a large arc going into space and then falling back to Earth. Phase III of Project Mercury involved adapting the Atlas rocket to launch a capsule into orbit with a human aboard. An orbital flight is a spaceflight whose trajectory moves around, or orbits, the planet.

NASA created the Space Task Group to set up and manage Project Mercury. Robert Gilruth, an expert in rocket testing and development, was assigned to lead the group. The Space Task Group designed a capsule that would hold one human. The capsule would use retrorockets and parachutes to return to Earth. A retrorocket is *a small auxiliary rocket on a spacecraft that is designed to slow down the craft*. During re-entry, the space capsule would reach extreme speeds, so NASA needed a way to slow down the capsule to safely deliver the astronaut back to Earth's surface. The capsule designed for Project Mercury was extremely small. It had room for only one adult. The cone-shaped capsule was approximately 11 feet long and 6 feet wide. Each launch utilized a different capsule that was given a unique name.



The Mercury capsule during construction.
Courtesy of NASA

The first test flight for Project Mercury launched from Wallops Island, VA on December 4, 1959. This was an impressive feat because the first test flight occurred about a year after the launch of the project. The test flight was a suborbital flight with the capsule occupant being a rhesus monkey named Sam. The test flight was a success, and testing continued. On January 31, 1961, a chimpanzee named Ham flew 157 miles into space during a 16 minute and 39 second suborbital flight. Ham's capsule was launched using a Redstone rocket. NASA was concerned that the Redstone rocket didn't have enough power to launch a heavier capsule, so it began to adapt the Atlas rocket for Project Mercury. A chimpanzee named Enos would complete two orbits around Earth after launches that used the Atlas rocket. Sam, Ham, and Enos successfully and safely returned to Earth, providing NASA the proof that it was ready to begin sending astronauts to space.

Ham the Space Chimpanzee prepares for flight aboard Mercury Redstone rocket.
Courtesy of NASA

On May 5, 1961 Alan Shepard became the first American to reach space in the Freedom 7 capsule. Shepard completed a 15-minute suborbital flight. The first two manned flights of Mercury used the Redstone rocket, but the remaining Mercury flights used the Atlas rocket. Although this was a huge accomplishment for the United States space program, the Soviets beat the Americans into space by putting a human into orbit in April 1961.

NASA was determined to continue Project Mercury and reach its goal of putting a man in orbit around Earth. On July 21, 1961, Virgil "Gus" Grissom became the second American in space when he completed a suborbital flight aboard the Mercury capsule Liberty Bell 7. The flight had problems after re-entry. After splashdown in the Atlantic Ocean, the capsule's hatch blew off too early. Grissom's capsule was dropped into the sea without a hatch and quickly filled with water. Grissom barely escaped.

The Right Stuff

NASA's astronaut selection process was rigorous for its first mission into space. It opened the pool of candidates to young, physically fit men who were also seasoned pilots. Each applicant had to be under 40 years of age and under 5′ 11″ due to the cramped space inside the Mercury capsule. In addition, candidates needed a bachelor's degree, 1,500 hours of flight time, and qualification as a jet pilot. The candidates would go through a process of interviews, written tests, psychiatric evaluations, and medical history reviews.

Group portrait of the "Mercury Seven."
Courtesy of NASA

In April 1959, NASA selected seven candidates from the original pool of around 3,000 applicants to be the "Mercury Seven." All of the astronauts were active-duty military members who would begin intensive training to prepare for a possible flight to space.

The "Mercury Seven" consisted of the following officers:

- Marine Lieutenant Colonel John Glenn Jr.
- Navy Lieutenant Commander Walter "Wally" Schirra
- Navy Lieutenant Commander Alan Shepard Jr.
- Navy Lieutenant Commander Scott Carpenter
- Air Force Captain Gordon Cooper
- Air Force Captain Virgil "Gus" Grissom
- Air Force Major Donald "Deke" Slayton

On February 20, 1962, John Glenn became the first American to orbit Earth. His capsule, Friendship 7, orbited Earth three times in the 4 hour and 56 minute flight. His flight also had complications. During orbit, the autopilot controls failed and Glenn had to fly the last two orbits manually. John Glenn already had a reputation as one of the best test pilots in the country. After his flight to space, he quickly became an American hero for his accomplishments and boosted the reputation of the NASA program.

Between 1962 and 1963, Project Mercury completed three additional flights. On May 20, 1962, Scott Carpenter completed three orbits of the Earth aboard Aurora 7. And on Oct. 3, 1962, Walter “Wally” Schirra completed six orbits aboard Sigma 7. Finally, on May 15, 1963, Gordon Cooper completed a record 22 orbits in 34 hours aboard Faith 7. Remember, the capsules for Project Mercury were very small and the astronauts were confined to their seat for the entire flight. Project Mercury had exceeded its goals and put a man into orbit.

John Glenn entering the Friendship 7 capsule prior to launch.
Courtesy of NASA

Project Gemini

Project Gemini would be the next major project for NASA. Project Gemini had three main goals:

1. Learn how to maneuver, rendezvous, and dock with another spacecraft.
2. Allow astronauts to practice working outside the spacecraft.
3. Gather physiological (human performance) data on long spaceflights.

Gemini means “twins” in Latin and is the name of the third constellation of the zodiac. It seemed an appropriate name for the new two-man crew and the project’s relationship to Mercury. Project Gemini was the stepping stone to reaching the Moon. NASA and its astronauts needed to successfully complete the goals of Project Gemini in order to send a man to the Moon.

This image of NASA’s Gemini 7 in space was taken by Gemini 6A as the two capsules meet during a rendezvous.
Courtesy of NASA

The Project Gemini capsule was designed to hold a two-astronaut crew. The program ran from 1965 to 1966. It was a relatively short project for NASA, but was an extremely successful one. Over the course of the program, Project Gemini flew 10 missions.

