Shuttle Tribute

National Aeronautics and Space Administration

NASA

The Dryden

X-PRESS

Volume 53 Number 11 June 17 2011

X-Press
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Thank you, AFFTC and Dryden, for contributions

As the page is turned on America's remarkable space shuttle era and the next chapter begins in our nation's extraordinary story of exploration, we reflect on the contributions from across the nation that made the shuttle program a success.

I want to thank the men and women at the Air Force Flight Test Center and at NASA Dryden Flight Research Center on Edwards Air Force Base for their exemplary service to the space shuttle program.

Dryden's contributions predate the orbiters. The center's work with research aircraft that validated aerodynamics, structures, thermal properties, flight controls and human physiology was key to decisions made during early stages of shuttle development. Dryden also conducted the Approach and Landing Tests with the space shuttle prototype Enterprise, which validated that the shuttle would be capable of safe unpowered landings.

Nine of the first 10 space shuttle missions landed at Edwards Air Force Base. At the backup landing site, the men and women of the AFFTC and Dryden always were prepared for a landing, right up until STS-135 was safely on the ground at Kennedy Space Center, Fla., in July.

The shuttle program brought our nation many firsts. There were many proud moments, some of which I was privileged to experience personally as a shuttle commander. In fact, my first two shuttle missions as a shuttle pilot concluded at Dryden. I was very proud to be part of the program, and will carry those experiences with me for the rest of my life.

As we move forward, we stand on the shoulders of our astronauts and the thousands of people who supported them on the ground, as well as with those who cheered their triumphs and mourned their tragedies.

The final shuttle flight marked the end of an era, but we recommit ourselves to continuing human spaceflight and taking the necessary – and difficult – steps to ensure America's leadership in human spaceflight for years to come.

We look forward to Dryden's contributions as NASA continues its work in human exploration.

I want to send American astronauts where we've never been before. We can do this by focusing our resources on exploration and innovation while leveraging private-sector support to take Americans to the International Space Station in low-Earth orbit.

On the bold path President Obama and Congress have set out for us, we will continue the grand tradition of exploration.

Children who dream of being astronauts today will not fly on the space shuttle, but one day they may walk on Mars. The future belongs to us, and just as those who came before us did, we have an obligation to set an ambitious course and take an inspired nation along for the journey.

I'm ready to get on with the next big challenge, and I want you all with me!

The future is bright for human spaceflight and for NASA. American ingenuity is alive and well. And it will fire up our economy and help us win the future, but only if we dream big and imagine endless possibilities. That future begins today.

Charlie B.

NASA Administrator Charlie Bolden

Also Inside:

Front and back covers:

This Dennis Calaba design incorporates iconic images of space shuttle work. Front, clockwise from left, are: a NASA image of the STS-135 final launch; Tom Tschida's image as the sun sets on the Crew Transport Vehicle, where astronauts were first taken after a landing at Edwards; a Jim Ross photo of a NASA 747 ferry of Columbia; and a NASA image taken during an Enterprise Approach and Landing test. On the back cover are, clockwise from top left, a NASA photo of Columbia's transport from Palmdale to Dryden; a Tony Landis image of Endeavour taken after landing as Columbia, atop the NASA 747, departed for return to Kennedy; Jim Ross' image of Endeavour back from its maiden STS-49 flight and housed safely in the Mate/Demate Device; a Discovery landing; former President Ronald Reagan's appearance at Edwards and Dryden for STS-4; and a Jim Ross image of Discovery's return-to-flight landing and astronaut greeting at Dryden.

Endeavor image above a NASA photo by Carla Thomas

Saluting the shuttle

By Jay Levine
X-Press Editor

The familiar double boom signifying the return of a space shuttle from space thrilled people for more than 30 years.

At Edwards Air Force Base and Dryden, the noise was commonplace during the early years of the shuttle program. Edwards was the main landing site for the space shuttles as the new space transportation system was tested and regular space operations began. Later in the program, Edwards and Dryden remained active as the backup-landing site when weather at Kennedy Space Center, Fla., was unfavorable.

Dryden played an important role in the shuttle program from its earliest stages. The space shuttle prototype Enterprise was flown at the center in a 1977 series of flight tests that evaluated glide and landing characteristics of the 100-ton vehicles.

The first NASA 747 shuttle carrier aircraft, or SCA, was subsequently used to launch the prototype Enterprise and both SCAs ferried shuttles back to Kennedy.

In fact, before the orbiters flew into space, four of the five space shuttles were towed from Rockwell International (later purchased by The Boeing Company) facilities at Air Force Plant 42 to Dryden to be mated to the NASA 747 for transport to Florida. It was only on the completion of the final orbiter, Atlantis, that the shuttle came directly from the factory atop the SCA.

When the first space shuttle mission concluded, a lakebed full of spectators greeted Columbia. When Columbia completed the fourth space shuttle mission on July 4, 1982, then President Ronald Reagan and NASA Administrator James M. Beggs were on hand, as well as a base-wide crowd of about 500,000 people.

Endeavour had just landed to conclude STS-68, while Columbia was perched on a NASA 747 from Kennedy Space Center, Fla., on its way to Palmdale, Calif., for major modification and maintenance work.

EC94 42789-05
NASA Photo
by Tony Landis

Between the first orbital mission in 1981 and the final one in July 2011, Dryden hosted 54 of the 133 space shuttle landings.

More than a decade before Enterprise flew, Dryden was involved with the space shuttle program. Dryden pilots and engineers tested and proved concepts on research aircraft that provided information used in developing the shuttle's design as well as its thermal protection and flight control systems.

Early concept vehicles called lifting body aircraft were used to validate aerodynamic information that reinforced design elements used in development of the shuttles. Those data led directly to NASA's decision to build the orbiters without air-breathing jet engines, which would have been used during descent and landing operations and would have added substantially to vehicle weight and complexity as well as to program costs.

Dryden's work with the rocket-powered X-15 aircraft, considered one of the most successful flight research programs in history, also contributed directly to the space shuttle program. The X-15 program provided a vast amount of information on aerodynamics, structures, thermal properties, flight controls and human physiology that was key to decisions made during early stages of shuttle development. It also was the first aircraft to fly to space and return to Earth to fly again. Additionally, Dryden aircraft were used in research on the shuttle tiles that protect the orbiter and crew against the heat of re-entry to Earth.

Photo courtesy U.S. Air Force

NASA Photo

***Above**, the X-15 makes one of that program's 199 flights.*

***At left**, the precision unpowered landing of the X-24B on the main concrete runway at Edwards led space shuttle designers to eliminate from prospective designs the jet engines that had been intended to aid shuttle landing approaches.*

Dryden conducted research flights from 1972 to 1985 using the first aircraft equipped with a digital flight control system, the F-8 Digital Fly-By-Wire. That project had direct applications used in developing a safer, digital fly-by-wire control system for the shuttle flight control system.

The orbiters were key to building and resupplying the International Space Station. They delivered the Hubble Space Telescope to space and twice completed missions to fix and upgrade it, and launched NASA's Chandra X-ray Observatory. Individual descriptions of the orbiters on the pages that follow will include many more shuttle program highlights.

A few of the hundreds of technologies developed for space travel that have benefited people on Earth include artificial hearts, home insulation, infrared camera development used in fire fighting, materials for prosthetics, and biodegradable lubricants.

The space shuttle program also saw tragedy. Two crews perished during the 30-year program in separate shuttle tragedies – Challenger's loss on Jan. 28, 1986, and Columbia's on Feb. 1, 2003. The sacrifices of the brave crewmembers are recognized in a special tribute in this salute to the shuttle program.

Dryden supported the research done to return the shuttles to service following Columbia's loss. Divots were created on the orbiters when air was trapped under the foam on the shuttle's external fuel tank and conditions on launch caused the delicate tiles' adhesive to fail, resulting in a section of foam popping off of the tank. Dryden's F-15B was used for the divot tests. Discovery completed the first return-to-flight mission with a landing at Dryden on Aug. 9, 2005.

The space shuttles were the first reusable spacecraft to carry humans to orbit, and greatly expanded the world's knowledge. They inspired adults and children alike, proved the resiliency of the nation in adverse situations, instilled in Americans a sense of awe for something larger than themselves and generated optimism for the future. The last mission is safely on the ground, but the contributions of the shuttle program will continue to have people thinking about the stars – and beyond.

