# CHAPTER 7


On 12 April 1981 *Columbia* blasts into space for the first time. The space shuttle made 36 orbits around Earth. It was the first of five orbiters to fly into space.
*Courtesy of NASA*

# The Space Shuttle

## Chapter Outline

LESSON 1 The Shuttle Program

LESSON 2 Lessons Learned: *Challenger* and *Columbia*

"Whether outwardly or inwardly, whether in space or time, the farther we penetrate the unknown, the vaster and more marvelous it becomes."

*Charles Lindbergh,* Autobiography of Values

# LESSON 1 The Shuttle Program

## Quick Write

Imagine you were one of the astronauts aboard *Endeavour*. What about the mission would be of most concern or interest to you?

## Learn About

- why the space shuttle was developed
- the space shuttle's main features
- the shuttle's legacy

On 2 December 1993 space shuttle *Endeavour* launched on an 11-day mission to repair the defective Hubble Space Telescope. Faulty optics meant that the scope's performance fell far short of what astronomers had hoped for. The telescope's primary mirror was shaped incorrectly, and so it could not focus all the light from an object to a single sharp point. Instead, Hubble "saw" everything with a halo around it.

Although NASA developed computer software that significantly improved Hubble's focus, a very difficult and complex repair mission seemed the only way to fully correct the situation. NASA had designed Hubble in such a way that astronauts could service it while it remained in orbit. But not everyone was convinced that NASA was up to the job. NASA's reputation was on the line.

*Endeavour*'s mission, known by its NASA designation as STS-61, was one of the most sophisticated in the shuttle's history. This was the first mission ever having five spacewalks. One of these lasted nearly eight hours, the second-longest spacewalk in history.

On flight day No. 2 *Endeavour* began a series of engine burns to let the shuttle close in on Hubble, in orbit high above the Earth. With each 95-minute orbit, *Endeavour* came about 70 miles closer to Hubble. Finally *Endeavour* got close enough that commander Richard O. Covey could maneuver it manually to within 30 feet of the Hubble. Then Claude Nicollier, a mission specialist, used *Endeavour*'s robot arm to grab the telescope and pull it into the shuttle's cargo bay.

*Endeavour*'s crew spent five days tuning Hubble up. They installed two devices that compensated for the incorrect shape of Hubble's primary mirror.

The astronauts also replaced the telescope's solar arrays, which collect energy from the Sun to power Hubble. The old arrays wobbled too much during the stressful transitions from cold darkness to bright warmth and back again as Hubble orbits. The new arrays are steadier. The crew also replaced defective gyroscopes—*a device with a spinning wheel at its center that helps objects retain their balance*—and other electronic equipment.

Hubble's improved vision soon led to a string of remarkable discoveries. And STS-61 also proved that "on-orbit servicing" could be an effective way to keep a valuable scientific instrument in shape.

### Vocabulary

- gyroscope
- aft
- foreign national

Three engine test stands pop up above a thick fog at NASA's Stennis Space Center in Mississippi. In many ways these test stands symbolize where space exploration—old and new—begins. They are not only where the space agency tested the *Saturn V* rockets for the Apollo program, but they are where engineers have tested the space shuttle program's main engines as well. The space shuttle began as part of a larger vision at NASA for what to do after the country had reached the Moon.

*Courtesy of NASA/SSC/Allen Forsman, Pratt and Whitney Rocketdyne*



## Why the Space Shuttle Was Developed

Putting astronauts on the Moon was a dramatic achievement. But it wasn't clear what NASA would do for an encore. The *Apollo 11* lunar landing had come only a few brief years after President Kennedy's ringing call to make the race for the Moon.

America's political and economic environment changed vividly over those years. Kennedy himself was assassinated in 1963. His successor, Lyndon Johnson, soon had his hands full with his ambitious War on Poverty. Not long after, the costs and domestic political turmoil of the Vietnam War would consume his presidency. When Richard Nixon took office as the next president, he had little appetite for anything like another Project Apollo. He called for cutting NASA's budget as sharply as was politically feasible.

### The Original Concept of the Shuttle

The space shuttle began as part of a larger vision at NASA for what to do after the country had reached the Moon. After the lunar landings, according to this vision, the next step would be the construction of a series of ever-larger space stations circling Earth, holding up to 100 people at one time. Then would come space stations circling the Moon, and then lunar bases to be used as a staging ground for the exploration of Mars.

