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The X-15

The X-15 program has been called the most successful aeronautical research effort in history.

The aircraft was conceived in the mid-1950s as the world's first piloted vehicle to study the realm of hypersonic flight -- speeds of Mach 5 and beyond.

Three aircraft were built with two basic design goals. One goal was to achieve a speed of Mach 6, six times faster than the X-1 when it exceeded the speed of sound just a decade earlier. The other goal was to reach an altitude of 250,000 feet -- nearly 50 miles above the earth's surface, where there is no atmosphere to support wings and conventional control surfaces. The X-15 program reached those goals, and more.

By the time the nearly 10-year program ended at 199 flights in October 1968, an X-15 had been flown to a blistering speed of Mach 6.7 (4,520 mph), a record that still stands for winged aircraft. An X-15 also topped the altitude goal of 250,000 feet by nearly 19 miles. That record of 354,200 feet for a winged aircraft also remains intact.

But the X-15s produced more than speed and altitude records. Their accomplishments in several scientific disciplines can be traced to the development and growth of other aerospace programs and vehicles.

An X-15, with landing skids and nose wheel down, nears the dry lakebed at Edwards AFB following a research flight, while accompanied by a NASA F-104 chase aircraft.
NASA Photo EC88-180-9

A Global Legacy

Seldom-recognized contributions of the X-15 program can be appreciated every time a Space Shuttle is launched into orbit and returns to Earth.

The X-15 program clearly demonstrated that pilots could fly rocket-powered vehicles out of the Earth's atmosphere, successfully control them in an airless environment, reenter the atmosphere and then land at a predetermined site. This is the basic profile of a Space Shuttle mission, and while they are flown with computerized flight control systems, direct control can be assumed by pilots if desired or necessary.

The X-15s were the first aircraft to use reaction control systems to control pitch, yaw, and roll motions on the fringe of space where air is too thin for conventional aerodynamic controls. Reaction controls are small thrusters (jets) that are fired, mostly in short bursts. The X-15s used small hydrogen peroxide thrusters in the nose and on the wingtips for directional control during their brief scientific excursions in space when conventional aerodynamic system could not be used. The same control concept, developed into a very robust system, is used on the Space Shuttles.

On the high altitude flights, the X-15 pilots blended the use of reaction controls with conventional control systems as they transitioned from atmospheric flight to an airless environment, and back into the atmosphere again. Development of these control techniques, and the validation of reaction control technology, produced a legacy that now lives on in the Space Shuttles.

Space Shuttle reaction control systems are more robust and sophisticated than the elementary systems used by X-15 pilots, but the principle is the same. Reaction controls used by shuttle pilots give the big spacecraft precision maneuvering capability to deploy and retrieve satellites in space, dock with the International Space Station and orbiting satellites, and to properly align the vehicles for a variety of scientific events. Shuttle reaction control systems also keep the vehicles in a proper attitude when deorbiting events begin and shuttle crews commence their return to Earth. As the vehicles are pulled earthward by gravity and guided to the landing site, there is a transition from the reaction control systems to conventional aerodynamic flight control surfaces, just as there was in the days when X-15s were pioneering spacecraft reentry techniques.

A Shared Legacy in Space

During the first years that X-15 pilots were routinely using reaction controls to carry out research and test activities in the lower reaches of space, astronauts of Project Mercury began using reaction controls for the first time to stabilize and control spacecraft orbiting the Earth. The Mercury systems were followed by improved systems on Gemini and Apollo spacecraft.

As reaction control technology matured through the X-15 program and Projects Mercury, Gemini, and Apollo, refined systems were beginning to be used with increased frequency to stabilize and control orbiting satellites. That control concept is now used on nearly every communications, reconnaissance, and weather satellite in circular and stationary orbit. Other versions of reaction controls also keep planetary exploration spacecraft stable as they travel millions of miles through space to study and photograph other bodies in the solar system to increase human knowledge of the universe.

