

# TO **BOLDLY** GO

The space shuttle program has had a remarkable run that has spanned more than three decades and helped shape many Boeing careers

*By Bill Seil*

The space shuttle and its essential role in the assembly of the International Space Station have defined the Space Age for a full generation.

The first shuttle to orbit Earth, *Columbia*, was launched 30 years ago, on April 12, 1981. When *Atlantis* makes the final shuttle flight, tentatively scheduled for July, it will mark the end of a remarkable chapter in the history of space exploration and discovery—one that Boeing and its heritage companies helped write.

While lacking a dazzling climactic moment of success, such as the Apollo 11 moon landing, the space shuttle has gradually and forcefully transformed the ability of humans to live, build and respond to challenges in space. It has also set the stage for future lunar and interplanetary missions.

John Mulholland, vice president and program manager, Boeing Space Shuttle

***“It’s going to go down as a remarkable achievement and its legacy will be very strong. It’s been inspirational to the nation, and its success has made an enormous contribution to our future in space.”***

*— John Mulholland, vice president and program manager, Boeing Space Shuttle Program*

**PHOTO:** *Columbia* lifts off from Kennedy Space Center on the first shuttle flight into space in April 1981. NASA



Program, said the shuttle has revolutionized human access to space. It has also created an important base of knowledge, he noted, in moving forward on programs such as Commercial Crew transportation and, eventually, exploration beyond low Earth orbit.

“The beautiful thing about the shuttle is its unique combination of crew and cargo access,” Mulholland said. “On mission after mission, it has demonstrated that human beings can perform tasks that can’t be done by robotics. The repair of the Hubble Space Telescope is a good example.”

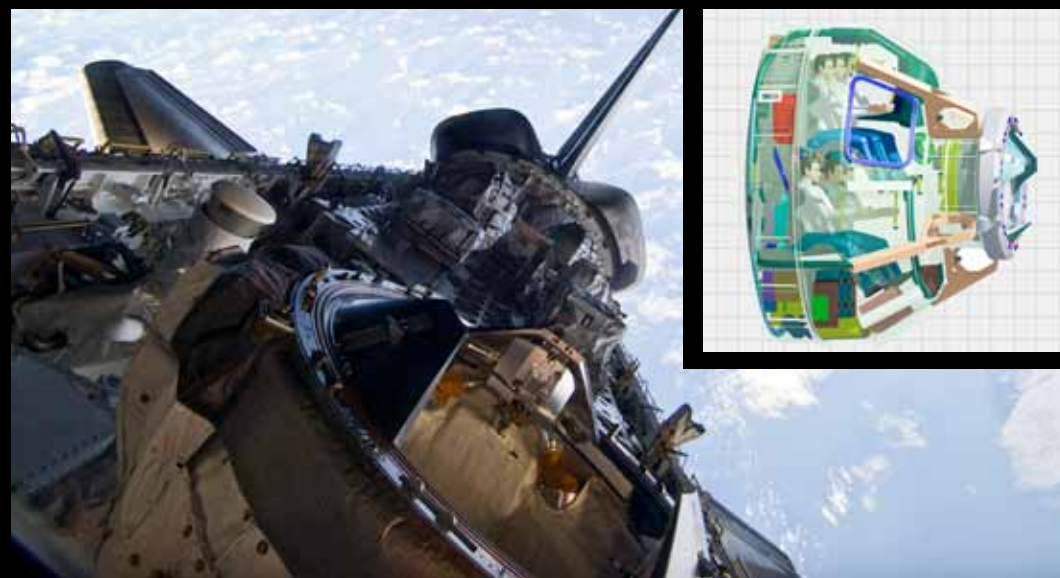
Boeing is well-positioned to take a leadership role in both near-term and long-term space exploration, Mulholland said. In the near term, the International Space Station, or ISS, for which Boeing is the prime contractor, has years of useful service ahead. Boeing also is competing to build the Commercial Crew vehicle for NASA, which will transport astronauts to and from the ISS and other low Earth orbit destinations.