The idea of a space shuttle, a vehicle that would take crews and supplies to low-Earth orbit, grew out of this vision. And to save money, NASA planned to develop a fully reusable spacecraft.

But the concept of a shuttle cruising to space stations ran afoul of political realities. With budget cuts hitting the agency, NASA placed its space station program on hold. It canceled further production of the *Saturn V* rockets, which had lifted the *Apollo* modules into space. This left NASA with the space shuttle as the only manned spaceflight program it could hope to undertake. But what would the shuttle do if it weren't ferrying people and parts to orbiting construction sites?

NASA needed a new rationale for the shuttle. That rationale emerged from three intense years of technical study and budget negotiations. These discussions tried to reconcile the conflicting interests of NASA, the Department of Defense, and the White House.

NASA managed to win approval from the White House by attempting to meet certain terms. The shuttle had to be reusable. It had to be capable of delivering private and government satellites to space (the Department of Defense was particularly interested in this ability). And it also had to carry out repair missions on satellites. NASA ingenuity met many of these demands.

## The Original Six Orbiters

"Orbiter" is NASA's term for what most people think of as "the space shuttle." It's the space plane with the distinctive wings that rides into space with the help of a couple of rockets and an enormous fuel tank.

The first orbiter NASA and its contractors built was the *Enterprise*. It was a test aircraft that flew but lacked systems to go into space. NASA used it, however, for approach and landing tests and several launch pad studies in the late 1970s.


*Enterprise*, a test model for the space shuttles to follow, takes a test run atop the 747 shuttle carrier aircraft (SCA). During early trials in the shuttle program, the SCA would take off and land with the shuttle on its back. During later checks, such as this one in 1977, the shuttle would release from the SCA's back around 19,000 feet to 26,000 feet altitude to glide without power back to Edwards Air Force Base. *Enterprise* never went into space.

*Courtesy of NASA/DRFC*

*Columbia* was the first actual space shuttle orbiter delivered to NASA's Kennedy Space Center in Florida in March 1979. It was the heaviest of the orbiters. Its role was somewhat limited during its years of service. It weighed too much and lacked the equipment needed to help assemble the International Space Station. But *Columbia* achieved a number of notable "firsts" in spaceflight, including flying the first orbiter mission in space.

*Challenger* started out as just a test vehicle for the space program. But it eventually made it into space. NASA wanted a lighter-weight orbiter than *Columbia*. Once the agency had a lighter airframe design, it needed a test vehicle to make sure the new design could handle the stress of spaceflight. Computer modeling software wasn't advanced enough at the time to be of much help in this. And so the best test NASA engineers could come up with was to submit the vehicle to a year of intense vibration and heat exposure.

By early 1979 NASA decided that the lighter airframe had passed the test. Making *Challenger* spaceworthy was a big job. It involved taking apart and replacing many parts and components. But in July 1982 *Challenger* arrived at the Kennedy Space Center, as the second space-rated orbiter in the fleet.

The third spaceworthy orbiter was *Discovery*. It arrived for the first time in Florida in November 1983. NASA launched it on its first mission, to deploy three communications satellites, on 30 August 1984. *Discovery* can claim the distinction of flying more than 30 successful missions. That's more than any other orbiter. *Discovery*'s notable missions have included the launch of the Hubble Space Telescope in April 1990 and the second and third missions to service Hubble, in February 1997 and December 1999.

Next came *Atlantis*. Its construction began on 3 March 1980. Thanks to lessons learned from building and testing the earlier orbiters, construction of *Atlantis* took only about half as many person-hours as were spent on *Columbia*. This was largely because *Atlantis* had large thermal protection blankets wrapped around its upper body rather than individual tiles. Those tiles had caused problems from the start.

*Atlantis* was also nearly 3.5 tons lighter than *Columbia*. The fourth orbiter arrived at the Kennedy Space Center on 9 April 1985 to prepare for its first flight. On that first spaceflight, launched 3 October 1985, it carried a classified payload for the Department of Defense. *Atlantis* later carried four more Defense payloads.