Today, dozens of communications and data relay satellites in space high above the Earth, either in orbit or in geosyncronous positions, relay electronic signals -- television, telephone, E-Mail, radio, and computer networking -- around the world. Each spacecraft has reaction controls to automatically keep it precisely oriented so there is no interruption of electronic signals being received and retransmitted. Sports, motion pictures, breaking news, educational shows, and world finances -- all are delivered into homes in every nation by satellites stabilized with reaction controls.

Weather satellites are another type of spacecraft that help people the world over. Reaction control systems keep these space sentinels in proper attitudes while they automatically transmit atmospheric data to meteorologists. Daily weather forecasts and warnings of approaching storms ashore and at sea have become a routine part of personal and business life, and they are a necessary equation in every aspect of aviation and spaceflight.

Military and national security agencies also depend on stabilized satellites. Reconnaissance spacecraft monitor international activities with photography and other detection methods to help U.S. government leaders keep abreast of situations abroad that are vital to American interests.

The Scope of Accomplishments

The scope of the X-15 research and test program encompassed many aerospace disciplines: hypersonic aerodynamic performance, heating rates, structural behavior at high heat rates, flight loads at high speeds and high temperatures, stability and control at hypersonic speeds, pilot performance and physiology, and controllability of the aircraft as they exited and reentered the atmosphere.

After the program's original research and test goals were met, the three aircraft became testbeds to carry out a broad range of experimental packages at high altitudes and high speeds.

More than 760 research reports were written from information produced by the pilots, from data produced by the aircraft instrumentation systems during flights, and from individual experiments. This storehouse of knowledge is still being used by engineers and scientists today as they develop piloted and unpiloted aerospace vehicles that are yet to fly. No other research program in aviation history has produced as much data as the X-15s.

Many X-15 program accomplishments, spawned by flight research associated with the hypersonic and high altitude goals, and from testbed experiments and investigations, have been singled out as very significant to the development of the Space Shuttles. Among them are:

First use of reaction controls for attitude control in space; successful transition between aerodynamic controls and reaction controls; demonstration of a pilot's ability to control rocket-boosted aerospace vehicles through atmospheric exit; first piloted, aerodynamic atmospheric reentry; development of large supersonic drop tanks; demonstration of a pilot's ability to function in weightless environment; first application of energy-management techniques; development of the first large restartable "man-rated" controllable rocket engine; first application of hypersonic theory and wind tunnel data to a piloted flight vehicle; and development of first practical full-pressure suit for pilot protection in space

Other developments and accomplishments of the X-15 program benefiting the scientific and engineering professions include:

Development of improved high temperature seals and lubricants; first reusable super alloy structure capable of withstanding the temperatures and thermal gradients of hypersonic reentry; development of new techniques to machine, form, weld, and heat-treat Inconel X and titanium; development of nitrogen cabin conditioning; discovery that hypersonic boundary layer flow is turbulent and not laminar (smooth); discovery that turbulent heating rates are significantly lower than theorized; first direct measurement of hypersonic skin friction, and discovery that skin friction is lower than earlier predicted; discovery of "hot spots” generated by surface irregularities; and discovery of methods to correlate base drag measurements with tunnel test results, allowing corrected wind tunnel data

Several other significant spin-offs from the X-15 program continue to be used.

Astronaut capsule communicators (capcoms), the voice link between mission control rooms and orbiting astronauts, are an outgrowth of the X-15 program. The practice began when it was decided that an experienced pilot on the ground was the best person to speak to an X-15 pilot in the air, especially in an emergency. Capcoms continued their work through the Mercury, Gemini, and Apollo missions and are a vital part of each Space Shuttle mission.

The star tracker navigational systems used on Air Force U-2s and SR-71s, and each Space Shuttle vehicle, can trace its history to a successful X-15 experiment that collected data on the radiation characteristics of the daytime sky background.

During X-15 missions, pilot heart rates often ranged from 145 to 185 beats per minute during events such as launch, engine shutdown, atmospheric reentry, and landing. These rates were significantly higher than the 70 to 80 beats per minute during test fights on other aircraft. But since no physical problems were associated with the high heart rates of the X-15 pilots, physiological experts reevaluated -- and boosted -- rate limits for Project Mercury and the spaceflight programs to follow.