TABLE 2.1 Project Gemini Timeline

Mission / Date	Event
Gemini 3 March 23, 1965	Virgil "Gus" Grissom and John White were the first Gemini mission crew.
Gemini 4 June 3, 1965	Edward White II was the first American to spacewalk.
Gemini 5 August 21, 1965	The Gemini 5 mission stayed in orbit for more than a week.
Gemini 6A December 15, 1965	Gemini 6A and 7 were in space at the same time.
Gemini 7 December 4, 1965	Gemini 7 stayed in space for two weeks.
Gemini 8 – March 16, 1966	Gemini 8 successfully connected to an unmanned spacecraft in orbit.
Gemini 9A June 3, 1966	Gemini 9A tested methods for flying near another spacecraft.
Gemini 10 July 18, 1966	Gemini 10 successfully connected to an unmanned spacecraft in orbit and then used its engines to move both spacecrafts.
Gemini 11 September 12, 1966	Gemini 11 flew higher than any other NASA mission.
Gemini 12 November 11, 1966	Gemini 12 worked on solving complications with spacewalks.

Did You Know?

On June 3, 1965, during the Gemini 4 mission, Edward White II set another first for the US by becoming the first American to spacewalk. White spent 30 minutes outside of the spacecraft. He used a propulsion gun that released nitrogen to move through space. He was connected to the spacecraft with only an oxygen hose.

Astronaut Edward White during the first American spacewalk.

Courtesy of NASA

Project Apollo

NASA's Apollo project began on January 27, 1967. This was the NASA program that would put a man on the Moon. The proposed name, "Apollo," was the name of the Greek god of archery, prophecy, poetry, and music; most significantly, he also was god of the sun in Greek mythology. In his horse-drawn golden chariot, Apollo pulled the sun on its course across the sky each day. The Apollo missions had four goals:

- Establish the technology to meet other national interests in space.
- Achieve preeminence in space for the United States.
- Carry out a program of scientific exploration of the Moon.
- Develop human capability to work in the lunar environment.

The Apollo spacecraft had three parts. The command module (CM) housed flight control and the crew's quarters. The service module (SM) housed the propulsion and spacecraft support systems. When these two systems were connected, they were referred to as the CSM. The lunar module (LM) was the portion of the craft that would take a two-man crew to the lunar surface.

The project began in disaster. During a preflight test on January 27, 1967, a fire broke out in a pressurized, oxygen-rich area of the CM. The oxygen-rich environment fueled the fire, and it spread rapidly. Because the module of the spacecraft was pressurized, it took NASA longer than usual to open the hatch. By the time they were able to access the spacecraft, three astronauts had perished: Virgil "Gus" Grissom, Edward White, and Roger Chaffee. These men were the first fatalities of the US space program. After the accident, NASA halted the mission for a complete investigation. It made improvements to the design and established safety measures for the Apollo spacecraft. NASA agreed to resume the mission.

Apollo 1 astronauts, left to right, are Virgil "Gus" Grissom, Edward White, and Roger Chaffee.

Courtesy of NASA

On December 21, 1968, Apollo 8 launched with Frank Borman, James Lovell, and William Anders on board. Four days later (on Christmas Eve), Apollo 8 broadcast live from space for all of America to see. They provided the country with spectacular images of the Earth as they successfully orbited the Moon.

Did You Know?

Apollo 8 captured pictures of Earth while orbiting the Moon. The images soon became famous and were known as "Earthrise" because they showed the Earth rising as a small planet above the Moon's surface.

The first Earthrise image taken by the crew of Apollo 8.

Courtesy of NASA

The Apollo 9 and 10 missions were used to further test the lunar module and orbit the Moon. On July 16, 1969, Apollo 11 launched from Kennedy Space Center with astronauts Buzz Aldrin, Neil Armstrong, and Michael Collins aboard. Over the next three days, the astronauts would travel to the Moon to start their orbit. On July 20, 1969, the lunar module dubbed "Eagle" was separated from the command/service module (CSM) of Apollo 11 and began its descent to the Moon.

Neil Armstrong and Buzz Aldrin were in the lunar module (LM), while Michael Collins stayed in the CSM. Armstrong and Aldrin had a stressful lunar landing because the automatic landing controls were directing the LM to land in a boulder field. Armstrong took over the controls to manually pilot the LM to a more suitable landing location. The fuel on the LM quickly dropped. With barely 30 seconds of fuel remaining, the LM touched down on the lunar surface. Shortly after, Neil Armstrong announced to Mission Control, "The Eagle has landed." NASA had successfully put a man on the Moon. Now it was time for the astronauts to have some fun!

An astronaut's footprint on the Moon. The Moon does not have erosion from wind or water so the footprints left by astronauts on the Moon will be there for a long, long time.