ECN77 8608 **NASA Photo**

The first of Enterprise's five free flights from the NASA 747 Shuttle Carrier Aircraft at Dryden in 1977 were part of the shuttle program approach and landing tests. The tests verified orbiter aerodynamics and handling characteristics in preparation for orbital flights with Columbia. A tail cone over the main engine area of Enterprise smoothed turbulent airflow during flight. It was removed on the last two free flights to enable accurate check of approach and landing characteristics.

Proving Grounds

Enterprise validated shuttle concepts

By Peter Merlin
Dryden History Office

The space shuttle orbiter was the first spacecraft designed with the aerodynamic characteristics and in-atmosphere handling qualities of a conventional airplane. To evaluate the orbiter's aerodynamic flight control systems and subsonic handling characteristics, Dryden Flight Research Center undertook a series of flight tests, known as the Approach and Landing Test program, at Edwards Air Force Base in 1977.

A full-scale orbiter prototype, named Enterprise, was built for the program. Because the vehicle would not be subjected to reentry heating, Enterprise had no need for a thermal protection system. It was not covered with the space shuttle's reusable surface insulation, but with substitute materials, primarily polyurethane foam and Fiberglas. The flight deck had two crew stations for the commander and pilot. Aerodynamic controls included a body flap at the aft end, elevons and a split rudder that doubled as a speed brake. Reaction control systems, unnecessary at low altitude, were not installed. For the captive flights and the first three free flights, an aerodynamic fairing covered the orbiter's aft end. Three dummy main engines were installed for the final two flights to simulate weight and aerodynamic characteristics of an operational orbiter.

The Enterprise was to be carried aloft by, and eventually released for flight from, a modified Boeing 747. This Shuttle Carrier Aircraft, as it came to be known, had a fuselage strengthened at key stress points, two vertical fins attached to the horizontal stabilizers, and three attach points on top of the fuselage to anchor the orbiter. All original seating except that of the first-class section of the main deck was removed.

NASA selected two two-man orbiter crews for the ALT: Fred W. Haise Jr. (commander) and C. Gordon Fullerton (pilot), and Joe H. Engle (commander) and Richard H. Truly (pilot). Crewmembers for the 747 SCA included pilots Fitzhugh L. Fulton Jr. and Thomas C. McMurtry and flight engineers Victor W. Horton, Thomas E. Guidry Jr., William R. Young and Vincent A. Alvarez.

Wind-tunnel-model tests allayed concerns over the separation characteristics of the two vehicles in flight. Because of the orbiter's positive angle of attack while mated, the Enterprise tended to climb relative to the SCA. Meanwhile, the 747 tended to descend mildly as the crew idled the engines and deployed spoilers, allowing the orbiter to clear the SCA's tail in about 1.5 seconds.

Five captive flights with the inert, unmanned orbiter verified the airworthiness of the 747 as an orbiter transport vehicle and established an operational flight envelope for ALT operations. These were followed by three captive-active flights, with Enterprise powered up and crew in its cockpit to test controls and other functions.

The final phase of the ALT program comprised five free flights during which the orbiter was released from the SCA and glided to a landing at Edwards. Three of these were made with the aerodynamic tailcone on the orbiter, but the last two were made with the tailcone replaced by dummy engines in an effort to replicate actual flight conditions experienced by an orbiter returning from space.

Except on the last free flight, Enterprise landed on Rogers Dry Lake. The final flight ended on the 15,000-foot concrete runway at Edwards, an important demonstration of precision landing capabilities necessary for later operational missions.

At touchdown, the orbiter experienced a pilot-induced oscillation, or PIO, in which the vehicle skipped and bounced down the runway several times before safely coming to a stop. Prior to the start of the shuttle's orbital flight-test program, the PIO issue was corrected through additional research with Dryden's F-8 Digital Fly-By-Wire test bed aircraft, which was equipped with an IBM AP-101 flight control computer identical to that used on the orbiter. Dryden engineers recreated the PIO with the F-8 and developed a software filter to correct for it.

The ALT program demonstrated the orbiter's capability for safe approach and landing after an orbital flight from space. It also validated crucial onboard control systems necessary for the shuttle program's next step: the launch of Columbia, on April 12, 1981.

E77 8142 **NASA Photo**

Flight crewmembers of Enterprise and the host NASA 747 Shuttle Carrier Aircraft include, from left, Fitz Fulton, Gordon Fullerton, Vic Horton, Fred Haise, Vincent Alvarez and Tom McMurtry.

E76 5806 **NASA Photo**

Science fiction met science fact when the crew of the starship Enterprise saw NASA's space shuttle prototype Enterprise. From left are then NASA Administrator James Fletcher and Star Trek cast members DeForest Kelley (Leonard McCoy), George Takei (Hikaro Sulu), James Doohan (Montgomery Scott), Nichelle Nichols (Nyota Uhura), Leonard Nimoy (Spock), series creator Gene Roddenberry, an unidentified man, and Walter Koenig (Pavel Chekov).

Columbia descends for its first landing, on Rogers Dry Lake.

EC81 15103 **NASA Photo**

First flight

By Jay Levine
X-Press Editor

Astronaut Bob Crippen spoke to Dryden employees April 15, 2011, about his mission as the pilot of the first space shuttle mission, which had concluded at Dryden 30 years earlier.

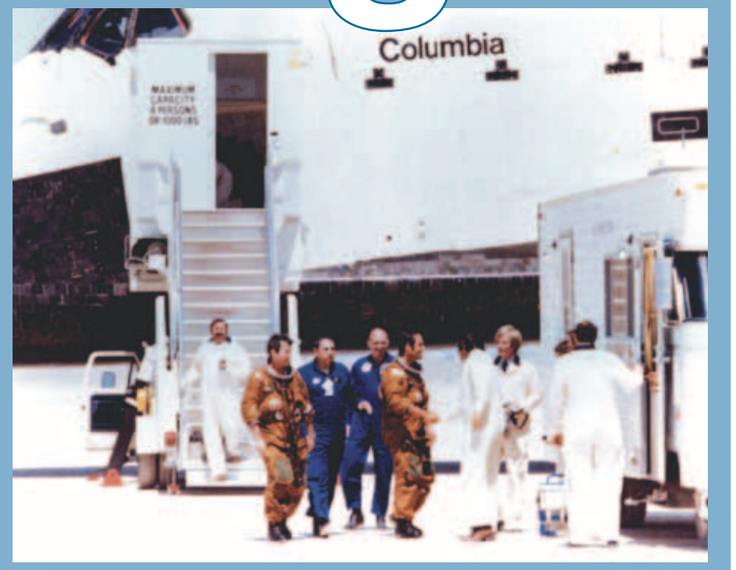
Crippen and shuttle commander John Young landed Columbia on April 14, 1981, on Rogers Dry Lake. Unprecedented crowds came to Edwards to see the landing.

Crippen explained that, early on, there had been debate about leaving the crew off of the first flight in favor of an automated landing. But it was determined that the shuttle system's complexity required a crew capable of reacting to an emergency, he said.

Although there were ejection seats on the first four shuttle flights – seats taken from the high-altitude, Mach 3-plus SR-71 – they were "primarily a placebo," Crippen said.

"There was a ton of flame from the solid rocket boosters. If you ejected you would have to go through that, and you would get very toasty."

On launch day, he said, only after the clock started ticking down to under one minute did he believe the STS-1 mission would begin. The shuttle computers had not been communicating with each other a few days earlier, and he was expecting a scrub.



ECN 15388 **NASA Photo**

Astronauts John Young, left, and Robert Crippen (wearing tan suits) are greeted at Edwards upon Columbia's return.

ECN 15388 **NASA Photo**

From left, Dryden orbital flight test program manager Melvin Burke, then-Dryden Center Director Isaac "Ike" Gillam, pilot Fitz Fulton and JSC orbital flight test program manager Donald "Deke" Slayton give Columbia a humorous sendoff before its ferry flight back to Florida.

ED06 0045-3 **NASA Photo**

Huge crowds gathered on Rogers Dry Lake at Edwards Air Force Base to witness the first landing of Columbia. When President Ronald Reagan attended STS-4, it was estimated that more than 500,000 people were at Edwards Air Force Base for the landing.

But "all systems were go and it was quite a ride" traveling 17,000 miles per hour. The solid rocket boosters shook Columbia, which he likened to "driving my pickup fast over a washboard country road."

The Columbia was "well above our trajectory," he said, and he watched as the solid rocket boosters jettisoned from the orbiter and across the vehicle's windshield. Then the acceleration began to tail off, and it was quiet. "I thought we had lost the main engines," he said. But everything was fine, and it was time to start the mission.

Once Columbia was in orbit, Crippen released himself from the confines of his seat and began to make his way around the shuttle. "It's topsy-turvy without gravity; up was whatever direction I was pointed."