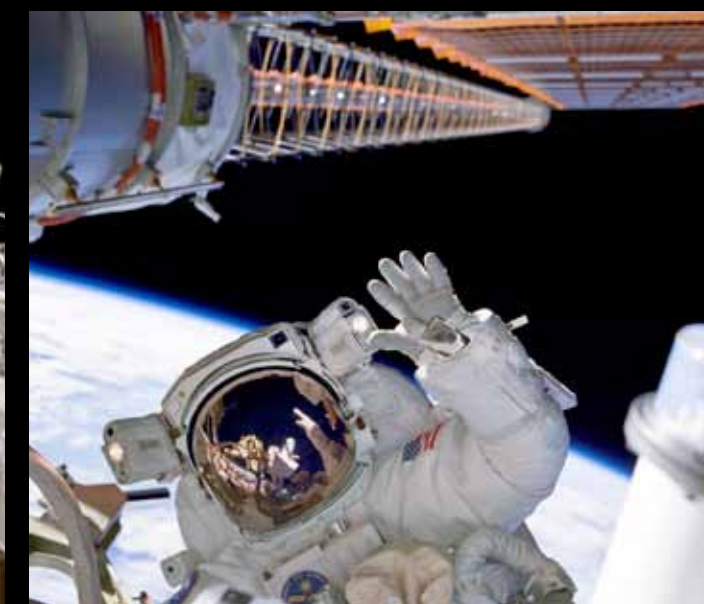
Mike Burghardt, manager of spacecraft development for Commercial Crew, said Boeing’s design would accommodate up to seven crew members and would be compatible with a variety of expendable launch vehicles. Depending on NASA’s final schedule, it could be ready to fly as early as 2015.

“In some respects, it’s similar to the Apollo command and service modules, which were built by Boeing legacy company North American Rockwell,” Burghardt said. “But unlike Apollo, the Commercial

**PHOTOS: (Right)** *Atlantis* is docked to the International Space Station on a mission in May 2010 to install a Russian-built compartment named *Rassvet*, or Dawn, which is visible in the shuttle’s cargo bay.

**(Insets, from left)** The payload bay, vertical stabilizer and other features of *Atlantis* are captured in this photo taken by a crew member during the STS-129 mission to the space station in November 2009; a drawing of Boeing’s Commercial Crew vehicle that could one day carry astronauts to the space station. NASA





**PHOTOS: (Far left)** Astronaut Story Musgrave stands on the end of *Endeavour's* robotic arm during the first servicing mission for the Hubble Space Telescope in 1993. Fellow astronaut Jeffrey Hoffman is inside the shuttle's payload bay.

**(Insets, from top)** *Endeavour*, with its cargo bay doors open and robotic arm partially extended, is shown above Earth during the STS-126 mission in November 2008, bringing supplies and equipment to the International Space Station; mission specialist Carlos Noriega waves during a spacewalk on STS-97, the sixth construction flight to the International Space Station, installing a truss segment that included a solar array. NASA

Crew spacecraft will be reusable and carry a larger crew."

In addition to working on Commercial Crew, Burghardt was part of the space shuttle team from 1987 until early 2010. He has mixed feelings about the shuttle program winding down. The shuttle was a magnificent vehicle with enormous capabilities, Burghardt said, but he's excited about moving forward in developing new spacecraft.

Development of the space shuttle began in July 1972 when the National Aeronautics and Space Administration (NASA) awarded North American Rockwell the contract to build the first shuttle orbiter. Rockwell (which became Rockwell International the following year) went on to build the rest of the shuttle fleet. The shuttle program became part of The Boeing Company in 1996 when Boeing purchased Rockwell International's aerospace and defense assets.

Construction of the space station was the shuttle's most important accomplishment, but it completed many other complex assignments over the past three decades. Hubble, which the shuttle deployed on orbit in 1990, was a particularly delicate payload. The shuttle has also launched interplanetary space probes, such as the Galileo spacecraft, which was attached to a Boeing-developed Inertial Upper Stage with enough fuel to propel it on a gravity-assisted six-year trip to Jupiter.

The shuttle, in addition to launching satellites from its cargo bay, captured and repaired existing satellites that had failed in orbit. In some cases,

satellites were captured and returned to Earth for more complex repairs. The shuttle also hosted a number of scientific experiments that required zero gravity or other conditions unique to space.

After winning the contract, Rockwell named George Jeffs, who had been heading the Apollo program, to become the first space shuttle program manager. Jeffs, who later became president of Space and Energy Operations, said Rockwell's performance, processes and relationships with NASA, which had been developed during Apollo, played an important part in Rockwell winning the shuttle contract.

"It was a major challenge to develop the space shuttle, which is truly a marvel of hypersonic flight," Jeffs said. "The orbiter was the first vehicle of its type, and there were major aerodynamic, flight control, thermodynamic and software problems to solve. It was a hill to climb; there's no question about that."

Jeffs, who ran the shuttle program from 1972 to 1982, said the shuttle was the first spacecraft that could "land with dignity," like an aircraft on a runway. During the Gemini program, Jeffs led the development of a paraglider system to bring that spacecraft down on land, but NASA opted for splashing down in the ocean. For Jeffs, the shuttle was a dream come true.