Courtesy of NASA

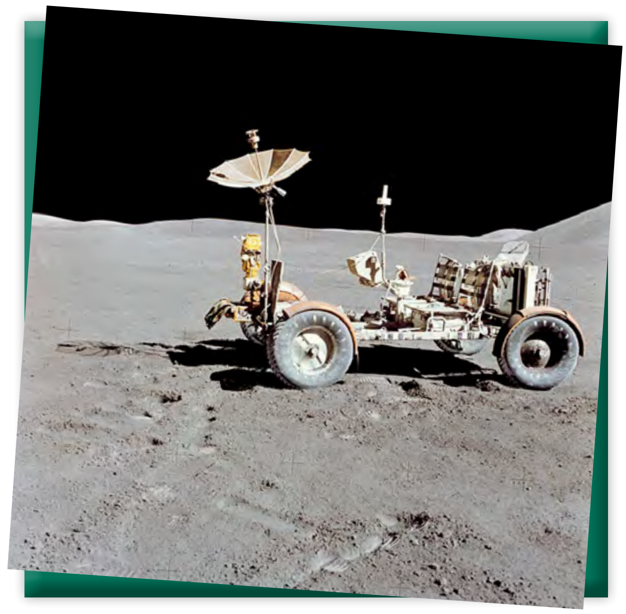
Armstrong and Aldrin were scheduled to take a five-hour rest after they landed on the Moon. They skipped their scheduled rest because they were too excited. They put on their spacesuits and stepped out of the LM. Neil Armstrong was the first to exit the LM. As he stepped on the lunar surface, he exclaimed, "That's one small step for a man, one giant leap for mankind." Buzz Aldrin joined him on the lunar surface for the first moonwalk. While on the moon, they planted an American flag, collected soil and rock samples, and set up experiments for NASA.

This would not be Apollo's last mission to the Moon. In November 1969, Apollo 12 returned to the Moon with Charles "Pete" Conrad and Alan Bean. The astronauts completed two moonwalks, each approximately four hours in length. They set up experiments on the moon to measure seismic activity, solar wind flares, and the Moon's magnetic field.

Apollo 13's famous mission launched on April 11, 1970. It was to be the third trip to the Moon for Americans. Astronauts James Lowell, Fred Haise, and John Swigert were aboard Apollo 13. At 56 hours into their mission, an oxygen tank ruptured, damaging the power, electrical, and life support systems in the command module (CM). As a result, the CM had limited resources to support the astronauts aboard. The lunar module (LM), however, was not affected. The astronauts remained in the LM until Mission Control could figure out how to get them home safely. NASA had to think quickly and work with limited resources to adapt the spacecraft so that it could return to Earth safely. The success of Apollo 13 proved that NASA had the ability to not only send a man to the Moon, but to successfully avoid catastrophes in space.

The original Apollo project was to have 20 missions. Due to budget cuts, the program was scaled back and only completed 17 missions. During the Apollo missions, astronauts deployed over 50 experiments on the moon, 12 astronauts walked on the Moon, and the Lunar Roving Vehicle (LRV) was deployed on the Moon to allow astronauts to travel greater distances on the Moon. To date, the United States is the only nation to have sent humans to the Moon.

Buzz Aldrin walking on the Moon.
Courtesy of NASA



Lunar Roving Vehicle (LRV) photographed against a desolate moon landscape during the Apollo 15 mission.
Courtesy of NASA

Did You Know?

A movie, Apollo 13, was released in 1995 to document the safe return of the spacecraft and astronauts to Earth.

Why Develop a Shuttle Program

In early 1969, President Richard Nixon formed a new Space Task Group, a group of NASA engineers. Their task: identify the future vision of space exploration, beyond the Moon. Later that year, the group presented a plan involving a shuttle, space station, and eventually, manned missions to Mars.

Much like we may take a subway to travel between work and home, the shuttle would take a crew of astronauts, reusable supplies, and food, to a larger space station. The space station would remain there for future shuttles. The shuttle would be used to exchange crews, make any necessary repairs to the space station, and conduct new projects.

NASA proposed a fully reusable space shuttle that would go to and from the space station. This plan was short lived. Nixon thought the plan was much too pricey and cut NASA's budget, focusing on one aspect of the plan: the space shuttle itself. A space shuttle is *a reusable spacecraft designed to transport people and cargo between Earth and space.*

The space shuttle, or STS (Space Transportation System), provided a way to easily, economically, and safely leave the surface of Earth. NASA wanted to move away from a costly spacecraft and utilize a reusable shuttle with a large payload bay to haul equipment.

The space shuttle prototype, Enterprise, flies free of NASA's 747 Shuttle Carrier Aircraft (SCA) during one of five "free flights" carried out at the Dryden Flight Research Facility, Edwards, Calif., in 1977 as part of the shuttle program's Approach and Landing Tests (ALT).

Courtesy of NASA

The space shuttle could haul up to 45,000 tons of cargo and fly up to 250 miles above Earth. In addition, the shuttle could hold up to 10 astronauts, although the typical flight carried a crew of seven.

The first space shuttle, named Enterprise, rolled out in September 1976. Enterprise made some flights, but never reached space. Over the 30 years of the Space Shuttle Program's history, NASA built five other space shuttle orbiters for flight. These include Columbia, Challenger, Discovery, Atlantis, and Endeavour.

With 135 completed missions, the Space Shuttle Program was extremely successful. It ferried 852 astronauts to space.

The Shuttle's Missions

The space shuttle Columbia made the first space flight of the Space Shuttle Program, achieving many milestones in space exploration. Columbia's first flight launched on April 12, 1981 from Kennedy Space Center in Florida. It had been six years since an American had been in space. The first Columbia flight made 36 orbits in a two-day span and then landed as an aircraft at Edwards Air Force Base in California. The Columbia missions provided proof that a reusable spacecraft could complete a mission into orbit and return safely to Earth. Columbia finished three more missions, testing its performance at each phase of the flight.

Did You Know?

Columbia was the heaviest space shuttle, weighing in at 178,000 pounds.

Columbia conducted its first operational mission on November 11, 1982. With a crew of four, Columbia recovered several satellites from orbit and became the first manned spacelab mission designed for human medical research.

The next space shuttle for NASA was the Challenger. For its first mission in 1983, Challenger took off from NASA's Kennedy Space Center and marked the first spacewalk of the Space Shuttle Program. It also deployed the first Tracking and Data Relay System satellite, among many other accomplishments. You will learn more details about Challenger later in this lesson.

Following Challenger, Discovery launched a mission to deploy several communication satellites in 1984. Discovery's claim to fame is the number of missions it flew. Completing over 30 successful missions, Discovery made more flights than any other orbiter in NASA's history.