He floated over to the control panel facing the payload bay doors to open them, standard practice when an orbiter gets to space to release heat from the radiators. Once the doors opened, he said, "John, look at that," as he pointed to some areas where there were dozens of missing tiles, the thermal protection used to protect the orbiters during re-entry.

The missing tiles were not essential, but the two men were concerned about what might be missing on Columbia's hottest areas on its underside. They were fairly confident they would land safely.

The engines were fired for the de-orbit burn halfway around the world from the landing site. The shuttle's exterior glowed pink, and it felt like he was "flying through a neon tube," he recalled.

As Columbia approached the landing site, Crippen said he could see the huge mass of vehicles and people gathered on the lakebed to welcome the crew back to Earth.

As the shuttle program drew to a close in July, there was a lot of conversation about the achievements of the program and the inspiration it created. It was a crew of two, however, that completed what is considered one of the greatest flight tests in history and one that ushered in a new era in human space flight.

From program's outset, the shuttles inspired

By Gray Creech
Dryden Public Affairs

Before the orbiter Columbia began its journey to space from Kennedy Space Center, Fla., a laborious trek across the desert, from Palmdale to Dryden, had been undertaken two years previously.

Columbia traveled by city streets and desert roads to Dryden on March 8, 1979, after emerging from Rockwell International's (later The Boeing Co.'s) Plant 42 facilities in Palmdale, Calif. Columbia's overland delivery to Dryden took 10 hours. During the following two weeks, the orbiter was prepared for and mated to a NASA 747 Shuttle Carrier Aircraft for its first ferry flight to Kennedy to begin processing for its first space flight.

The other three orbiters also were transported by truck to Edwards, where they were mated with the SCA. That first experience hauling Columbia to Dryden was slow, but the experience resulted in shuttle transport times being decreased to about eight hours. Endeavour, the fifth and final shuttle, was the first to be mated to a NASA 747 SCA at Plant 42.

The route taken through Lancaster by Columbia and the other shuttles followed 10th Street East, later renamed Challenger Way. Shuttle viewing along 10th Street East became a field trip for Antelope Valley area schools when the orbiters began the lumbering initial journey to Edwards and, eventually, to Kennedy and space. Residents, school

children, reporters and the world watched as the behemoths passed a few feet away, casting people in their shadows. Columbia's wings seemed low enough for children to jump up and touch.

Joe D'Agostino, Dryden's former shuttle manager and then director of management support, oversaw multiple shuttle support functions at Dryden, including photo, video, security, transportation, logistics and other institutional components. Managing the Dryden elements and coordinating the effort with other NASA and industry groups was "no walk in the park" in the massive undertaking of preparing Columbia.

"Working with so many people from the other NASA centers and the industry partners was like preparing for 500 dinner guests, each with a very specific need," D'Agostino recalled. "They all had their own concerns, and we had only one chance to meet their needs in a timely fashion."

ECN 10370 NASA Photo

Columbia lumbers along 10th Street East at Avenue J in Lancaster on its way to Dryden March 8, 1979. The city renamed 10th Street East as Challenger Way to salute the lost orbiter and its crew. In 2003, Lancaster officials renamed Avenue M for Columbia and its crew; the street is now known as Columbia Way.

In addition, while Columbia was readied for and mated with the NASA 747, D'Agostino and his staff had to plan and prepare for the second and third shuttle flights, scheduled to follow closely on the landing of the first orbiter.

Larry Biscayart, Dryden shuttle program management consultant, recalls watching Columbia moving down the taxiway onto Dryden's ramp for the first time.

"My first thought, watching Columbia roll in, was how large it was, and how were they going to get that huge thing into space," Biscayart said.

"When I was young, my dad worked for North American Rockwell in Downey on the Apollo service modules and one day I got the thrill of my life – dressing up in a bunny suit and going through two clean rooms to peer inside an Apollo capsule. That was my reference for a spacecraft comparison to the shuttle. How huge Columbia was!"

Three former Dryden employees flew on Columbia.

Former astronaut and Dryden research pilot Gordon Fullerton piloted Columbia during STS-3 in March 1982. Mission highlights included the first test of the shuttle's remote manipulator arm in space. STS-3 landed at White Sands, N.M., because Rogers Dry Lake was temporarily unusable following seasonal rains, the lone mission to end at White Sands. Fullerton had an opportunity to land a shuttle at Dryden when he commanded Columbia's STS-51F Spacelab 2 mission in 1985.

Vance Brand, former Apollo-Soyuz astronaut and member of Dryden's management team, commanded Columbia twice, on STS-5 and STS-35. STS-5, in 1982, deployed two commercial communications satellites. In 1990, STS-35 utilized the ASTRO-1 observatory's four telescopes to provide around-the-clock ultraviolet and X-ray celestial observations.

Richard Searfoss, a Dryden pilot from 2001 to 2003, was STS-58 pilot on the seven-person life science research mission aboard Columbia. The orbiter launched from Kennedy on Oct. 18, 1993, and landed at Edwards Nov. 1, 1993. The crew performed several medical experiments on themselves and 48 rats, expanding knowledge of human and animal physiology.

Searfoss also commanded Columbia and a seven-person crew on the STS-90 Neurolab mission launched on April 17, 1998. The crew served as subjects and operators for life science experiments focusing on the effects of microgravity on the brain and nervous system. STS-90 was the last and most complex of the 25 Spacelab missions and landed at Kennedy on May 3, 1998.

Columbia's achievements also included recovery of the Long Duration Exposure Facility satellite from orbit during mission STS-32 in January 1990, and the STS-40 Spacelab Life Sciences mission in June 1991 – the first manned Spacelab mission dedicated exclusively to human medical research.

NASA's first woman shuttle commander, Eileen Collins, flew on Columbia for mission STS-93, during which the Chandra X-ray Observatory was deployed. STS-94 marked the first re-flight by the same shuttle, crew and payload following STS-83, shortened as the result of a fuel cell problem.

Columbia was lost returning from a mission on Feb 1, 2003, and a salute to the Columbia and the STS-107 crew appears elsewhere in this publication. The successes achieved by Columbia and its crews, however, ushered in the age of the space shuttle.

EC82-21135 NASA Photo

Challenger is mated with the NASA 747 Shuttle Carrier Aircraft for initial delivery to the Kennedy Space Center. All of the shuttles were assembled at Rockwell International (later The Boeing Co.) facilities at Air Force Plant 42 in Palmdale, Calif. Except for the final shuttle built, Endeavour, the orbiters were then transported overland by truck to Dryden for mating with the 747 for delivery to Florida.

Challenger's mission

Challenger was built to serve as a structural test article for the shuttle program. A lighter-weight orbiter was NASA's goal during the years in which the orbiter fleet was being built, but a test article was needed to ensure that a lighter airframe could handle the stress of space flight. Computer software of the era wasn't able to accurately predict how the orbiters' new, optimized design would respond to intense heat and stress. The design underwent a year of intensive vibration and thermal testing.

NASA awarded shuttle manufacturer Rockwell International (now The Boeing Co.) a contract in 1979 to convert STA-099 to a space-rated orbiter, later named Challenger. Conversion began late that year. Although STA-099 would be more easily converted than would the shuttle prototype Enterprise, such major modifications involved disassembly and replacement of many parts and components.

Challenger, the second in NASA's orbiter fleet, arrived at Kennedy Space Center, Fla., on July 1982. Challenger made seven landings at Edwards, the last at the conclusion of STS-61A on Nov. 6, 1985.

The shuttle was named after the British naval research vessel HMS Challenger that sailed the Atlantic and Pacific oceans during the 1870s. The Apollo 17 lunar module also was called Challenger. Like their predecessors, Challenger and its crews made significant scientific contributions.

Challenger's first mission was STS-6, launched April 4, 1983. That mission included the first spacewalk of the shuttle program, as well as deployment of the first satellite in the Tracking and Data Relay System constellation. The orbiter's crew included Sally Ride, the first female American astronaut, on mission STS-7. Challenger also was the first shuttle to host a crew that included two U.S. women astronauts, on mission STS-41G.

The first orbiter to launch and land at night, on mission STS-8, Challenger also made the first shuttle landing at Kennedy, concluding mission STS-41B. Spacelabs 2 and 3 flew aboard Challenger on missions STS- 51F and STS-51B, as did the first German-dedicated Spacelab, on STS-6A. Challenger's missions included a host of scientific experiments and satellite deployments.