*Endeavour* was authorized by Congress to replace *Challenger*, lost in an accident in 1986. (You will read about that in the next lesson.) *Endeavour* arrived at the Kennedy Space Center on 7 May 1991, piggybacked atop NASA's new space shuttle carrier. It lifted off exactly a year later, on 7 May 1992. One of its primary objectives on that mission was to retrieve and repair a communications satellite that was still orbiting but no longer functioning.

The shuttle wasn't expressly designed for this mission. But *Endeavour* succeeded anyway, after four spacewalks, including the longest one in history up to that time, lasting more than eight hours.

### The Shuttles' 'Enterprising' Names

*Enterprise*, the first space shuttle orbiter, was originally going to take the name *Constitution*. But fans of the popular show *Star Trek* campaigned to have the orbiter named for the spaceship that figures in the television series. NASA named all its other space shuttles after famous sailing ships, each with a role in exploration.

- *Columbia* got its name from a sailing frigate—one of the first that the US Navy sent around the globe—that launched in 1836.
- *Challenger* took its inspiration from a Navy ship of the same name that spent four years—from 1872 to 1876—exploring the Atlantic and Pacific oceans.
- *Discovery* had two famous namesakes. One was Henry Hudson's ship in which the famous explorer looked for a northwest passage from 1610–1611. He ended up finding the bay now named for him, Hudson Bay. The other famous early *Discovery* was the ship in which the eighteenth-century British explorer Captain James Cook discovered the Hawaiian Islands.
- *Atlantis*'s namesake was a twentieth-century exploring ship, a two-masted ketch, sailed by the Woods Hole Oceanographic Institution of Massachusetts from 1930 to 1966. It covered more than half a million miles conducting ocean research.
- *Endeavour* took its name from another of Captain Cook's ships.

## The Shuttle's First Mission

*Columbia* was the first of the space shuttles to go into outer space. NASA launched that first mission, designated as STS-1, on 12 April 1981. Captain John W. Young, a veteran of the Gemini and Apollo programs, was the commander. Robert L. Crippen was the pilot.

On this maiden voyage the goals were to check out the overall system, ascend safely into orbit, and return safely to Earth. NASA was confident that the shuttle met these objectives. Officials decided that the shuttle was spaceworthy. The spacecraft had only one payload—a package of sensors and measuring devices to track the orbiter's performance and record stresses that occurred at each step of the flight.

Post-flight inspection of the *Columbia* revealed that the ship had lost 16 heat-shield tiles and that an additional 148 had been damaged. In all other respects, however, *Columbia* came through with flying colors.

After orbiting Earth 36 times, *Columbia* landed on a dry lakebed runway at Edwards Air Force Base in California. The ship made three more research missions to test its performance. Its first operational mission, with a four-man crew, was STS-5, launched on 11 November 1982.

**Star POINTS**

NASA launched *Columbia* on its first flight on the 20th anniversary of Yuri Gagarin's first flight into space in 1961.

*Columbia* blasts into space for the first time on 12 April 1981. The shuttle was the first of five orbiters to go into outer space.

Courtesy of NASA



## Numbering Shuttle Flights

NASA designates individual shuttle missions (flights) with numbers beginning with the initials STS, short for "space transportation system." *Columbia*'s first mission, for instance, was STS-1.

Following STS-9, NASA changed the flight numbering system for space shuttle missions. Thus, the next flight, instead of being designated STS-10, became STS 41-B. The new numbering system was designed to be more specific in that the first numeral stood for the fiscal year in which the launch was to take place, the "4" being 1984. The second numeral represented the launch site "1" for the Kennedy Space Center and "2" for Vandenberg AFB, California. The letter represented the order of launch assignment—"B" was the second launch scheduled in that fiscal year. After the *Challenger* accident, NASA reestablished the original numerical numbering system. Thus the first flight following STS-51-L is STS-26.

## The Space Shuttle's Main Features

The space shuttle is not only the world's first reusable spacecraft. It's also the first spacecraft that can carry large satellites into orbit, and then retrieve them. The shuttle is launched like a rocket, maneuvers in orbit like a spacecraft, and lands like an airplane.

### The Orbiter

As noted earlier, the orbiter is what many people think of as "the space shuttle." Actually, the orbiter is but one element in the space shuttle or "space transportation system." But it's both the brains and the heart of the shuttle. It contains a pressurized crew compartment, which can carry up to eight people, a huge cargo bay, and three engines mounted **aft**—*the rear of a spacecraft or any other ship*.