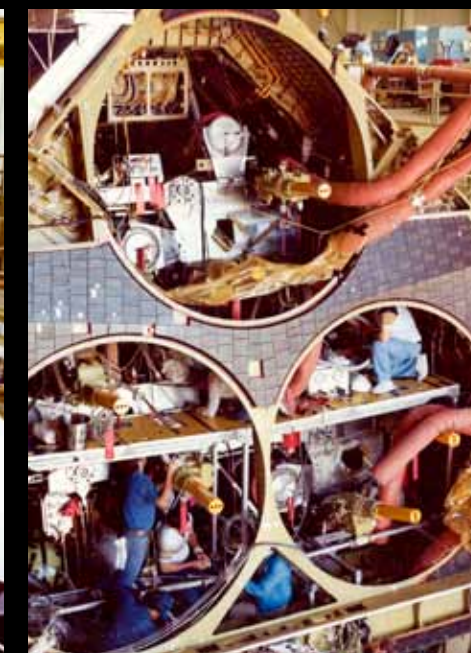
Bob Minor, who headed the shuttle program from 1988 to 1997, started work on the program in 1970 when he was a manager on the original team that prepared Rockwell's bid for the shuttle contract. Once the contract was won, he went to work on the design.

"Designing the shuttle was a daunting task, but it is a privilege that we all shared," Minor said. "We had a bunch of engineers who were just fantastic. And NASA was a great customer."

Minor, who retired in 1999, said the challenge of developing the shuttle's thermal protection system was "a sporty one," something that had never been done before. The system of tiles that protect the shuttle during the high heat of re-entry was particularly difficult. He said the team spent many late evenings and weekends developing procedures for installing the tiles and ensuring that they would remain in place during liftoff.

And the shuttle's unique role—a space vehicle that could

**PHOTOS: (Near right)** A technician checks the thermal protection tiles on the bottom left wing of *Atlantis* after it returned from a mission. **(Insets)** The first shuttle, *Enterprise*, which was not designed to fly into space, is shown at the plant in Palmdale, Calif. Employees built the forward fuselage, crew module and aft fuselage of the shuttles at Downey, Calif. NASA



*"Working at Downey, Calif., during the space shuttle program was an experience. Huge paint flakes on the inside walls looked like they could fall off and hurt you—most memorably above a door to the outside used daily by hundreds of employees. The roof leaked, so we had varying processes for catching and diverting water when it rained. But we didn't complain because we sensed that magic was happening, and we knew the whole world was watching us."*

— Anita Gale, Associate Technical Fellow and senior project engineer, Space Shuttle Payload & Cargo Integration

land like a glider—required diverse technical talent involving both aviation and space expertise.

The company's Downey, Calif., facility served as the design center for the space shuttle program. It also manufactured major sections of the shuttle.

Downey employees manufactured the forward fuselage, the crew module and the aft fuselage. These sections were transported to the company's nearby Palmdale, Calif., plant, where Palmdale employees assembled the orbiters.

"It was fantastic, and things were busy every day," said Dwight Woolhouse, recalling his early days at Downey. He joined the shuttle program in 1972 and currently serves as program manager for Orbiter Design. "Drawings were being released as the design of the shuttle matured and various tests were going on. There was always something new."

The first orbiter to be completed, *Enterprise*, rolled out at Palmdale on Sept. 17, 1976. *Enterprise* was not designed to be flown in space. Instead, it was used in approach and landing tests to confirm that the orbiter could fly in Earth's atmosphere and land like a glider. These tests were conducted at the Dryden Flight Research Center at Edwards Air Force Base in 1977. *Enterprise* was attached to the top of a specially modified Boeing 747 and released over Edwards. The tests were a success.