Discovery carried satellites into space, along with crews of astronauts to perform many experiments on the International Space Station (ISS). Discovery also made two flights to the Russian space station, Mir. Importantly, Discovery took the Hubble Space Telescope into space in 1990.

In 1981, space shuttle Columbia and STS-1 lifted off from NASA's Kennedy Space Center, marking the first flight of the Space Shuttle Program.
Courtesy of NASA

Did You Know?

Like Columbia and Challenger, Discovery was named for an exploration ship from our past: the ship used by Henry Hudson to explore the Hudson Bay.

Lastly, we have Atlantis and Endeavor. Atlantis conducted several important missions for the Department of Defense in 1985. Atlantis also linked with the Russian space station, Mir, to form the largest spacecraft in history.

Endeavor, endorsed by Congress as a replacement for Challenger (Challenger's fate will be covered later in the lesson), was first launched in 1992. Along with satellite repairs, Endeavor is credited with the longest spacewalk in NASA history.

TABLE 2.2 *Project Gemini Timeline*

Shuttle	Number of Flights	Earth Orbits	Miles Traveled	Total Crew	Time in Space
Columbia	28	4,808	121,696,993	160	300 days
Challenger	10	995	23,661,290	60	62 days
Discovery	39	5,830	148,221,675	252	365 days
Endeavour	25	4,671	122,883,151	173	299 days
Atlantis	33	4, 848	125,935,769	207	307 days
TOTAL	**135**	**21,152**	**542,398,878**	**852**	1,333 days

Astronaut Paul Richards, STS-102 mission specialists, works in the cargo bay of the space shuttle Discovery.
Courtesy of NASA.

Did You Know?

The longest spacewalk was 8 hours and 56 minutes, performed by Susan J. Helms and James S. Voss during STS-102 on March 11, 2001.

The Right Stuff

Over the 30 years of its history, the Space Shuttle Program accomplished some of the greatest achievements in NASA's history. Not only did it help build the International Space Station (ISS) and launch the Hubble Space Telescope, it also brought nations together. For Americans, it marked many first-in-flights for individuals of all backgrounds.

In 1983, Guy S. Bluford Jr., a mission specialist, became the first African American in space. His first launch, aboard the Challenger on NASA's STS-8, was especially memorable. At lift-off, the audio recording captured someone laughing as they ascended into space. That person was Guy Bluford, clearly delighted to be going into orbit!

Also, in 1983, Dr. Sally K. Ride was the first American woman to go into space. Ride had an impressive education, including a doctorate in astrophysics. She was one of the few women selected for astronaut training.

Training was hard and complicated. Ride trained in parachuting, water survival, microgravity, and g forces. The hard work paid off. Ride made it to space and also became a pilot. She contributed to the design of a robotic arm that would be used to deploy and retrieve satellites.

In 1985, Air Force Colonel Ellison Onizuka, became the first Asian American in space. He was aboard Challenger on NASA's STS-51C Defense Department mission and the STS-51L mission.

Other firsts in flight include Franklin Chiang-Diaz, the first Hispanic American to fly into space aboard Columbia STS-61-C in 1986. In 1992, Dr. Mae Jemison became the first African American woman in space, aboard Endeavor STS-47. In 1993, Dr. Ellen Ochoa was the first Hispanic woman in space, on the STS-56 Discovery mission.

At NASA's Johnson Space Center, astronaut Sally K. Ride takes a break from training as a mission specialist for NASA's STS-7 spaceflight in Earth orbit.
Courtesy of NASA/JSC

Current State of the Shuttle Program

The Space Shuttle Program's achievements are considerable! The shuttle program was used to retrieve, repair, and replace satellites. It was designed as a workhorse and certainly proved itself as such. Although the shuttle program was not designed specifically for science, each mission included a science component. Some of the greatest cutting-edge research was performed during the shuttle missions.

Thanks to the shuttle program, the US successfully assisted in the building of the largest structure in space, the ISS. During all of the flights, the shuttles accumulated over 21,000 orbits and more than 500 million miles. There have been hundreds of shuttle crew members, including men and women from 16 different countries, with a total flight time of almost four years. The program also allowed NASA to expand its astronaut program to include non-pilot astronauts. Guests, mission specialists, and scientists were able to experience the view from space through the shuttle program.

Despite all of these accomplishments, in 1994, President George W. Bush revealed a new vision for space exploration. The new vision did not include the shuttle program. President Bush announced the shuttle program would come to an end, and it did with the final flight of Atlantis on July 21, 2011.

Bush's vision was to develop a new Crew Exploration Vehicle (CEV). The goal would be to go beyond the Moon, to Mars. Unfortunately, Congress did not provide enough funding for Bush's vision.

The launch of Atlantis on the STS-135 mission and the final flight of the shuttle program.
NASA/Bill Ingalls

Since the end of the Space Shuttle Program in 2011, the US has paid Russia to transport American astronauts and cargos to the ISS. NASA has requested additional funding from our government. It has also picked two private companies, SpaceX and Boeing, to develop a spacecraft to replace the shuttles. SpaceX is scheduled to test the Crew Dragon spacecraft in 2019. When testing is complete, NASA will use this spacecraft to ferry US astronauts to and from the ISS, replacing the need for Russian Soyuz spacecraft.

In addition, NASA's Orion spacecraft is being developed; however, it is not expected to carry astronauts until 2023. In this American-European project operated by NASA, the Orion is being built by the US company Lockheed Martin and European partners.

The Space Shuttle's Main Components

Each space shuttle has four main components. These include the spacecraft (orbiter) itself and three components that supply the energy needed to propel the craft into space. The external tanks, rocket boosters, and engines supply the energy.