The orbiter is boosted into space partly on the strength of those engines—but mostly on the power of the solid rocket boosters (SRBs). You'll read more about them shortly.

NASA likes to describe the orbiter as comparable in size and weight to the DC-9—a workhorse civilian jetliner long in use for short- to mid-length passenger flights. In other words, the orbiter is a good-sized aircraft, much bigger than the *Mercury* capsules that Navy helicopters plucked from the sea. On the other hand, the orbiter is much smaller than big long-haul aircraft such as the Boeing 747 "jumbo jet."


*Discovery* lifts off on 12 September 1993 for STS-51 from the Kennedy Space Center in Florida. This image offers great views of all the elements working together: the orbiter with main engines firing, the external tank (the tallest element in the photo painted a rust color), and the solid rocket boosters giving off the brightest glow at their base. But the orbiter is what many people think of as "the space shuttle."
*Courtesy of NASA*

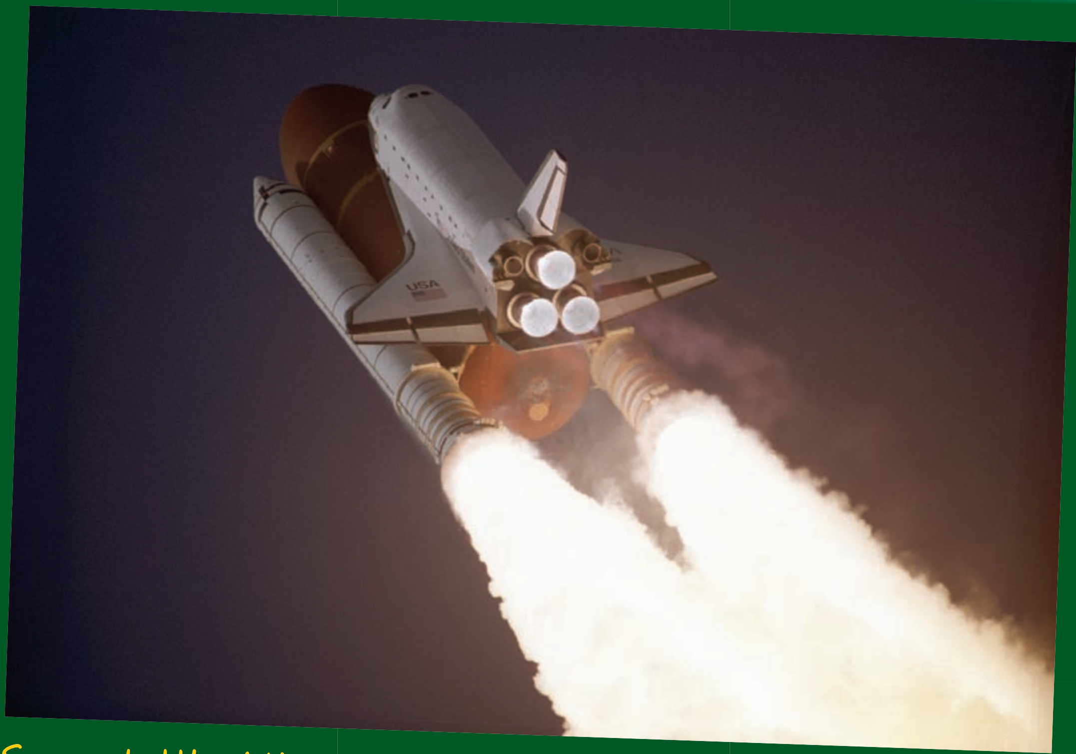
Unit 3: Manned and Unmanned Spaceflight

## The Shuttle's Main Engines

The shuttle has three main engines. These are known in NASA-speak as Space Shuttle Main Engines, or SSMEs. These engines combine with the boosters to get the shuttle off the ground in the initial ascent. They operate for 8.5 minutes after launch.

After the shuttle jettisons its boosters, the engines provide thrust—that is, they push the shuttle forward. This accelerates the shuttle from 3,000 mph (4,828 km per hour) to 17,000 mph (more than 27,358 km per hour) in just six minutes to reach orbit. The engines create a combined maximum thrust of more than 1.2 million pounds.