Challenger and its crew of seven astronauts on STS-51L were lost on Jan. 28, 1986. Please see the special salute to the vehicle and its crew elsewhere in this publication. Challenger and its crew live on as part of NASA's space shuttle legacy. The discoveries made on the shuttle's many missions continue to improve mankind's knowledge of space flight and its applications to life on Earth.

EC91 659-05 NASA Photo by Jim Ross

Technicians begin preparations for Atlantis' attachment on the back of a 747 Shuttle Carrier Aircraft for the ferry flight back to Kennedy Space Center, Fla., following the STS-44 landing at Edwards in December 1991. Post-flight servicing of the orbiter and mating operations were carried out at Dryden in the Mate/Demate Device, the large gantry-like structure used in hoisting the spacecraft during post-spaceflight processing.

MDD

Mate/Demate Device key to shuttle prep for return to Kennedy

By Jay Levine
X-Press Editor

The most extensive overhaul in the 29-year history of Dryden's Mate/Demate Device was completed in 2004, and involved replacing the mammoth structure's original coating of lead-based paint with a fresh coat of non-toxic paint.

Contractors and NASA personnel collaborated to develop a way of disposing of the lead-based paint removed from the structure by recycling it into commercial cement. The alternative was sending it to a landfill as hazardous waste – all 240 tons of it. The MDD had not been repainted since it was first built, though it had been retouched.

The structure has served NASA well, as Dryden was the primary landing site during the early days of the space shuttle program. About a year before it would hoist prototype shuttle Enterprise onto the NASA 747 Shuttle Carrier Aircraft for the first time, the gargantuan steel frame had been erected and stood ready to do the heavy lifting.

Dryden remained the primary backup landing site when clouds rolled in at Kennedy Space Center, Fla., and the weather wasn't good enough for a landing there. In all, 54 shuttle landings took place at Dryden, including those of the first nine orbiter flights minus STS-3, in which Columbia landed at White Sands, N.M. That 54-flight total includes all of the first landings of new orbiters as each joined the fleet.

The MDD consists of two 100-foot towers with stationary platforms every twenty feet from 20 to 80 feet on each tower, and a horizontal structure mounted at the 80-foot level between the two towers. The horizontal unit cantilevers 70 feet out from the main tower units, guiding and controlling a large lift beam that attaches to the orbiters to raise and lower them.

Three large hoists are used to raise and lower the lift beam. Two of the hoists are connected to the aft portion of the lift beam and one is attached to the beam's forward section. The three hoists operate simultaneously. As a unit they can lift 120 tons, or 240,000 pounds; space shuttles weighed in at about 231,000 pounds. Joe D'Agostino was originally hired as a shuttle security officer and served for decades as the Dryden space shuttle manager before his retirement in 2007. He recalled the first time the MDD was used.

"We had a technical problem [mating Enterprise]. The operation lasted almost 14 hours. We got it to the point where we were ready to lower Enterprise onto the 747, and then we learned the orbiter didn't fit. To make it fit we moved the forward strut on the 747. It was nerve-wracking," he said.

The second time Enterprise was lifted was much more streamlined and the effort took about eight hours, he said. Shuttle landings later required changing work schedules in order to keep staff on site around the clock until the orbiter was safely mated to the NASA 747 and winging its way back to Kennedy Space Center.

Dryden and Kennedy are home to NASA's two MDDs. Dryden's MDD is more complex than the one at Cape Canaveral, D'Agostino said, because the one here is used as a work site for tasks that, when they are necessary in Florida, are undertaken at Kennedy's Orbiter Processing Facility. Dryden's structure is similar to its Florida twin, but the Dryden MDD has elevators and had extra equipment built into it that were required in the early days of the shuttle program.

What was essentially one of the world's largest Erector sets became a permanent structure at Dryden as the needs of the space shuttle program changed and required welds, concrete and additional work platforms and heavier lift capability in the MDD. Modifications since the MDD's completion in 1976 have cemented the device into Dryden history – not just physically but metaphorically as well.

EC05-0166-22 NASA Photo by Tom Tschida

EC05-0166-22 NASA Photo by Tony Landis

Above, *lightning flashes are seen in the distance as Discovery is in the Mate/Demate Device, awaiting better weather for a lift atop the NASA 747. The SCAs carried the orbiters on ferry flights from Dryden back to Kennedy Space Center, Fla.*

At left, *Discovery in the MDD after STS-128, which concluded at Dryden on Sept. 11, 2009.*

NASA Photo

The docked space shuttle Discovery and the Canadian-built Dextre, also known as the Special Purpose Dexterous Manipulator, were photographed by an STS-133 crewmember on the International Space Station. The blackness of space and Earth's horizon provide the backdrop.

Space Shuttle Discovery

Missions were busy and productive on the final frontier of space

By Jay Levine
X-Press Editor

Dryden employees gained insight into Space Shuttle Discovery's final mission when its commander and a mission specialist visited April 26.

STS-133 Commander Steve Lindsey and mission specialist Alvin Drew explained elements of the 13-day mission that included attaching a new module for storage to the International Space Station, bringing spare parts and preparing the orbiting laboratory for future research.

Lindsey and Drew are familiar with Edwards Air Force Base; they were assigned to the Air Force Test Pilot School. Drew is a veteran of two shuttle flights, both on Discovery. Lindsey is a veteran of five shuttle missions on three orbiters, including three missions on Discovery and one mission each on Atlantis and Columbia.

Discovery's final crew also included pilot Eric Bow and mission specialists Michael Barratt, Nicole Slott and Steve Bowen, who was a late replacement when lead spacewalker Tim Kopra was injured and could not make the flight.

One of the mission tasks was teaming up with the space station crew to move an equipment platform out of the shuttle's cargo bay and onto the station's truss. Barratt and Slott operated the space station's robotic arm and handed it off to the shuttle's robotic arm, operated by Bow and Drew, and the platform was maneuvered to its permanent location on the station's backbone.

Among a host of new science experiments and hardware was the Robonaut 2, the first dexterous humanoid robot in space. Its first priority is to test its operation in microgravity, but upgrades are planned that will develop it as an astronaut assistant for dangerous or boring tasks.

The astronauts answered questions about their best memories in space and their experiences with the space shuttles.

"What really sticks with me was the first time I looked out the window on my first mission. I was stringing some coaxial cable for a local area network when I looked out and it was one of those 'you're not in Kansas anymore' moments, especially when a satellite whizzed by about 1 kilometer away," Drew said.

Lindsey agreed that the view is extraordinary.

"I think something that sticks with you no matter how much time you have in space is seeing Earth from space. It's spectacular, and it never gets old. Every time you look at the Earth, you see something different even if you've flown over it a thousand times," he said.

Another question was about seeing meteor showers and color in space.

"You see meteors below you, which is really cool," Lindsey said. "Through the window, you look down at Earth and you can see the meteors entering the atmosphere. You can see all kinds of colors. Every hour and a half, you orbit the Earth, so every 45 minutes you see a sunrise or sunset – as opposed to just seeing the sky dim as you do on Earth, you can actually see multiple color bands in the atmosphere.

"I think one time I counted 12 or 13 colors. At night, if you turn off all the cabin lights so there are no reflections, you can see unbelievable stars in all kinds of different colors that you don't see even in high-altitude flight. It's pretty spectacular."

The shuttle commander thanked Dryden employees for their roles in providing shuttle support.

"We need shuttle support here to fly out there. From the bottom of our hearts, thank you for making Discovery's last flight a success."

The landing at Kennedy Space Center marked the conclusion of Discovery's 39th mission to orbit and the first space shuttle to be retired. Discovery has flown more missions than any other shuttle in the fleet; missions included carrying the Hubble Space Telescope to orbit and sending the Ulysses robotic probe on its way to the sun. It was also the first shuttle to rendezvous with the Mir Space station, and it delivered the Japanese Kibo laboratory to the ISS.

Among Discovery's 180 passengers was Eileen Collins, who was the first female pilot, and, on a separate mission, the first shuttle female commander. Bernard Harris became the first African American spacewalker and Jake Garn became the first sitting member of Congress to fly in space, on STS-51D in April 1985.

The two members of Discovery's crew said although the vehicle will no longer travel to space, it will continue inspiring young people as they reach for the stars.

ED 09 0253-02 NASA Photo by Tom Tschida

Discovery concluded missions at Edwards and Dryden 15 times, including this landing that wrapped up STS-128 on Sept. 11, 2009.