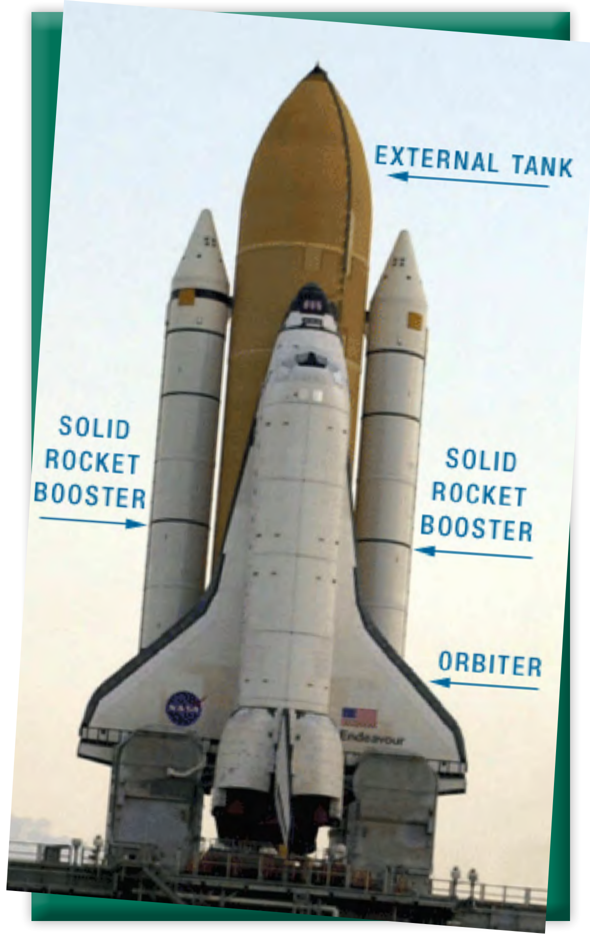
The Orbiter

An orbiter *is what NASA calls a space shuttle. It is a space plane that is one of the four components of what most people think of as the space shuttle.*

The orbiter launches into space like a rocket but looks like a jet plane and returns to Earth by landing on an airfield just as a plane does. It is the crew's home during the flight and is capable of docking with the ISS for studies there.

Each orbiter is about 122 feet long (almost half the length of a football field), 57 feet high (about the height of a six-story building), and has a wingspan of 78 feet (about half the width of a football field).

An orbiter is approximately the size of a DC-9 passenger plane. It weighs about 4.5 million pounds and travels in orbits of 115 to 400 miles high. It travels at speeds greater than 17,000 miles per hour.



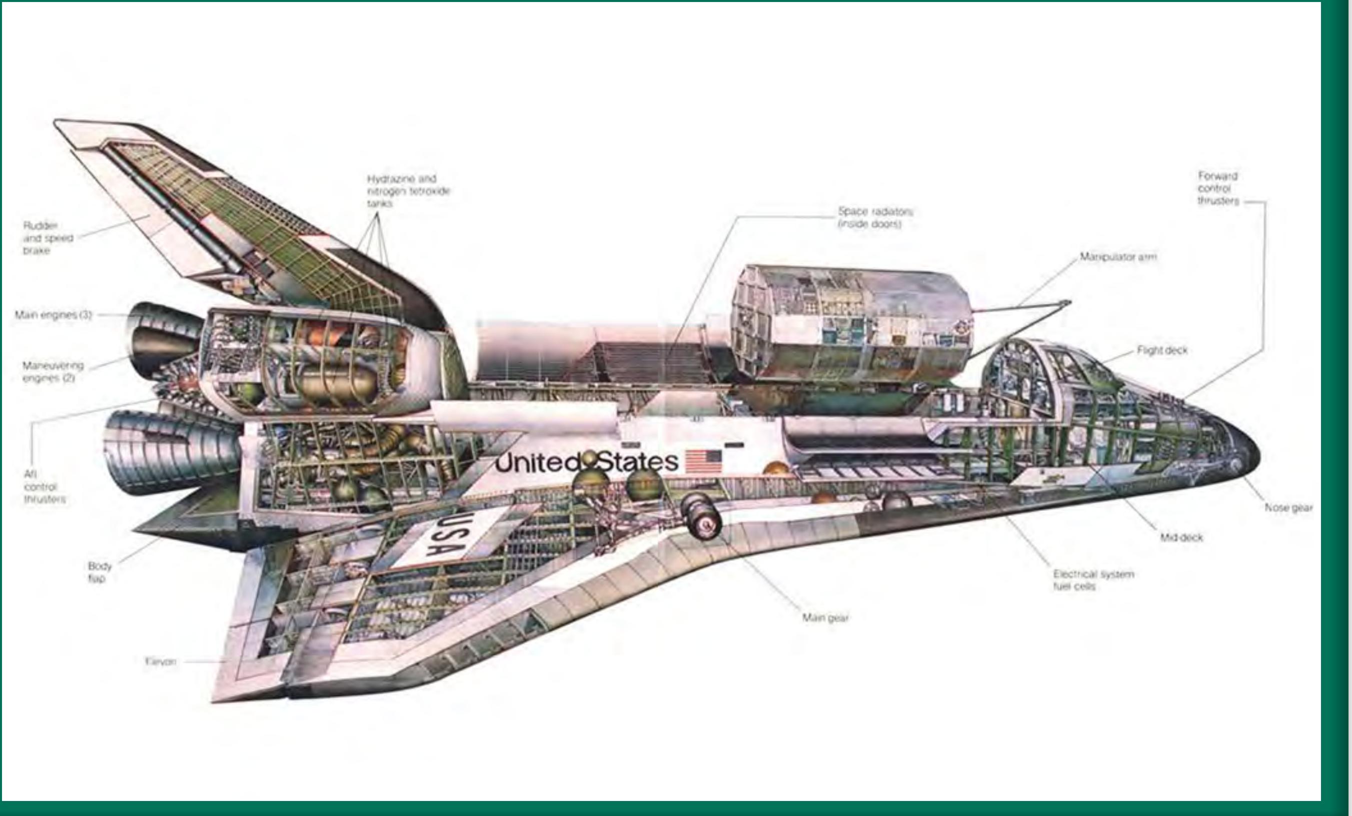
The space shuttle's main components. All of the components are reused, except for the external fuel tank, which burns after each launch.