The X-15s were used as a platform for some of the first Earth resources photography, and to test exterior insulation used on the big Saturn 5 rockets that were part of the Apollo launch system. Pilots in the X-15s also tested horizon-measuring instrumentation equipment that helped in the development of Apollo navigation systems.

The Aircraft and its Origins

The X-15 program grew out of a need by the United States in the early 1950s for a vehicle to conduct hypersonic aerodynamics and heating research, areas that needed to be studied if future flights into space were to be made.

Studies by engineers of the NACA (National Advisory Committee on Aeronautics, which became NASA in 1958), led to a joint agreement in 1954 between the U.S. Air Force, the Navy, and NACA to design, build, and fly a high-speed, high-altitude research aircraft. The X-15 would become the first major investment of the U.S. in manned aerospace flight technology.

The agreement gave NACA technical control of the program, while the Air Force and Navy funded the design and construction of the three aircraft, with the Air Force administering those two phases. The aircraft would be transferred to NACA, which would conduct flight-testing and report all subsequent results, once contractor demonstration flights were completed.

The contract to build the trio of research aircraft was awarded to North American Aircraft (later the North American Aircraft Division of Rockwell International) in September 1955. In late 1958, the first aircraft was delivered to what is now the NASA Dryden Flight Research Center, where all X-15 flight operations were based.

Development and construction of the X-15s broke new ground in the aviation industry. The single-seat monoplanes had an outer skin of a new nickel-chrome alloy called Inconel X, developed to withstand aerodynamic heating temperatures of 1,200 degrees F when flying in the atmosphere. The interior structure, including the wings and tail components, was composed mostly of titanium, Inconel X, and stainless steel.

The cockpit area was built of aluminum, and isolated and insulated from the outer structure to protect the pilot from exterior heat generated by high speeds.

About 50 feet long with wings spanning 22 feet, the X-15s were designed to be powered by XLR-99 rocket engines that could be throttled to produce a thrust range of between 28,000 and 57,000 lbs. The powerplants were built by the Reaction Motors Division of Thiokol Chemical Corp. At a speed of 4,000 mph, 57,000 lbs of engine thrust was equal to 608,000 hp. The engines were fueled by anhydrous ammonia and liquid oxygen carried in tanks inside the fuselage. Pressurized helium fed the fuel into the engines, and hydrogen peroxide powered the rocket engine's turbopump.

The XLR-99 engines were not ready for the first flights of the aircraft beginning in June 1959. To fill the engine gap, two XLR-11 engines -- each producing 16,380 lbs of thrust -- were installed in each of the first two aircraft to fly. The XLR-11 engines were the same models used in the Bell XS-1, the first aircraft to fly faster than the speed of sound. First use of an XLR-99 engine in an X-15 was in November 1960, when the No. 2 X-15 flew the program's 26th flight. The smaller XLR-11 engines, though less powerful and unable to be throttled, achieved a top speed of 2,196 mph during its brief lifetime with the program.

A distinct feature of the X-15s were the main retractable landing gears, which used skids instead of wheels for simplicity and weight reduction. The skids, coupled with a non-steerable nose-landing wheel, required the aircraft to land on a dry lakebed rather than a conventional concrete runway. The intended dry lakebed on all flights was Rogers Dry Lake at Edwards AFB, but other lakebeds in California and Nevada were used several times for emergency landings.

For flight in the atmosphere, the X-15s used conventional aerodynamic controls consisting of rudders on two wedge-shaped vertical stabilizers, one atop the fuselage and the other extending beneath. They controlled yaw movement. Canted horizontal surfaces on the tail controlled pitch when moved in the same direction, and roll when moved differentially. When the landing skids were down, the lower vertical tail extended below the skids and was dropped by parachute just before landing.