X-Press September 2011

Uniquely Dryden

ED11 0237-18 NASA Photo by Carla Thomas

NASA's 747 Shuttle Carrier Aircraft No. 905, foreground, and No. 911, background, fly in formation over the Rio Tinto borax mine west of Boron, Calif. The NASA 747s carried shuttles from California to Kennedy Space Center, Fla., and will continue operations delivering the retired spacecraft to museums coast to coast.

EC84 30263-10 NASA Photo

EC90 255-1 NASA Photo

Above, *the space shuttle solid rocket booster drop test vehicle is released from the NB-52B.*

At left, *an experimental drag chute is deployed in a cloud of dust behind NASA's B-52 research aircraft just after landing on Rogers Dry Lake, adjacent to Dryden. Tests with the NB-52B led to development of a drag chute that improved the shuttle's capability to land safely and easily.*

ECN 3276 NASA Photo

The F-8 Digital-Fly-by-Wire aircraft created a revolution in aircraft design. This control system is used on most modern aircraft, including the shuttles, and complex aircraft would not be flyable without it.

EC94 42596-1 NASA Photo

This CV-990 was modified with installation of a shuttle landing gear system between the two main sets of landing gear. The 155 test missions flown with the aircraft led to the orbiters' capability to land in higher crosswinds.

EC05 0028-18 NASA Photo by Carla Thomas

Dryden's F-15B test bed aircraft flew a series of flights in the Lifting Insulating Foam Trajectory, or LIFT, research as part of the center's contributions to NASA's return-to-flight activity.

NASA Photo

NASA F-104G No. 826 carried shuttle thermal protection system materials on the sides of an underbelly pylon. The flights exposed the materials to greater aerodynamic loads than would be encountered during a shuttle launch.

Ever ready

Workforce was always ready to host a landing, even if one didn't happen

Shuttle workers were prepared to support an emergency landing at any time. One such moment came Dec. 1, 1991, with STS-44, when Atlantis landed at Dryden three days early.

EC91 0641-1
NASA Photo

By Jay Levine
X-Press Editor

Between the time when a shuttle was launched into space and it was safely on the ground, Dryden was ever ready in case a situation arose that would require the orbiter to land at Edwards Air Force Base.

An often-unsung workforce gave up weekends, holidays and even family vacations when the nation needed them to be at their posts to support the space program and ensure the safety of astronauts in flight.

Dryden Center Director David McBride said the shuttle team was always ready to step up when the call to action came for a California landing.

"This team has been ready for any shuttle configuration and contingency. They have handled with grace and skill dangerous propulsion components and fuel, and payloads from delicate scientific and medical materials to Buzz Lightyear," he said.

Dryden hosted 54 shuttle landings, but there hasn't been a landing here since 2009. Regardless, shuttle managers usually began planning for potential landings a month prior to an orbiter launch from Kennedy Space Center in Florida.

A small but dedicated crew of about 75 at Dryden worked year around, regardless of how many landings there were, to maintain the equipment and facilities that would be needed if the shuttle landed. They also trained with U.S. Department of Defense personnel from the Air Force Flight Test Center, the China Lake Naval Air Warfare Center near Ridgecrest, Calif., and Fort Irwin, near Barstow, Calif. When a shuttle landed at Edwards, 116 Dryden employees and 159 DOD employees supported it.

Ever ready

"We never had a failure on any landing here of any of this [shuttle] equipment, which is a tribute to the professionalism and the care that the Lockheed Martin and Kay & Associates technicians had for this old equipment that was well past its life expectancy," said Larry Biscayart, shuttle program management consultant and a Kay and Associates employee. He started working on the shuttle program in 1980 prior to the first shuttle mission, in April 1981, and continued until the program's conclusion, minus a few years of retirement in 2004.

George Grimshaw, Dryden space shuttle operations project manager, said it takes a whole team to continually verify that equipment is ready for the day it is needed. Grimshaw started supporting the shuttle program in 1979, when he worked at the AFFTC mission control center. He helped relocate that facility in December 1980 to the Ridley Mission Control Center, also at Edwards, where he supported the first shuttle missions. He started working at Dryden in 1984.

In addition to Dryden's work force, dedicated contractor teams from Lockheed Martin, United Space Alliance, Computer Services Corp., Kay & Associates, Arcata Associates, Tybrin Corp. and EMCOR Government Services provided day-to-day support for shuttles in orbit as well as on landing, during recovery and with turnaround facilities and equipment.

"The bulk of mission preparation began about a month before the mission," Grimshaw explained. "That's when annual validation and periodic maintenance of facilities and equipment were accelerated for those assets required during the mission. That work had to be complete two weeks prior to the launch, or waived until after the mission."

EC01-0129-07 **NASA Photo by Tony Landis**

Dryden shuttle worker Phil Burkhardt, right, and an unidentified employee tow Endeavour to Dryden's Mate/Demate Device following the completion of STS-100 at Edwards on May 1, 2001.

During the two weeks prior to launch, preoperational checks were completed. At that point, shuttle staff members at Dryden and Air Force Flight Test Center partners on Edwards intensified planning and communications. Dryden and AFFTC preparation involved facilities, information technology, fire, security, range, safety and mission assurance, public affairs, medical operations, air ambulance, search and rescue, and mission and runway support.

The AFFTC played a critical role by providing landing contingency support. If something went wrong, the AFFTC was tasked with and prepared for responding immediately within 25 miles of Edwards. Fortunately, astronauts landed safely throughout the program and did not require the emergency services the Air Force always stood ready to provide.

"Nothing we have done with the space transportation system would have been possible without the assistance and cooperation of the Air Force and the Edwards community. Our heartfelt thanks go to Brig. Gen. [Robert C.] Nolan II and his predecessors for their full support of NASA, the STS and the Dryden Flight Research Center," McBride said.

A day or two prior to a launch a site-readiness report was completed and submitted to the Kennedy Space Center convoy commander to verify that all Dryden and Edwards elements were in place and ready to support a shuttle launch and potential early emergency landing. If anything broke, it was reported, and potentially threatened the launch.

Additional staff also came to Dryden prior to a launch. A 30-person United Space Alliance contingent from Kennedy traveled to Edwards and stayed throughout the entire shuttle mission. Another 30 people were sent to Dryden two days prior to landing. In the event of an Edwards landing, a team of another 100 USA staff from Kennedy would come to prepare the orbiter for return to Florida.

All that preparation didn't mean a shuttle mission would land at Dryden. That call did not usually come until about 90 minutes before landing.

EC08-0306-27 NASA Photo by Tony Landis

Floodlights cast long shadows over Endeavour as technicians prepare to tow the orbiter from the Edwards Air Force Base runway after landing on Nov. 30, 2008.

EC09-0266-1 NASA Photo by Tony Landis

Dryden Center Director David McBride, left, and Dryden space shuttle operations project manager George Grimshaw welcomed Buzz Lightyear back to Earth at Dryden. Buzz flew back Sept. 11, 2009, on Discovery after a nine-month stay on the International Space Station. Buzz was part of a joint NASA-Walt Disney collaboration for teaching lessons in science, technology, engineering and mathematic, or STEM, disciplines to children.

"There were many times we would roll our convoy to the end of the runway due to bad weather at Kennedy; in most cases, they would find a hole in the cloud deck and go to Kennedy, but we were stirred up and ready to go. And many times, just when we didn't expect that it would come here, weather didn't improve at KSC in the final moments prior to de-orbit burn and, at the last moment, it came here," Biscayart said.

The Mate/Demate Device that lifts and lowers the space shuttles onto the back of the NASA 747 Shuttle Carrier Aircraft also was reliable.

"We never had a failure in 35 years. The time to find something wrong was not when you were lifting an orbiter," Biscayart said.

The NASA 747s have a near-flawless operation record as well and have been workhorses for the shuttle program, Biscayart said. Computer Science Corp. employees based at Dryden, but who are employees of Johnson Space Center, Houston, maintain those aircraft.

A dedicated workforce

Being a space shuttle worker did have its setbacks.

"During a mission, [shuttle employees] change their schedule to meet the potential for a shuttle landing. After launch, it can land here four hours out of every 24-hour period. We had landing opportunities here, so our people shifted their schedules to be here two hours before the first potential landing.

"In the event something was to happen, people would be here," Biscayart said.

After a shuttle launched, there was a potential for an emergency landing in the early part of the mission, which meant Dryden staff had to be on site to assist in clearing runways, preparing the microwave landing systems and shuttle-specific runway lights and alerting Air Force contingency forces.

"We used to tease that the shuttle was a holiday-seeking lawn dart because it seemed the missions would always shift to a holiday. For every holiday when the shuttle flew or was in space, our people were here to cover those potential landings," he said.