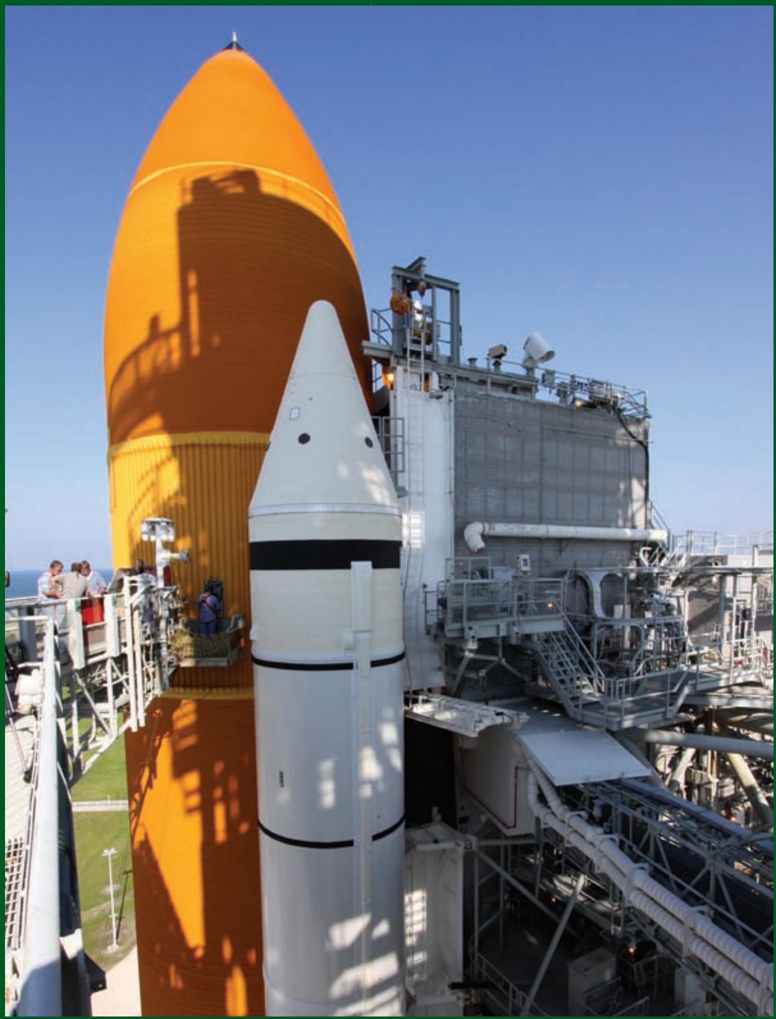
During this acceleration, the engines burn through half a million gallons of liquid propellant. The propellant consists of liquid oxygen and liquid hydrogen.



**Space shuttle *Atlantis* takes off from Kennedy Space Center in Florida on 2 December 1988.**

While the rocket boosters give off the most dramatic flames, the space shuttle's three main engines (in a triangle of fainter glows at the shuttle's base) are nonetheless giving off 375,000 pounds of thrust. The main engines operate for 8.5 minutes after launch.

*Courtesy of NASA*



Workers remove a seal from the external tank (in orange) to more closely inspect the external tank after NASA had to cancel two launches due to a hydrogen leak. Attached to the tank is one of the solid rocket boosters (in white with the black stripes). The external tank is the only one of the shuttle's components that is not reused.
*Courtesy of NASA/Jack Pfaller*

## The External Tank and the Solid Rocket Boosters

The shuttle's three main engines get their propellants from the huge rust-colored external tank (ET). It's the only one of the shuttle's components that is not reused. Rather, at each shuttle launch, the fuel tank burns up in the Earth's atmosphere.

The solid rocket boosters (SRBs), on the other hand, are reusable. They are the largest solid-propellant motors ever flown. And they are the first designed for reuse. Each is nearly 150 feet long and a little more than 12 feet in diameter.

The SRBs provide most of the power for the first two minutes of a shuttle flight. At launch, their weight is about 1.3 million pounds apiece. Most of that is fuel. Once they have spent their fuel, the empty boosters fall away into the Atlantic Ocean, about 140 miles off Florida's east coast.