Courtesy of NASA

The front end of the orbiter is the crew cabin, which includes the cockpit or flight deck. This area is pressurized and can accommodate seven crew members. It also has a nose gear and landing wheel because it lands like a plane. The flight deck is further divided into three regions: the front flight deck, the mid deck, and the airlock.

Did You Know?

The shuttle flies as a glider for reentry and landing, so the crew only gets one attempt at landing. The shuttle must also slow from 17,300 mph to 250 mph for the landing.



Parts of the orbiter. A detailed cutaway diagram.
Courtesy of NASA

Astronaut conducts spacewalk attached to RMS.
Mike_shots/Shutterstock

The front flight deck is the area for the flight commander and pilot with the commander sitting on the left and the pilot on the right. This is much the same as the seating arrangement in a plane for the pilot and co-pilot. The commander controls the operations of the orbiter, and the pilot is responsible for operating the payloads. The pilot is able to use a Remote Manipulator System (RMS), which is *a 50-foot long mechanical arm that deploys and retrieves things on the outside of the orbiter*.

The mid deck area contains the food and supplies and is the area used for eating, sleeping, and personal hygiene. The *last area of the flight deck* is the airlock. This pressurized area allows access for spacewalks.

The official term for a spacewalk is extravehicular activity (EVA), *when an astronaut leaves the protective environment of a spacecraft and enters outer space*. Behind the flight deck is the middle part of the orbiter, which is the cargo/payload area. This is a storage region for research materials and projects that are to be conducted on the flight and for items that are taken to or returned from the ISS.

The rear part of the orbiter is the *region where the main engines and maneuvering systems are located* to propel and guide the orbiter. This is known as the aft.

External Tank

A very large external tank feeds the fuel to the engines. It also acts as the backbone of the shuttle by supporting the orbiter and the booster rockets until the tank is empty. This is the only part of the shuttle that is not reused. After the first eight and a half minutes of flight, the empty tank is released. Most of the tank disintegrates in the Earth's atmosphere, and the rest falls into the ocean.

The tank weighs about 78,000 pounds empty and about 1.6 million pounds when loaded with fuel. It holds about 670,000 gallons of liquid fuel. The one-inch thick protective thermal coating keeps the fuel at the right temperature. The electrical system distributes the power evenly and protects the tank from lightning. The fuel is released from the tank through a 17-inch diameter tube that branches into three smaller hoses, one for each main engine.

Splashdown of the right hand SRB from the launch of STS-124.

Courtesy of NASA.

Rocket Boosters

Attached to the shuttle when it is launched are two solid rocket boosters (SRBs), *large solid propellant motors that provide 80% of the thrust needed during the first two minutes of launch*. After the initial thrust and at about 24 miles in altitude, the SRBs separate from the shuttle and return to Earth on parachutes by landing in the ocean. There, they are retrieved and can be used again. The fuel from the boosters burns off in just two minutes!

Besides providing the thrust for launch, the SRBs also guide the shuttle along a flight path. Each SRB has more than one million pounds of propellant. The solid fuel is mixed in 600-gallon bowls and poured into a mold. The final product looks and feels like a hard, rubber compound.

Space Shuttle Main Engines

The Space Shuttle Main Engines (SSMEs) *are three large engines located on the rear of the orbiter*. These provide about 20% of the thrust needed to launch the shuttle into space and to continue powering it for another eight and a half minutes after launch.

The SSMEs are powered by fuel from a large external tank during this period of operation. They accelerate the shuttle from about 3,000 miles per hour up to over 17,000 miles per hour within six minutes to reach its orbital velocity.

Did You Know?

The SSMEs burn half a million gallons of liquid hydrogen (the second coldest liquid on Earth) and liquid oxygen. The amount of water in an average family swimming pool is about equal to the amount of liquid fuel burned in the SSMEs in 25 seconds!

Lessons Learned from Challenger and Columbia

On January 28, 1986, millions of Americans, young and old, gathered around the television to watch the much-anticipated Challenger launch. This was a milestone launch, as it included the first civilian crew member in the shuttle program's history. From over 11,000 applicants, teacher Christa McAuliffe was taking the civilian seat as part of the Teacher in Space program. She was going to teach lessons from space by satellite and help restore America's interest in space exploration.

At lift-off, the crowd was full of smiling faces and enthusiastic cheers. At first, everything seemed fine. The Challenger launched into the sky as normal. At 73 seconds into flight however, something went terribly wrong. The cheers were silenced as the Challenger burst into a plume of smoke and fire. The crew was lost.

President Ronald Reagan appointed a commission to investigate the causes of the Challenger accident. Using computer graphics and NASA photos, the Commission was able to identify the origin of the smoke. They determined the first puff of smoke came from a joint on one of the SRBs. They further concluded that there must be a break in the joint's seal.

As Challenger took off, one of the seals broke enough to allow exhaust to leak out. Hot gases filled the external tank causing the first sign of fire. After that, the external tank started leaking liquid hydrogen fuel. The liquid hydrogen met with the flame and the liquid oxygen tank, creating a fiery ball in the sky.