"People would set vacations and then, at the last minute, have to change their plans to be here. They would try to plan a vacation around a mission. They did their very best to plan. Talk about professionalism and dedication – it would affect families, when we would be here on Christmases, Thanksgiving and a lot of other traditional holidays. But again, this job was more important than any individual, and that's the dedication that I think employees and families understood," Biscayart said.

When it was needed

All of the work, all of the preparation and all of the coordination came down to single moments.

One such moment came on STS-44 Dec. 1, 1991, when Atlantis had to land three days early at Dryden. It was also the last lakebed landing. The shuttle, commanded by Fred Gregory, had experienced an on-orbit inertial measurement unit problem. The shuttle had three of the units that fed data into the flight controls, but the failure of one unit caused the orbiter to come back early.

The units functioned together to provide location information, much as a global positioning system works. Both can tell a person where they are, but with the IMU, a person had to input precise location data so the system would know where it [the system] was, Grimshaw said.

"You would not want to get down to one unit," Biscayart said. Another issue arose that was notated as a braking test, he added, and as a result of the two anomalies the shuttle landed on the lakebed. Because the orbiter rolled and rolled on landing, the convoy of vehicles raced after it.

Getting the runway ready

Endeavour landed on Nov. 30, 2008, on the then new Edwards temporary runway. As a result of a well-coordinated effort, it was possible to land on the new asphalt runway, which was only half as wide and 2,500 feet shorter than the original main runway, which was replaced due to its age.

Contingency plans had been made in the 1990s for the possibility of a landing on a temporary runway in the event that the main Edwards

ED09-0253-81 NASA Photo by Carla Thomas

Discovery is surrounded by the Mate/DeMate Device gantry and ground support equipment at Dryden during processing for a ferry flight back to Kennedy Space Center, Fla.

runway was under construction. In 2007, parallel preparations were ongoing for having both runways ready in the event of a shuttle landing.

When Grimshaw began heading shuttle operations in 2007, implementing the final planning for the runway was at the top of his to-do list. Biscayart had returned from his brief "retirement" and was instrumental in planning for the runway move. But even with the help of Biscayart and Lance Dykhoff, Lockheed Martin site manager for shuttle operations, it was a tough task, Grimshaw said.

To be operational for a shuttle landing, the temporary runway needed a redundant Microwave Scanning Beam Landing System, or MSBLS. The system, which had been tested, validated and first installed at Dryden, provided the commander and the pilot with precise instrument-landing system information needed to fly the shuttle on the correct landing approach.

Also of note, the 750-million-candle-power Xenon lighting that guided the shuttle during night landings was designed at Dryden. Former Dryden employee Charlie Baker was awarded the Federal Incentive Awards Program Presidential Commendation in 1986 for his idea, which led to the lighting's development.

In addition, two visual landing aid systems, the precision approach path indicator, or PAPI, lights and a ball-bar light system were required. These visual reference systems provided a series of lights that guided shuttle pilots to the proper landing destination.

Additional MSBLSs for the new runway were obtained from Kennedy and the White Sands Space Harbor in New Mexico. Additional ball-bar and PAPI lights were obtained from Kennedy. The newly acquired equipment was prepared and installed on the new main runway, which then had a full complement of PAPI lights, ball-bar lights and microwave landing systems.

Because of the preparation activity, the Federal Aviation Administration flight-certified the MSBLSs on the temporary runway. In May 2008, the MSBLSs on the new runway were ready for FAA testing and fully certified. The navigation aids were ready, power systems were up, and operational checks were completed with the use of the shuttle training aircraft.

On the air field

Coordination was always important in having people and equipment in place and ready 24-hours a day, seven days a week, to be ready for an

See Shuttle workers, page 25

Final Flight

NASA Photo by Tony Gray/Tom Farrar

Riding a plume of fire, space shuttle Atlantis heads into the cloud-laden sky over Launch Pad 39A at NASA's Kennedy Space Center in Florida.

EC11-0267-80 NASA Photo by Tom Tschida

STS-135 mission specialists Sandy Magnus and Rex Walheim autograph a modified G-II Shuttle Training Aircraft recently acquired at Dryden. The astronauts visited Dryden Aug. 23, 2011.

EC11 00267-20 NASA Photo by Tom Tschida

From left, STS-135 crewmembers Chris Ferguson (commander), Doug Hurley, Sandy Magnus and Rex Walheim share their experiences of the final shuttle mission with a Dryden audience.

By Jay Levine
X-Press Editor

Space shuttle Atlantis completed its last mission in July, but the mission continued on for its crew, who traveled the nation to thank people for their support of the space program and recap some of the mission's highlights.

On one such visit to Dryden Aug. 23, the STS-135 crew met an enthusiastic audience. The last four to fly a space shuttle were mission commander Chris Ferguson, pilot Doug Hurley and mission specialists Sandy Magnus and Rex Walheim. Walheim was based at Edwards during the early part of his career and graduated from the Air Force Test Pilot School.

"I personally feel like this is our second home – we've had more than 40 percent of the shuttles land out here," said Ferguson, who landed Endeavour at Edwards when mission STS-126 concluded on Nov. 30, 2008. "We came out here practically seasonally to practice in the Shuttle Training Aircraft," he added.

In fact, while the crewmembers were touring Dryden during their recent visit, they autographed the nose of NASA 944, a modified Gulfstream II Shuttle Training Aircraft. The aircraft is being retired and will eventually be on display at the center.

Ferguson also noted Dryden's aeronautics work and the prototype shuttle Enterprise ALT work in 1977, both of which made major contributions to the shuttle program in confirming the shuttle's aerodynamics and unpowered-landing capabilities.

He also recognized the first Enterprise crew of Fred Haise and Gordon Fullerton, the first NASA 747 Shuttle Carrier Aircraft crew of Fitz Fulton and Tom McMurtry, and the early shuttle crews.

"They were our heroes," Ferguson said. He then acknowledged Fullerton's wife Marie, who was in the audience.

The historical significance of being the final space shuttle crew was not lost on the STS-135 astronauts.

"We were extraordinarily honored to be part of this final mission. We tried to send it off, and we are so elated that we were able to put it to bed in the best way we knew – with a very successful mission," Ferguson said.

The STS-135 mission delivered a stockpile of supplies and parts to the International Space Station. During an eight-day docking with the ISS, more than 11,600 pounds of supplies and equipment were unloaded and more than 5,700 pounds of equipment and discards no longer needed on station were returned to Earth on Atlantis.

Another key mission element, and a task for which space shuttles were uniquely suited, was retrieving the nonfunctioning 1,400-pound cooling system pump module that was replaced after it stopped working in 2010. The pump was moved from temporary storage aboard the space station and placed in the shuttle's cargo bay. Returning the pump to Earth will allow engineers to determine what caused its failure and then refurbish it as a spare.

Magnus, who on a previous mission had worked on the ISS for more than four months, said the return was "extra special" because she didn't think that after her earlier, long-duration mission she would have an opportunity to return.

"It was really thrilling. Once we docked and the [ISS] hatch was opened, it was like I never left. It looked a little bigger than when I left it two years ago, but it felt like home. When you visit on the shuttle you have your head down doing the job, and you can't really take it in the way you can when you live there because it's your lifestyle. You relax there, you work there and you live there, and it's a completely different experience. After a few weeks, you feel like you've lived there forever.

"One thing that strikes us anew, no matter how many times you've docked with the space station, is what an amazing thing it is that we accomplished," she added, referring to the station's construction.

To give people an idea of the station's scale, Magnus described it as being "about a football field long and a football field wide." Constructing it was successful due to the capabilities of the space shuttles, which carried large structures to space in their payload bay.

Walheim juggled a number of science experiments on board the shuttle on STS-135. He also is a spacewalk expert. What impressed him the most was seeing the distinctive Edwards area from space and the view of the entire West Coast, especially considering he never thought he'd be seeing it from the vantage point of a space shuttle in space.

NASA Photo

Space shuttle Atlantis is photographed from the International Space Station as it flies over the Bahamas prior to docking with the station. The Raffaello multipurpose logistics module can be seen inside the shuttle's cargo bay.

"You can see from Seattle to the Gulf of California," he said.

Walheim also noted that Dryden chief engineer Jim Smolka had taken Walheim on his first T-38 flight, when both worked at Edwards.

The STS-135 mission was not originally on the shuttle flight manifest, but Atlantis and its crew were readied as a contingency rescue mission for STS-134. Until Endeavour's safe landing at the end of STS-134 on June 1, it was not certain there would be one more flight, Hurley said. Once added to the manifest, STS-135 was limited to a four-member crew due to the potential difficulty of getting the astronauts to Earth safely in the event of an emergency. The STS-135 mission was the first mission since the shuttle's return to flight in 2005 during which there was no contingency shuttle on the pad poised for a rescue mission.