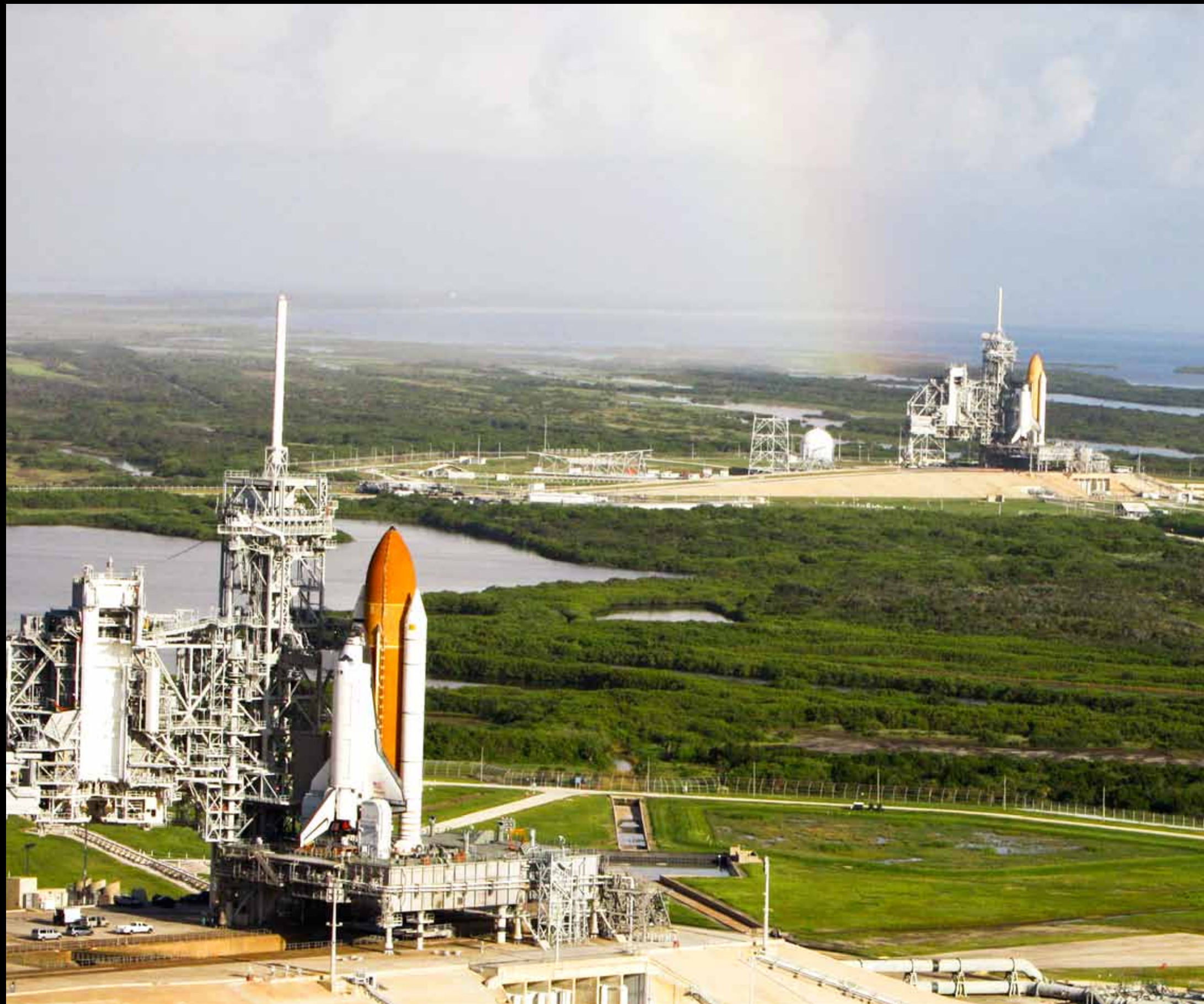
"To me, the real heroes of the space shuttle program are the people who validated the *Enterprise*," said Bob Kahl, shuttle program manager at Palmdale. "That first separation flight—with the *Enterprise* lifting off the back of a 747, then gliding down—had to be the most incredible thing I've ever witnessed. The astronauts who performed those tasks

***"This mating of two large vehicles was highly unusual, and there were concerns over how well it would work. But the first flight went perfectly. After we gained confidence, we began our approach and landing tests."***

— Bob Minor, former vice president and general manager, Boeing Space Systems division, talking about the crucial test flights of *Enterprise* after it was carried aloft on the back of a modified 747

**PHOTO:** *Enterprise* is released from the back of a modified 747 and subsequently glided to a landing at Edwards Air Force Base, Calif., Feb. 18, 1977. This critical early test flight proved the shuttle could fly and land like a glider. NASA





played a vital role in getting us to where we are today.”

Other orbiters followed: *Columbia* made its first flight in 1981, *Challenger* in 1983, *Discovery* in 1984, *Atlantis* in 1985 and *Endeavour* in 1992.

During the history of the program, dignitaries, celebrities and public officials visited the Downey and Palmdale facilities. In 1982, some 6,000 employees welcomed President Ronald Reagan as he toured the plant and delivered a speech on America’s future in space. In 1983, England’s Queen Elizabeth II and Prince Philip visited the Downey plant. Jeffs led the queen on a tour and helped her to “fly” the space shuttle simulator.