The Commission's final conclusion was failure of the joint between the two lower segments of the right SRB. No other element of the space shuttle system was to blame. But were there more than technical issues that contributed to the Challenger accident?

Did You Know?

Many people describe the Challenger accident as an explosion. It sure looked like an explosion with the huge plumes of smoke and fire. In fact, there was no explosion at all, at least not by scientific standards. It was the flood of liquid oxygen and hydrogen that created the huge fireball in the sky.

Space shuttle Challenger disaster. Space shuttle exhaust plumes entwined around a ball of gas after a few seconds after the rupture of the O-rings.
Courtesy of Everett Historical/Shutterstock

The Commission concluded that the failure of the solid-fuel rocket booster seal was due to a flawed design. The Commission focused on a part called an O-ring, *a type of gasket, used in the field joints between each fuel segment of the SRBs*. O-rings are designed to spring back into place after being compressed.

The O-ring design used in Challenger did not take into account a number of factors, such as temperature. Challenger launched on the coldest day (32 degrees to be exact) recorded in the history of all launches. The O-ring simply did not provide a tight enough seal in the cooler temperatures.

The Challenger flight was originally planned to launch on January 20, 1986. It was postponed several times during the eight days that followed, for technical issues and bad weather.

Engineers knew of the O-ring problem from previous flights. They realized it would be most susceptible to failure during the launch at max-Q, *when aerodynamic forces reach their maximum*. The engineers notified NASA management personnel about the problem before Challenger could be approved for launch. Management ignored the problem instead of investigating it.

Did You Know?

The coldest temperature during a launch before Challenger was 52 degrees. That is 20 degrees warmer than the day the Challenger launched.

The Right Stuff

The crew of the Challenger shuttle mission in 1986

The Challenger crew. Left to right are Teacher in Space payload specialist S. Christa Corrigan McAuliffe; payload specialist Gregory Jarvis; and astronauts Judith A. Resnik, mission specialist; Francis R. (Dick) Scobee, mission commander; Ronald E. McNair, mission specialist; Mike J. Smith, pilot; and Ellison S. Onizuka, mission specialist.
Courtesy of NASA

The night before the launch, engineers from the company that manufactured the SRBs also told NASA they were concerned about the problem and wanted to postpone the launch. NASA opposed the delay, so the manufacturer reluctantly approved the flight.

The launch went ahead as scheduled on January 28, 1986. The max-Q point was reached 58 seconds into the launch, but the seal had been damaged and could be seen releasing gases from the right SRB. Aluminum oxides from the burned solid fuel sealed the joint temporarily but not long enough.

Francis R. (Dick) Scobee, Challenger's mission commander, received pilot training through the US Air Force and an aerospace engineering degree from the University of Arizona. After receiving his pilot's wings, Scobee flew a combat tour in Vietnam. With NASA, Scobee piloted the STS-41-C, the fifth orbital flight of the Challenger, prior to Challenger STS-51L.

Michael J. Smith was a commander in the US Navy. He received training through the US Naval Academy and the Naval Postgraduate School. Smith worked as a test pilot for the Navy and was selected as a NASA astronaut and shuttle pilot. Challenger was Smith's first space flight.

Judith A. Resnick received a doctorate in electrical engineering from the University of Maryland and worked in the medical field for several years. She was selected by NASA as a mission specialist. Resnik was the second American woman in orbit on the first flight of Discovery STS-41D.

Ronald E. McNair was also a mission specialist aboard Challenger. He received a doctorate in physics from MIT, with a focus on quantum electronics and laser technology. His work with lasers and satellite communications led to his acceptance into NASA. McNair was the second African American in space on Challenger STS-41B.

Ellison Onizuka was also a mission specialist on Challenger. He received a graduate degree in aerospace engineering from the University of Colorado, where he participated in the Air Force ROTC program. Onizuka served as a flight test engineer, officer, and a chief of engineering at Edwards Air Force Base (AFB). With status as an Air Force officer, Onizuka was selected as a mission specialist for a Department of Defense classified mission.

Gregory B. Jarvis, a payload specialist, received a graduate degree in electrical engineering from Northeastern University. Jarvis worked for Hughes Aircraft Corp.'s Space and Communications, where he was awarded a spot in the astronaut program. He was one of two nongovernment employees aboard Challenger.

S. Christa Corrigan McAuliffe, another nongovernment employee, was the first teacher in space. McAuliffe taught English and social studies at Concord High School in New Hampshire. NASA selected McAuliffe out of 11,000 applicants.

How NASA Changed After the Challenger Accident

President Reagan ordered NASA to put in place the recommendations made in the Commission's report to ensure safety of the shuttle. The report included nine recommendations. With just 30 days to develop a plan, NASA responded.

NASA redesigned the solid rocket booster, replacing the O-rings with rings made of more reliable material. They added an orbiter to spread out the flight schedule of the fleet. The shuttle management structure and communication procedures were improved at all levels. The pre-launch processes and review of shuttle components were made much more stringent and thorough.

In addition, President Reagan created a policy that would forbid NASA from holding the monopoly for launching government satellites. Reagan also opened the doors for the public sector in space by taking NASA out of the commercial launch business for satellites.

NASA spent three years diagnosing and correcting the Space Shuttle Program. In September 1988, the program successfully returned to flight with the launch of Discovery. Some questioned whether it was too soon and if all of the issues from Challenger's accident had been successfully addressed.

The Columbia Accident

On February 1, 2003 at Kennedy Space Center in Cape Canaveral, Florida, a couple of hundred viewers gathered to watch the space shuttle Columbia land after a 16-day mission. The landing was expected to be just another normal landing.

Sadly, just 16 minutes before touchdown, space shuttle Columbia broke apart on its way back to Earth. Hydraulic fluid temperatures and tire pressure went abnormally low. Other sensors failed and then communications with Mission Control were lost. Onlookers in the southwestern United States could see falling debris. Another shuttle and its crew were lost.