Though rescue by a Russian Soyuz was an option, a Soyuz would have been able to ferry just one astronaut at a time. Even with just four astronauts requiring rescue, planners estimated it would have taken a year to get all of the astronauts back to Earth.

"I drew the short straw, and would have stayed the longest," Walheim said.

The return to Earth was as spectacular as the mission itself, said Ferguson.

Coming in for a landing at Kennedy Space Center, "We all looked out the window," he said. "We had never seen that many people in one place. It was electric."

Atlantis was launched on its first space flight, STS 51-J, Oct. 3, 1985, with a classified payload for the U.S. Department of Defense. The vehicle carried four more DOD payloads on later missions.

Atlantis also launched many spacecraft from the payload bay on orbit, including planetary probes Magellan and Galileo and the Compton Gamma Ray Observatory. An array of on-board science experiments further enhanced space research in low Earth orbit.

Starting with STS-71, Atlantis pioneered the Shuttle-Mir missions, flying the first seven missions to dock with the Russian space station. The missions to Mir included the first on-orbit U.S. crew exchanges, now common on the ISS. On STS-79, the fourth docking mission, Atlantis ferried astronaut Shannon Lucid back to Earth after her record-setting 188 days in orbit aboard Mir.

Atlantis delivered several vital components to the ISS, including the U.S. laboratory module, Destiny, as well as the Joint Airlock Quest and multiple sections of the Integrated Truss structure that makes up the station's backbone.

Atlantis landed 13 times at Edwards, most recently on May 24, 2009.

Though the shuttles have now been retired, the astronauts stressed that the ISS mission continues. They also said they expect NASA astronauts will again travel to space in a new, American-built space vehicle in the years to come.

Shuttle workers ... from page 21

Edwards landing.

A convoy of vehicles was required for servicing the shuttle when it came to a stop after landing and to assist astronauts in exiting the orbiter. The convoy was assembled at Dryden's Shuttle Area A on the day of a scheduled landing. The convoy moved along the flight line to base Fire Department facilities, where the U.S. Department of Defense on-scene commander and forces and vehicles gathered with base fire and medical personnel for a final briefing by the NASA convoy commander.

From there, the forward convoy elements moved to the end of the selected runway and the other convoy elements deployed to the center taxiway, where they were in place for a landing.

Following the landing and the shuttle coming to a complete stop, the first group of vehicles moved in to a safe distance, 1,300 feet, from the orbiter. An assessment team checked for the possibility of hazardous gases emanating from the orbiter, to determine whether it could be safely approached and astronauts could begin preparations to disembark.

ED09 0127-12 NASA Photo by Jim Ross

Atlantis is towed to the Mate/Demate Device at Dryden so preparations can be made for transport back to Kennedy Space Center, Fla.

The convoy's command vehicle, a "purge" vehicle and a mobile cool unit were key components of the first group of vehicles. Both the cool and purge units were hooked up to the orbiter and provided power, purging and cooling for the orbiter during preparation and transport to the shuttle processing area. The purge system extracted residual hazardous gases in the lines, while the cooling system kept the shuttle systems from overheating while the orbiter was powered up.

When it had been determined that the orbiter and the area surrounding it were safe, the rest of the convoy moved forward with a mobile "white room," and a staircase unit was positioned next to the orbiter side hatch. Once the staircase was in place, the crew transport vehicle was elevated to the staircase and attached. Upon exiting the orbiter and entering the transport vehicle, the medical team gave the astronauts an initial post-flight checkup. Later, the crew was taken to another medical facility to undergo more detailed evaluation prior to their flight back to Houston.

Return to sender

Once the orbiter had been towed from the landing site to the MDD, further post-flight servicing in preparation for ferrying the orbiter back to Kennedy took place.

Processing of the orbiter for turnaround took about seven days. During that time, information stored on the orbiter during the mission was sent to Kennedy electronically, toxic fuels were removed and preparations were made for the cross-country transport flight.

On day five, hoisting the shuttle above the NASA 747 began. The Shuttle Carrier Aircraft was positioned beneath the shuttle, the orbiter was lowered onto its back and the shuttle was secured. The shuttle was lifted so slowly that the subtle movement was barely discernable.

Once the orbiter was positioned atop the SCA, the ferry flight to Kennedy was ready to begin.

It normally took two to three days to ferry the orbiter across the U.S. back to Florida, depending on weather. The mated SCA/orbiter had to steer clear of rain showers or turbulence during the ferry flight. A "pathfinder" aircraft flew ahead of the mated pair by 20 to 30 minutes. Together, the weight of the orbiter, the outside air temperature and density during takeoff and a standard cruising altitude of 15,000 feet meant several refueling stops. Ferry stops were made at civilian and military airfields.

No matter what time of day or night, or the emergency requiring it, Dryden crews were always ready to support the space shuttles. Workers surrendered their schedules – and sometimes holidays and vacations with their families – because they felt a part of something bigger than themselves.

"We were fortunate to have played such a major role in the program, and so many Dryden personnel and their families were also fortunate to have been able to witness such an historical event as a shuttle landing here at Edwards," Biscayart said.

Now, the nation will wait until a new vehicle is ready to travel to the stars – when a new generation will contribute to a program that will change the world again.

ED02 0131-9 NASA Photo by Carla Thomas

***Above**, Endeavour, mounted securely atop one of NASA's modified Boeing 747 Shuttle Carrier Aircraft, leaves Dryden at sunrise for Kennedy Space Center, Fla. **Below**, Endeavour's crew module is prepared for assembly at the then Rockwell International facilities at Air Force Plant 42 in Palmdale.*

A NASA Endeavour

Photo courtesy The Boeing Company

By Jay Levine
X-Press Editor

Space shuttle Endeavour will make one last flight – to its home in California. Its flight won't be powered by solid rocket boosters for this journey, but as a passenger atop the NASA 747 Shuttle Carrier Aircraft.

Its new home will be the California Science Center in Los Angeles. Southern California made major contributions to the shuttle program. Major orbiter components were built at North American Rockwell Space Division in Downey (now The Boeing Co.), with final assembly at Rockwell International Space Systems (which became the Boeing Reusable Space Systems Assembly, Integration and Test Facility) in Palmdale. In addition, Pratt & Whitney Rocketdyne built the space shuttle main engines at its Canoga Park, Calif., facility.

California contractors had other involvement. For example, the Aeroject Corp. of Sacramento supplied the space shuttle orbital maneuvering system thrusters, and the former Marquardt Corp. of Van Nuys, Calif. supplied the thrusters for the forward reaction control system.

Aside from the 54 landings at Edwards, Dryden's contributions are highlighted elsewhere in this publication. Endeavour landed at Dryden seven times, the last on Nov. 30, 2008.

Endeavour completed its final mission June 1, 2011, the end of a

EC92 05165-3 NASA Photo

Endeavour's maiden voyage concluded at Edwards with the first deployment of a drag chute on landing. The mission was extended two days to enable an Intelsat VI satellite rescue. Three astronauts rescued the satellite with a record space walk during which they took hold of the satellite and directed it to the shuttle. Once the satellite was in the cargo bay, a booster motor was attached to send it to its proper orbit.

16-day journey of more than 6.5 million miles.

Authorized by Congress in August 1987 as a replacement for the orbiter Challenger, Endeavour arrived at Kennedy Space Center's shuttle landing facility on May 7, 1991, piggy-backed on top of an SCA.

Endeavour marked the first time that an orbiter was named through a national competition involving students in elementary and secondary schools. Students were asked to select a name based upon an exploratory or research sea vessel.

Endeavour was named after a ship chartered to traverse the South Pacific in 1768 and captained by eighteenth century British explorer James Cook, an experienced seaman, navigator and amateur astronomer. He commanded a crew of 93 men, including 11 scientists and artists.

In service to the British Admiralty and the Royal Society, Cook's main task was to observe the Transit of Venus at Tahiti, which enabled astronomers to determine the distance of the sun from the Earth. That information was used as a unit of measurement in calculating the parameters of the universe. Cook's achievements on Endeavour included the accurate charting of New Zealand and Australia and successfully navigating the Great Barrier Reef. Thousands of new plant specimens and animal species were observed and illustrated on this maiden voyage. Cook also established the usefulness of including scientists on voyages of exploration.