The shuttle program enjoyed great success during the more than 130 missions. But there was also tragedy. On Jan. 28, 1986, *Challenger* exploded 73 seconds after liftoff, killing its seven-member crew. On Feb. 1, 2003, *Columbia*’s seven astronauts died when the vehicle broke up over Texas during re-entry. In both cases, lengthy investigations took place and a number of program changes were made before the fleet returned to flight.

Mulholland recalled that when *Columbia* was lost, Boeing employees didn’t hesitate to step forward to offer assistance.

“It wasn’t 24 hours after the accident,” he said, “that we were getting calls from throughout Boeing offering expertise that proved to be vital, not only in reconstructing what had happened, but in making the changes necessary to return to flight.”

Mulholland said his two greatest memories of leading the shuttle program center around having a remarkable, history-making product, and working with an exceptionally talented, dedicated and loyal team.

“We’ve been very lucky, because there are very few programs that have spanned the amount of time that this one has,” Mulholland said. “And it’s just amazing how many people have stuck with it—in some cases, for their entire careers.” ■

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**PHOTO:** It was a rare sight—two space shuttles on launch pads at Kennedy Space Center at the same time. But it happened in 2009 when *Atlantis*, foreground, waited on Launch Pad 39A for the final mission to service the Hubble Space Telescope, while *Endeavour* was on Launch Pad B. Once *Atlantis* lifted off, on May 11, *Endeavour* was moved to Pad 39A for the STS-126 mission to the space station. The two orbiters would subsequently make the final flights of the space shuttle program in 2011. NASA

# FROM MICE TO **SPACE PROBES**

Space shuttles hauled a variety of cargo into orbit—and sometimes back to Earth

Over the past three decades, the space shuttles hauled a variety of items into space—from small science experiments to major sections of the International Space Station.

“The space shuttle was designed primarily to operate like a truck, taking cargo into orbit and, in some cases, bringing things back,” said former shuttle astronaut Steve Oswald. “But I don’t think any of us imagined the full versatility of this vehicle and the kinds of payloads it would carry over the program’s 30-year history.”

Oswald, now chief operating officer, Information Solutions, Boeing Network & Space Systems, piloted two missions aboard *Discovery* in 1992 and 1993 and commanded *Endeavour* in March 1995. All three missions were primarily scientific. Oswald served as vice president and program manager of the Boeing Space Shuttle Program from 2001 to 2007.

Anita Gale, Associate Technical Fellow and senior project engineer, Space Shuttle Payload & Cargo Integration, said major shuttle payloads have included interplanetary probes, like the Galileo spacecraft in 1989, and a number of satellites.

One particularly challenging mission occurred in 1984, when *Discovery* retrieved two communications satellites that had been launched to the wrong orbits. Another major project was the deployment of the Hubble Space Telescope.

“Hubble was a huge, amazing integration process,” Gale said. “We worked for years to accommodate that one.”

The shuttle also was used to carry classified military payloads.

Don Stieler is the payload mechanical engineering lead on the final space shuttle mission, STS-135, *Atlantis*, which is scheduled for July. He has supported shuttle flights at Kennedy Space Center since the beginning, missing only the first space shuttle launch in 1981.

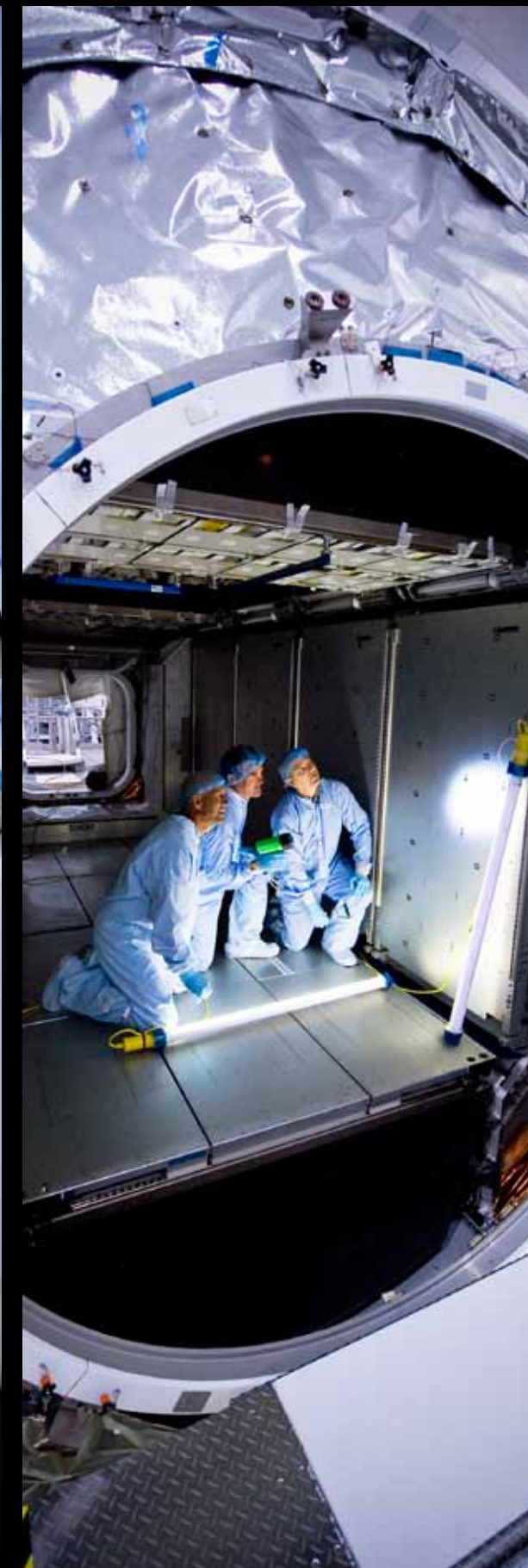
“There’s a lot of emotion involved in preparing for this final flight,” Stieler said. “Everybody is keeping their focus. We want this mission to be the best.”