### *Star* POINTS

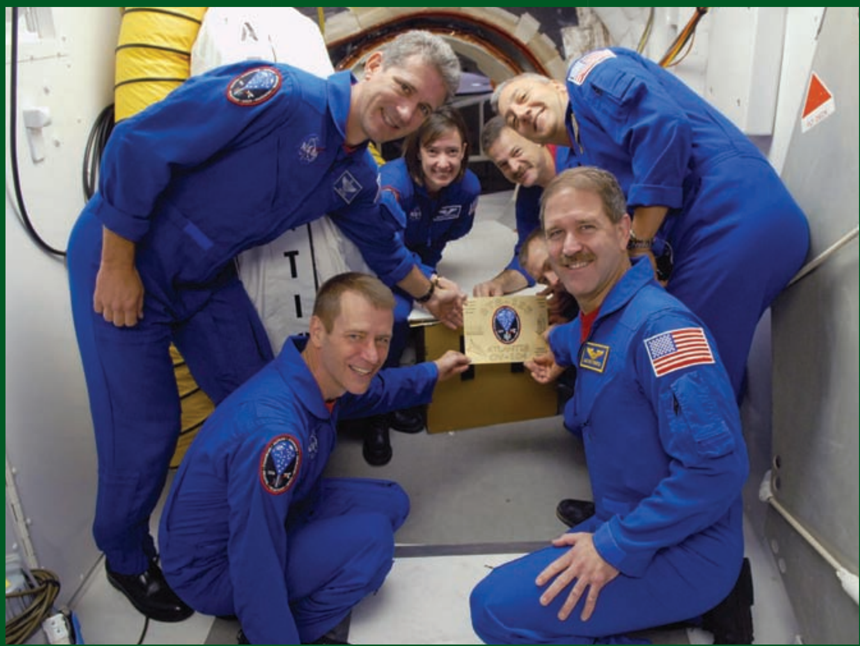
Each individual parachute in the main chute cluster that slows the shuttle booster rockets' return to Earth can withstand a load of 180,000 pounds and weighs 2,180 pounds.

Enormous parachutes slow their journey, but the spent boosters typically hit the water a little less than five minutes after separation. They are equipped with radio beacons and flashing lights. Once the recovery crew locates the boosters, they tow them back to the launch site for cleaning up and refurbishing for a future launch.

## The Shuttle Crew Positions

In Chapter 5 Lesson 2, you read about the different types of astronauts. The crews of space shuttle missions range from five to seven people. They vary according to different mission objectives. But the crew members fall into the same classifications that you read about earlier.

***Mission commanders*** come from the ranks of the pilot astronauts. The commander is the ship's captain, so to speak, with overall responsibility for the orbiter, the crew, mission success, and safety. A ***mission pilot*** helps control and fly the ship, and may also help with tasks such as deploying or retrieving satellites. Astronauts typically accomplish these tasks with the shuttle's robotic arm.



*Atlantis* STS-125 crew members are about to add their mission logo to the spacecraft's entrance. The 2009 mission's members are (*clockwise from left front*) pilot Gregory C. Johnson, mission specialists Michael Good and Megan McArthur, commander Scott Altman, and mission specialists Mike Massimino and John Grunsfeld.

*Courtesy of NASA/Cory Huston*

***Mission specialists*** are the astronauts who plan, coordinate, and manage the mission's activities. They don't actually fly the ship. But NASA fully trains them in the details of all the onboard systems. They have the lead role in EVAs, or spacewalks, and in operating the robotic manipulator system. They are also responsible for payloads and specific experiments.

If the demands of a given mission require, its crew may also include one or more ***payload specialists***. As the name suggests, the focus of these crew members is on specific payloads—a scientific experiment, for instance. Foreign nationals fly aboard the shuttle as payload specialists, but not as mission specialists or pilot astronauts. (A foreign national is *someone who owes allegiance to a foreign country*—someone not a US citizen, in other words.)

## The Shuttle's Legacy

As of this writing in early 2010, NASA plans to shutter its space shuttle program with five final flights the same year. It all depends on whether the numerous space agencies working on the International Space Station can complete construction of the orbiting lab by that time. All five final shuttle flights support this goal. Only three shuttles are still in use: *Discovery*, *Atlantis*, and *Endeavour*. NASA has scheduled *Discovery* to make the final flight in September 2010.

For nearly 30 years, NASA's space shuttles have served as the foundation for the human-spaceflight program in the United States. The shuttles represented a leap in thinking about rockets—reusing significant parts.