Endeavour embodies similar experiences. Its first mission, STS-49, began with a flawless liftoff on May 7, 1992, and would be a journey filled with excitement, anticipation and many firsts.

One of Endeavour's primary assignments was to capture INTELSAT VI, an orbiting but nonfunctioning communications satellite, and replace its rocket motor. The project sparked public interest in the mission and NASA received a deluge of suggestions on potential ways for the crew to catch its prey. It took three attempts to capture the satellite before repairs could be made. An unprecedented three-person spacewalk took place after the astronauts and ground team evaluated the procedure.

Between rescue attempts, the STS-49 crew was busy. They conducted medical tests assessing the human body's performance in microgravity, and recorded footage for an educational video comparing Cook's first voyage on Endeavour with the space shuttle orbiter's maiden voyage.

Once the new motor was attached, it propelled the satellite into the correct orbit, providing a relay link for the equivalent of 120,000 two-way simultaneous telephone calls and three television channels.

Endeavor's mission marked the first time four spacewalks had been conducted on a space shuttle mission and the first time three people from the same spacecraft walked in space at the same time. One spacewalk, lasting more than eight hours was the longest undertaken to date, a record that stood until Discovery's STS-102 mission in 2001.

Other Endeavour missions included the first repair mission to the Hubble Space Telescope, in 1993, on which two corrective components were delivered to improve the telescope's ability to focus, and delivery of Node 1, the first American component of the International Space Station, in 1998.

Just as James Cook set the standard with his seafaring voyage, more than 200 years later shuttle Endeavour's missions have continued to uphold and surpass those standards set by its namesake.

When you have a communications problem, you just need to get some WATR

ED11 0238-11 NASA Photo by Tom Tschida

Mike Webb, right, and Rick Dykstra are seen at the radar and triplex consoles, tools used by Western Aeronautical Test Range staff to support space shuttles on orbit and during landings at Dryden and to maintain communication with the International Space Station.

Photo courtesy Mike Yettaw

The Western Aeronautical Test Range communications facility is the location for these quad yagi antenna arrays and other equipment used to provide communications to the International Space Station.

By Jay Levine
X-Press Editor

When a space shuttle was in orbit, or landed at Dryden, the Western Aeronautical Test Range staff was ready and waiting to assist.

Theirs was a capability the space shuttle crews appreciated. When the Atlantis crew was flying over Dryden on the July 16 final shuttle mission, they paid tribute to the center's historic contributions and its ongoing communications, tracking and telemetry support.

"Like to say 'hi' to the folks down in Dryden," said Atlantis Commander Chris Ferguson. "We really appreciated all the work they've done over the years. They've been with the shuttle program since the beginning, and they also give us critical comm[unications] right before we land there at Edwards.

"They've been a super supporter over the years in orbit and in entry, and we can't thank them enough for all their contributions. We would not have been nearly as successful without them. So, just like to say 'hi' to all the folks down in Dryden today – the crew of STS-135 is thinking about 'em and we really appreciate all the work they've done," he said.

Ferguson is familiar with Edwards' capabilities, experiencing them firsthand when, as Endeavor commander, he landed the orbiter here on Dec. 30, 2008.

The WATR shuttle role, which is not much different from that of flight research range support, was coordination of center range assets and personnel with other NASA centers to support shuttle program stages, including launch, on-orbit requirements and landing. The WATR provided telemetry, radar, voice communication and video support for shuttle flights and will continue to provide services to the International Space Station.

On the orbiter's final mission, Dryden supported 69 orbits with radar. Included in that number were 45 orbits by Atlantis and 24 orbits by the International Space Station, said Arcata Associates' Robert Jones, WATR operations and maintenance manager. Dryden supported telemetry for 59 orbits, among them downlinks from the orbiter to Earth that included key transmission of a bulk of information known as information dumps.

"As the space station travels around the globe, there are about five or six opportunities a day for us to get a good track on it," Jones said. "The navigators in Houston [at Johnson Space Center] use our data along with data from other ground-based radars and from the TDRSS navigational system to do the mathematics to determine whether they've calculated the proper orbits, the proper position of the space station and proper calibration of the ground tracking systems and the TDRSS tracking system to make sure everything is ready."

The TDRSS refers to NASA's Tracking and Data Relay Satellite System.

The radar tracks are used to confirm the exact position of the shuttle in orbit, said Mike Yettaw, WATR communications and flight termination system group lead. The telemetry orbits are used to enable the shuttle to transfer data to the Dryden Aeronautical Test Facility, or ATF, site and then to Johnson Space Center.

The TDRSS station located at White Sands Missile Range in New Mexico provided the orbiter's primary voice communication link, and the WATR provided backup communication support for the TDRSS if a failure there occurred during a shuttle mission. The WATR facility was the primary means of communication support when an orbiter landed at Dryden.

The WATR also tracked the space station from the day prior to launch throughout shuttle missions, to provide critical docking and undocking information. During docking, Dryden capabilities were tapped to help engineers at Johnson Space Center calibrate calculations determining the orbiter's location in relation to the ISS. As the orbiter neared the space station, astronauts could manually control the shuttle through use of on-board computers, looking out windows to ensure safe docking.

ED11 0238-1 NASA Photo by Tom Tschida

Western Aeronautical Test Range, or WATR, employees include the radar, telemetry, communications, long-range optics and mission control room groups. Though they will no longer provide shuttle communications, WATR personnel have ongoing missions, such as support of flight research mission communications and telemetry and communications support for the International Space Station.

WATR telemetry systems also provided downlinked orbiter health and status information to Johnson and, when needed, the telemetry systems also had the capability to provide uplinked command data to the orbiter.

Dryden began mission support two days before launch. After launch of an orbiter, the range tracked the shuttle until rendezvous with the space station. Two or three days before a shuttle returned, it undocked with the ISS. Dryden's two radars independently tracked the shuttle and the ISS for separation and rendezvous during 12-hour shifts that could start any time of the day or night, depending on the orbits.

In addition, on the day before a landing the Dryden crew ensured that radar, telemetry, communications and video were ready for landing. Shuttle crews tested S-Band uplink and downlink, the radar did an active track and Johnson engineers communicated with the shuttle using the Dryden communication facility's UHF voice equipment, Yettaw said.

Guy Thomas, Arcata Associates field services engineer, offered additional insight into WATR services.

"The Aeronautical Tracking Facility, or ATF, at Dryden was an integral part of shuttle operations for all 135 missions. Day and night, Dryden's high accuracy tracking radars provided precise positioning data needed to successfully guide the shuttle in orbit high above the Earth as well as during landing at Edwards," he said.

"The ATF's versatile telemetry antennas provided important communications links between Houston and the space shuttle while in orbit above the western United States, and when mission requirements led to a local landing, Dryden telemetry captured the pilot's point of view video and beamed the many flawless desert landings to television screens the world over.

"The shuttle program left an indelible mark on the Dryden ATF technicians and engineers who had the pleasure of tracking and communicating with the shuttle over its 30-year history."

Dryden has one of just two ground stations capable of sending and receiving communications on all of the available ISS frequencies, Thomas added. The other station is at Goddard Space Flight Center's Wallops Flight Facility. Goddard is located in Greenbelt, Md., and Wallops near Virginia's eastern shore. These emergency communication links were used in the past to resolve critical anomalies on the ISS and on the MIR before the ISS became operational. In both cases the emergency links were the only remaining operational links between Johnson Space Center and the ISS.

When a shuttle landed at Edwards and was prepared for transport, a 24-hour, seven-day-a-week umbilical connection to Kennedy Space Center via WATR facilities was activated to allow data gathered during the mission to transfer electronically.

Additional WATR support provided during landings at Dryden included long-range optical and infrared cameras, video vans for runway video coverage and the Mission Control Center that offered key support personnel a location in which to coordinate and monitor landing activities.

Whatever kind of space vehicles next travel to Earth orbit and beyond, Dryden will be ready to provide support with tracking, telemetry and communication needs when vehicles are overhead.

We Will Always

The STS-51L crew included, front row from left, pilot Michael J. Smith, commander Francis R. Scobee and mission specialist Ronald E. McNair. In the back from left are mission specialist Ellison S. Onizuka, payload specialist Sharon Christa McAuliffe, payload specialist Gregory B. Jarvis, and mission specialist Judith A. Resnik.

NASA Photo

Remember

STS-107 crewmembers included, from left, mission specialist David Brown, commander Rick D. Husband, mission specialist Laurel Blair Sutton Clark, mission specialist Kalpona Chawla, mission specialist Michael P. Anderson, pilot William C. McCool and payload specialist Ilan Ramon.

NASA Photo