Mike Kinslow, a Boeing payloads flow manager at Kennedy Space Center, said payloads are generally loaded on the launch pad to allow late changes when needed. Some of the most challenging, he said, were orbiting observatories, which have sensitive sensors and optics, and interplanetary probes, which have their own fuel supply.

Scientific experiments contain living specimens, such as plants, insects or rodents. They have to be changed out if a mission is scrubbed.

“One team I supported had been working on a module for 20 years,” Kinslow said. “It’s been exciting to work with each of these teams and to be part of such an important program.” ■

**PHOTOS: (Near right)** Boeing employees Kevin Jackson, left, and Donald Stieler at Kennedy Space Center prepare a container packed with supplies that *Atlantis* will carry to the International Space Station on what will be the final flight of a space shuttle, a mission tentatively scheduled for July. **(Middle)** They are joined by Kevin Koby, shown at bottom of photo. **(Far right)** Stieler, from left, Koby and Jackson. BOB FERGUSON/BOEING



# From *Enterprise* to *Atlantis*

Key dates in the U.S. shuttle program

**Sept. 15, 1969** – The Space Task Group, an advisory panel appointed by the president, recommends the development of a new space transportation capability.

**Jan. 5, 1972** – President Richard Nixon approves the development of the space shuttle.

**Sept. 17, 1976** – *Enterprise*, a test vehicle not designed for orbital flight, is rolled out at Rockwell's Palmdale, Calif., facility.

**April 12, 1981** – *Columbia* becomes the first space shuttle to orbit Earth.

**Feb. 7, 1984** – Bruce McCandless becomes the first person to walk in space without being fastened to a spacecraft. He flies 320 feet (100 meters) away from the orbiter *Challenger*.

**Aug. 30, 1984** – *Discovery* is launched on its first mission.

**Oct. 3, 1985** – *Atlantis* makes its first flight.

**Sept. 29, 1988** – Following major design modifications, the space shuttle program returns to flight with the launch of *Discovery*.

**Oct. 18, 1989** – *Atlantis* is launched, carrying the Galileo/Jupiter Spacecraft and attached Inertial Upper Stage. Galileo is sent on a six-year trip to Jupiter.

**April 5, 1991** – *Atlantis* is launched. On the third day of the mission it deploys the Gamma Ray Observatory, the first observatory to be deployed by a shuttle since the Hubble Space Telescope.

**Aug. 17, 1993** – NASA selects Boeing as the prime contractor for the International Space Station.

**June 29, 1995** – *Atlantis* docks with the Russian space station Mir, marking the first time since the 1975 Apollo-Soyuz project that the two nations docked in space.

**Aug. 13, 1998** – Boeing announces that its Reusable Space Systems operations, including the space shuttle program, would vacate facilities in Downey, Calif. Manufacturing would move from Downey to Palmdale, Calif., and the remainder of its activities would relocate to Huntington Beach, Calif.

**Dec. 4, 1998** – The space shuttle fleet's role in the construction of the International Space Station begins. *Endeavour* carries the Boeing-built Unity Node into orbit and mates it with the Zarya Control Module, which had been launched atop a Russian Proton rocket on Nov. 20.