True, the shuttles couldn't lift as much mass into space as NASA's old Saturn V rocket. But their spacious cargo bays allowed scientists to envision, build, and use space-based observatories such as the Hubble Space Telescope and the Spitzer Space Telescope. These are giving humanity new views of the vast cosmos it inhabits.

The shuttles also paved the way for a new, higher level of global cooperation in space. This was first hinted at by the *Apollo-Soyuz* mission. It resumed modestly with the first flight in 1983 of *Spacelab*, a space-station-like laboratory built in Germany. *Spacelab* fit into *Columbia*'s cargo bay. It provided astronaut-scientists inside with a comfortable environment for conducting experiments in microgravity. It was a foretaste of what would come with the International Space Station, now on orbit. Major components of the station have come from Europe, Japan, Canada, and Russia, as well as the US. Astronauts who serve on the space station come from these and other countries. (You'll read more about space stations in Chapter 8.)

But perhaps the shuttle program's most important legacy is its reminder that human spaceflight must always be treated with respect. One successful launch after another made shuttle flights look routine, almost easy. The loss of *Challenger* and its crew in 1986 and the loss of *Columbia* and its crew in 2003 emphasized while space exploration is exciting, it also is risky. The next lesson will review what NASA learned from those accidents.

Xenon lights and lightning dramatically draw attention to Launch Pad 39A at NASA's Kennedy Space Center in Florida.

The bad weather delayed a *Discovery* launch in 2009 for a few days. NASA has many missions ahead for its astronauts that include the Moon and, perhaps one day, Mars.

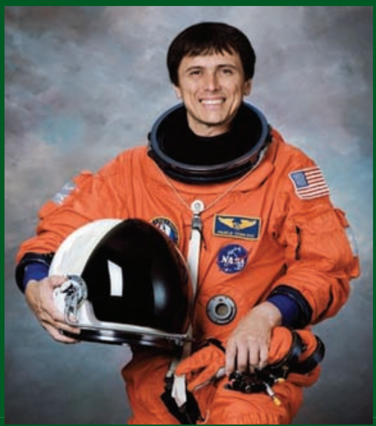
*Courtesy of NASA/Ben Cooper*

## Shuttle Firsts

**Guion S. Bluford Jr.** has the distinction of being the first African-American in space. He was a mission specialist aboard STS-8 in August-September 1983. It was *Challenger*'s third mission and the shuttle program's first nighttime launch and landing.

Guion S. Bluford Jr., the first African-American in space, exercises on a treadmill on *Challenger*'s mid-deck.

*Courtesy of NASA*



Franklin Chiang-Diaz was the first Hispanic American to fly in space.

*Courtesy of NASA*

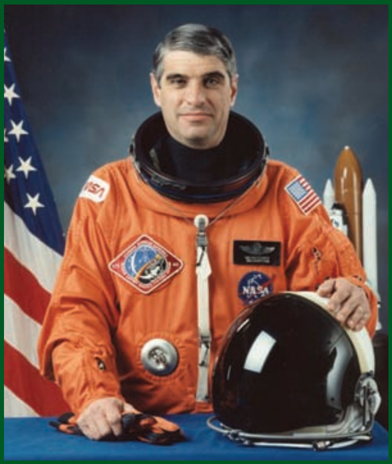
**Franklin Chiang-Diaz** was the first Hispanic American to fly in space. He first flew on STS-61-C and flew on seven flights in all, logging more than 1,601 hours in space. This included 19 hours and 31 minutes in three space walks. Holder of a doctorate in applied plasma physics, he served from 1993 to 2005 as director of the Advanced Space Propulsion Laboratory at the Johnson Space Center in Houston, Texas.

US Air Force Col **Eileen M. Collins** was the first woman shuttle pilot. On her first mission, STS-63, in February 1995, she piloted the *Discovery* on the first flight of the new joint Russian-American space program. She flew three more missions after that. On her third, in July 1999, she made history again as the shuttle's first woman commander. On her fourth and final shuttle mission in July 2005, she commanded STS-114 as well. This was celebrated as the "return to flight" mission after the loss of the orbiter *Columbia*. (You'll read more about that in the next lesson.)

Col Eileen M. Collins was the shuttle program's first woman pilot and commander.