An aluminum tank from space shuttle Columbia's STS-107 mission was uncovered in Lake Nacogdoches, Texas after being underwater for eight and half years. It was uncovered when the lake's water level receded during an ongoing drought.
Courtesy of NASA

An investigative group concluded that a large piece of foam broke off from the shuttle's external tank and breached the spacecraft wing during lift off. NASA had to conduct one of the largest land searches in American history, as debris was scattered all over east Texas.

After several months of debris retrieval and analysis, the Columbia Accident Investigation Board (CAIB) confirmed that faulty design was the technical cause. Instead of O-rings, this time it was the foam insulation. The damage from the foam striking the wing led to almost immediate breakup of the orbiter upon re-entry. When the crew module separated from the fuselage, the module immediately depressurized.

Just as NASA's management was held largely responsible for ignoring warnings about Challenger's O-rings, the same accusations were made about the Columbia disaster. In previous flights, similar but smaller pieces of foam had detached. They were much more numerous but smaller in size.

NASA did not identify the detached pieces of foam as a flight safety issue, despite engineering requirements stating that nothing should impact the shuttle during launch. NASA simply did not address the possibility of a larger piece hitting a vulnerable area like a wing.

As with Challenger, NASA management did not listen to its engineers, who were concerned that the landing gear could be damaged by such an impact. The engineers had requested the use of imaging satellites to view any damage to the landing gear. This equipment could help them take additional measures to ensure a safe landing.

Approximately 80 to 84 seconds after liftoff of space shuttle Columbia, a large piece of debris is observed striking the underside of the left wing.
Courtesy of NASA

Senior managers said there was no need for such information and did not approve the request. If approved, NASA would have had to redesign some of the instruments.

How NASA Changed After the Columbia Accident

As mentioned, the CAIB confirmed that faulty design was the technical cause of the Columbia accident. Once again, NASA responded with several changes.

NASA redesigned the orbiter's heat shield to minimize the loss of foam. Pre-launch inspection procedures were improved as well. NASA also created the Technical Engineering Authority to evaluate control hazards within the shuttle system. Video cameras, radar, and sensors mounted throughout the main systems were added.

As a result of the Challenger and Columbia accidents, NASA has much-improved protocol for rapid responses to serious events. For the future of space missions, NASA and the private sector will continue to improve spacecraft design and reduce the risk of future accidents.

The Right Stuff

The crew of the Columbia STS-107

Seated in front, from left, are astronauts Rick D. Husband, mission commander; Kalpana Chawla, mission specialist; and William C. McCool, pilot. Standing, from left, are David M. Brown, Laurel B. Clark, and Michael P. Anderson, all mission specialists; and Ilan Ramon, payload specialist, representing the Israeli Space Agency.

Courtesy of NASA

Rick D. Husband, Columbia's mission commander, received a graduate degree in mechanical engineering from California State University and pilot training at Vance AFB. After receiving his pilot's wings, Husband served as a test pilot in the US and in England with the Royal Air Force. With NASA, he was a pilot on Discovery STS-96, during which the first docking with the ISS was completed.

William C. McCool was pilot of Columbia. He received a graduate degree in aeronautical engineering from the Naval Postgraduate School, where he also completed Test Pilot School (TPS). After TPS and two years of NASA training, McCool was selected for flight assignment as a pilot. Columbia was McCool's first space flight.

David M. Brown received a doctorate in medicine from Eastern Virginia Medical School and worked as a US Navy flight surgeon. He was the only surgeon in over a decade to be selected for pilot training. He was selected by NASA as a mission specialist. Columbia was Brown's first space flight.

Laurel Blair Salton Clark was also a mission specialist aboard Columbia. She received a doctorate in medicine from University of Wisconsin, with a focus on pediatrics. She also served on the Navy's Diving Medicine Department as an Undersea Medical Officer and later as a Submarine Medical Officer, and Naval Flight Surgeon. Columbia was her only space flight.

Michael P. Anderson received a graduate degree in physics from the Creighton University and was commissioned as a second lieutenant. After pilot training at Vance AFB, he served as an aircraft commander, instructor pilot, and tactics officer. He was selected by NASA as a mission specialist. With NASA, Anderson also flew on the STS-89 Endeavor mission, prior to Columbia.

Kalpana Chawla, a mission specialist, received a doctorate in aerospace engineering from the University of Colorado. Chawla performed complex technical research related to EVA and robotics. She flew on STS-87 Columbia, prior to STS-107 Columbia.

Ilan Ramon, an Israeli Air Force fighter pilot and colonel, served as a payload specialist on Columbia. He received degrees in electronics and computer engineering from the University of Tel Aviv. Columbia was Ramon's only space flight.

✔ CHECKPOINTS

Lesson 2 Review

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

1. What were the three phases of Project Mercury?
2. What were the three main goals for Project Gemini?
3. Which Apollo mission was the first successful mission to the Moon?
4. What did the Apollo 13 mission demonstrate to America?
5. In what ways did Columbia's first mission achieve NASA's vision for the Space Shuttle Program?
6. What were some of the accomplishments of the Discovery space shuttle?
7. What is one major achievement of either shuttle Atlantis or Endeavor?
8. Is there a difference between a space shuttle and an orbiter? Explain.
9. What role do SRBs play in getting a shuttle off the ground?
10. What do the SSMEs do after the initial launch?
11. What were the technical causes of the Challenger accident?
12. What design changes did NASA put in place in response to the Commission's report on the Challenger accident?
13. What were the technical causes of the Columbia accident?

APPLYING YOUR LEARNING

14. How have the Challenger and Columbia tragedies changed NASA operations?