**May 19, 2000** – The launch of *Atlantis* introduces a host of enhancements, including an adaptation of the glass cockpit system used in the Boeing 777.

**Feb. 7, 2001** – The crew of *Atlantis* installs the Boeing-built Destiny Laboratory Module at the International Space Station. Destiny provides a shirt-sleeve environment for research projects in life sciences, microgravity sciences, Earth science and space science.

**Feb. 1, 2003** – *Columbia* and its seven astronauts are lost when the vehicle breaks up over Texas during re-entry.

**Jan. 14, 2004** – President George W. Bush announces a new Vision for Space Exploration. The shuttle's chief purpose will be to help finish the assembly of the International Space Station. Afterward, the shuttle fleet will be retired.

**July 26, 2005** – The space shuttle program returns to flight with the launch of *Discovery*.

**March 11, 2008** – *Endeavour* begins a 16-day flight, the longest shuttle mission to the International Space Station to date.

**May 11, 2009** – The crew of *Atlantis* launches on the final servicing mission to the Hubble Space Telescope.

**Feb. 24, 2011** – *Discovery* is launched on its final mission.

**May 16, 2011** – *Endeavour* is launched on its final mission.

*Atlantis* will be the final shuttle flight, tentatively scheduled for July 2011.

**July 20, 1969** – Neil Armstrong and Edwin Aldrin land the Apollo 11 lunar module on the surface of the moon.

**July 26, 1972** – North American Rockwell, a Boeing legacy company, wins the contract to build the first space shuttle orbiter. (North American Rockwell became Rockwell International the following year.)

**Feb. 18, 1977** – *Enterprise* is flown atop a modified Boeing 747 for the first time. The tests prove the orbiter can fly in the atmosphere and land like a glider.

**April 4, 1983** – *Challenger* is launched on its first mission.

**Nov. 8, 1984** – *Discovery* is launched on a mission that includes the retrieval of two malfunctioning communications satellites: Palapa B2 and Westar VI. Astronauts deposit the satellites in the shuttle's payload bay.

**Jan. 28, 1986** – *Challenger* explodes 73 seconds after liftoff; its seven-member crew is lost.

**May 4, 1989** – *Atlantis* is launched on a mission that deploys the Magellan/Venus radar mapper spacecraft and attached Inertial Upper Stage, or IUS. The Boeing-developed IUS sends the spacecraft on a trajectory to Venus.

**April 25, 1990** – The Hubble Space Telescope is deployed from Space Shuttle *Discovery*.

**May 7, 1992** – *Endeavour* is flown for the first time. It includes a number of technical improvements, including the first use of a drag chute during landing.

**Dec. 2, 1993** – *Endeavour* is launched on an 11-day mission to upgrade and service the Hubble Space Telescope, correcting a serious optical problem. It is one of the most challenging and complex manned space missions ever attempted.

**Dec. 6, 1996** – Boeing purchases the aerospace and defense units of Rockwell International, which includes the space shuttle program.

**Oct. 29, 1998** – John Glenn—who, in 1962, became the first American to orbit Earth—is launched into space on Space Shuttle *Discovery*. At age 77, he becomes the oldest person to fly in space.

**July 23, 1999** – *Columbia* is launched, carrying the Chandra X-Ray Observatory. Chandra becomes the third observatory to be deployed by a shuttle, beginning with the Hubble Space Telescope in 1990.



# The right stuff

Space shuttle fleet opened new frontiers for space exploration

## Enterprise

It was not designed to go into space—but the shuttle orbiter missions that followed would not have been possible without *Enterprise*. On Feb. 18, 1977, *Enterprise* was carried on the back of a 747 and released above Edwards Air Force Base, Calif., gliding to a safe landing. The test proved the shuttle could fly and land like a glider. It was supposed to be named “Constitution.” But through a write-in campaign, viewers of the science fiction TV show “Star Trek” urged NASA to name it after the starship *Enterprise*.

## Columbia

The first shuttle to be launched into space, on April 12, 1981, *Columbia* was named after a small sailing vessel that in 1792 explored the mouth of the Columbia River in the Pacific Northwest. *Columbia* was the first of the shuttles to carry Spacelab—a medical research lab that allowed astronauts to conduct experiments in the shuttle cargo hold—in orbit, in June 1991. *Columbia* was destroyed and its crew of seven died when the shuttle broke up while re-entering Earth’s atmosphere for landing on Feb. 1, 2003.