*Courtesy of NASA/Robert Markowitz*

Col **Sidney Gutierrez** was the first Hispanic shuttle pilot. A native of New Mexico and a US Air Force Academy graduate, he made two shuttle flights. On the first, STS-40, in June 1991, he was the pilot. On the second, STS-59, he was the spacecraft commander. After his first flight, he served as spacecraft communicator, or CAPCOM, for several shuttle missions. This is a crucial role—the voice link between the flight crew and Mission Control during a mission.

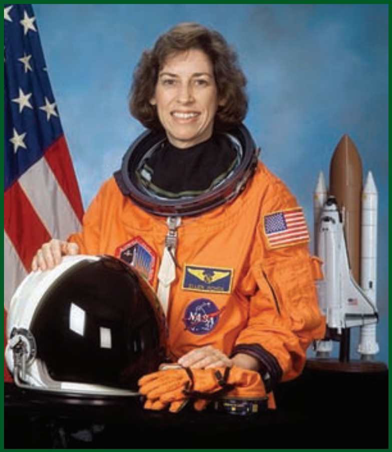


Col Sidney Gutierrez, posing for his official NASA photo in his launch and reentry suit, was the first Hispanic shuttle pilot.
*Courtesy of NASA*

In 1992 Dr. Mae Jemison, the first African-American woman in space, served as science mission specialist during STS-47.
*Courtesy of NASA*

**Dr. Mae Jemison** was the first African-American woman in space. A physician who also has a background in engineering, she was the science mission specialist on STS-47 in September 1992. This was a joint mission with the Japanese space agency.

**Dr. Ellen Ochoa** was the first Hispanic woman in space. A native Californian, she is a veteran of four spaceflights, starting with STS-56 in 1993, on which she was a mission specialist. She holds a doctorate in electrical engineering from Stanford University and is as of this writing deputy director of the Johnson Space Center in Houston, Texas.



Dr. Ellen Ochoa was the first Hispanic woman in space.
*Courtesy of NASA*

The first Asian-American in space was Col **Ellison Onizuka**. A native of Hawaii, he was also an Air Force officer with two degrees in aerospace engineering from the University of Colorado. In January 1985 he was a mission specialist on STS-51C, the space shuttle's first Defense Department mission. The next year he was a mission specialist aboard *Challenger*. He died along with his crewmates when their ship blew up shortly after launch. Onizuka was posthumously promoted to colonel and awarded the Congressional Space Medal of Honor.

Col Ellison Onizuka was NASA's first Asian-American in space. He died during his second mission when the space shuttle *Challenger* blew up shortly after launch.

*Courtesy of NASA*

Dr. Sally K. Ride floats on *Challenger*'s mid-deck during STS-7.

*Courtesy of NASA*

**Dr. Sally K. Ride** was the first American woman in space. A physicist by training, she was part of the STS-7 crew in June 1983. This was *Challenger*'s second mission.

Unit 3: Manned and Unmanned Spaceflight


Commander John W. Young (left) and pilot Robert L. Crippen pose with a model of *Columbia*. Each marked a first in spaceflight: Young was the first space shuttle commander, and Crippen was the first shuttle pilot.
*Courtesy of NASA*

**John W. Young** was the first space shuttle commander. He was already an experienced astronaut when he took off on STS-1, in the orbiter *Columbia*, in April 1981. It was his fifth spaceflight. **Robert L. Crippen** was the first shuttle pilot. His 36-orbit mission with Young was a shakedown cruise, meant to test out the new shuttle's performance. *Columbia* was the first winged reentry vehicle to return from space to a runway landing.

## CHECK POINTS

### Lesson 1 Review

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

1. The space shuttle began as part of what larger vision?
2. How did *Atlantis* benefit from lessons learned in construction of earlier orbiters?
3. What problem did post-flight inspection of *Columbia* identify?
4. The orbiter is comparable to what familiar civilian aircraft? In what way?
5. How much fuel do the shuttle's engines burn during acceleration? What kind of fuel is it?
6. What is unique about the shuttle's external tank?
7. When foreign nationals fly on shuttle missions, what is their role?
8. Who was the first shuttle commander? The first American woman in space? The first African-American in space?

## APPLYING YOUR LEARNING

9. Do you think it is important for the space program to have a specific goal, such as going to the Moon or building a space station? Why or why not?