## Challenger

The second orbiter to join the shuttle fleet, *Challenger* first flew into space on April 4, 1983. Named after a British naval research vessel that sailed the Atlantic and Pacific oceans in the 1870s, *Challenger* was the first shuttle to be launched and to land at night, during the STS-8 mission. And it was the first to land at Kennedy Space Center rather than the California desert. On Jan. 28, 1986, *Challenger* was destroyed and its crew of seven lost when a booster rocket failed and caused an explosion 73 seconds after launch.

## Discovery

The third orbiter to join the fleet, *Discovery* was launched on its first mission on Aug. 30, 1984. One of its most notable missions came in April 1990 when *Discovery* deployed into orbit the Hubble Space Telescope. *Discovery* completed more missions than any other shuttle. It was named after two famous ships—one used by Henry Hudson 1610–1611 to search for a northwest passage between the Pacific and Atlantic oceans, and the other by British explorer James Cook in the 1770s when he discovered the Hawaiian Islands.

## Atlantis

It lifted off from Kennedy Space Center on its first trip into space on Oct. 3, 1985. In addition to delivering vital components to the International Space Station, *Atlantis* has been used to launch a number of important spacecraft, including planetary probes Magellan and Galileo. It also flew the first of seven shuttle missions that docked with the Russian space station Mir. *Atlantis* will make the final flight of the space shuttle program, a mission tentatively scheduled for July.

## Endeavour

The fifth and last of the shuttles, *Endeavour* was built as a replacement for the *Challenger* after it was lost in an accident. *Endeavour*’s first space flight came on May 7, 1992. Among its many missions, *Endeavour* was used to begin construction of the International Space Station, when it carried the Boeing-built Unity node into orbit in December 1998. The node was attached by astronauts to a Russian-built control module.

SOURCE: NASA; PHOTOS: NASA

# ‘It was the most exciting thing that’s happened in my lifetime’

Those who worked on the shuttle program share their memories of an incredible adventure

**“Watching a shuttle launch is an emotional, powerful experience ... You feel it in your gut. It’s just a beautiful thing to see. And what makes it even more exciting is knowing that you’ve had a role in making it happen.”**

– Gloria Castellanos, product and service quality manager, Boeing Space Shuttle Program

**“I was always amazed at how well the space shuttle handled. In space, as we advanced into more complex missions, we came to realize what a neat flying machine the orbiter really was.”**

– Steve Oswald, former space shuttle astronaut and currently chief operating officer, Information Solutions, Boeing Network & Space Systems

**“When we were building the orbiters—even the Enterprise—the astronauts who had been assigned by NASA lived at Palmdale. They were here every day and knew the employees by name. It was as though they were part of the workforce.”**

– Bob Kahl, program manager, Boeing Space Shuttle Program, Palmdale, Calif.

**“I joined the space shuttle program in 1972. When I look back at those four decades, I have to say, what a stroke of luck it was for me to have a career working in a program that, in my opinion, was the best, most exciting thing that’s happened in my lifetime.”**

– Dwight Woolhouse, program manager, Orbiter Design

**“When I was growing up, because my father was a shuttle astronaut, we lived and breathed the space shuttle program and the whole idea of space exploration. I hadn’t planned on working in the program. I joined Boeing in 1999 and the opportunity opened up several years after I was hired. I’m particularly glad that I’m here with the program as it comes to an end.”**

– Darien Onizuka-Morgan, contract administrator, Boeing Space Shuttle Program, and daughter of astronaut Ellison Onizuka, who died when Challenger exploded in 1986.

**“Queen Elizabeth visited the Downey plant in 1983 and I had the honor of giving her a tour. She was a space buff. She told me she had seen every Apollo launch on television. When she tried flying the shuttle simulator, she didn’t do too badly. While she didn’t land the spacecraft, she did get it down on the glide path.”**

– George Jeffs, former president, Rockwell Space and Energy Operations

**“I will always remember my time with the program with great pride and satisfaction. And it was such a miraculous experience for me, having come to this country as a foreign student from Bangladesh and ending up in this amazing program.”**

– Shireen Rahman, Guidance, Navigation & Control Analyst, Boeing Space Shuttle Program

PHOTO: *Discovery* is launched on the STS-131 mission in April 2010. NASA

***“We’re just on the cusp of revolutionizing human access to space. What I’m really excited about is the next 50 years and what we’re going to be able to achieve. I believe it’s going to be as remarkable as the achievements of the past 50 years.”***

*– John Mulholland, vice president and program manager, Boeing Space Shuttle Program*



**PHOTO:** With its landing gear down, *Endeavour* approaches the runway at Kennedy Space Center for a night landing in February 2010, after a 14-day mission to the International Space Station. The shuttle program is coming to an end, and *Endeavour* made its final flight on May 16, 2011. NASA