An X-15 hangs from a pylon beneath the right wing of NASA's B-52 carrier aircraft as the moment nears to drop the rocket-powered aircraft on a high-speed research flight

NASA Photo EC65-885

Above Earth's atmosphere, at the high point of soaring research flights following engine shutdown, the X-15s used reaction controls to keep the aircraft stable and in the proper attitude for a safe return back into the atmosphere where conventional controls could be used again. Hand controllers in the cockpit were linked to tiny hydrogen peroxide rocket nozzles at the nose for pitch and yaw control, and on each outer wing panel for roll control.

Each flight of the X-15s began with an aerial drop from a pylon attached beneath the right wing of NASA's B-52 carrier aircraft. The usual drop altitude was about 45,000 feet at a speed of about 500 mph. Earlier "X" aircraft were also air dropped for each research and test flight. Air drops were used because the research aircraft could not take off with a heavy fuel load and still have enough fuel for the research portion of the flights.

Depending on the mission, the XLR-99 engine burned for up to two minutes, providing enough thrust for research flights as long as 12 minutes. After the X-15s glided back to the dry lakebed at Edwards, powerless landings were made at a speed of about 200 mph.

X-15 No. 2, with a white ablative coating and twin external fuel tanks, drops away from NASA's B-52 carrier aircraft. The aircraft, in this configuration, set the world's speed record of 4,520 mph for winged aircraft.

NASA Photo EC68-1889

Tracking X-15s as they streaked across the sky at hypersonic speeds required a lengthy instrumentation and control network. NASA established an X-15 tracking range that extended from Wendover, Utah, the northerly end of the flight corridor, to Edwards AFB, with radar and telemetry facilities at Ely and Beatty, Nev. A mission control facility was also built at the NASA center. Regardless of where the X-15s were air-launched along the route, continuous instrumentation and tracking coverage was available with the "High Range" network.

Launch weight of a fully fueled X-15 without external tanks was 31,275 lbs. This weight dropped to 12,295 at engine burnout. Aircraft weight increased to just under 57,000 lbs with the external tanks and extra fuel.

The White X-15

In 1963, after the program's design goals had been met, the Air Force authorized North American Aviation to modify the No. 2 aircraft with external fuel tanks to achieve faster speeds. The No. 2 aircraft had been damaged in a landing accident in November 1962 and the modifications became part of the repair process.

The external fuel tanks were attached to the lower sides of the aircraft and were jettisoned when empty. The fuselage was lengthened 29 inches to accommodate an additional liquid hydrogen tank that was to be used to power a small prototype ramjet that was to be mounted on the lower ventral fin. While an operational ramjet was never fired in flight before the X-15 program concluded, a dummy engine was carried to study its aerodynamic characteristics.

The "second" first flight for the No. 2 aircraft, after repairs and modifications, was in June 1964. It continued to serve as a testbed for research activities for the next two years. It was flown for the first time in November 1965 with empty external tanks in preparation for speeds beyond the unofficial world record of 4,104 mph that the No. 1 vehicle had set several years earlier.

As higher speeds were being sought, NASA was evaluating several ways to counteract high surface heat on the aircraft. One method was a white ablative coating applied to the entire aircraft. Consisting of a resin base, a catalyst, and glass bead powder, the coating was developed to provide protection from 2,000-degree surface temperatures that could seriously damage the aircraft. The first flight with the ablative coating was on Aug. 21, 1967, with the aircraft reaching a speed of 3,368 mph. The coating discolored in some places from heat, but was restored as the aircraft was prepared for a next and much faster flight.

On Oct. 3, 1967, the No. 2 aircraft was piloted to a speed of 4,520 mph -- Mach 6.7 -- a record for winged aircraft that still stands. The XLR-99 engine burned for 140.7 seconds, including 67.4 seconds on fuel from the external tanks, before shutting down. While the ablative coating protected most of the aircraft, excessive heating did damage several areas including the dummy ramjet and its pylon, the ventral fin, leading edges of the wings, and nosecap. The aircraft was repaired but never flew again after its return to NASA from North American.

X-15 No. 2, with a dummy ramjet mounted on the lower ventral fin, is pictured at the beginning of a research flight following an air drop from NASA's B-52 carrier aircraft.
NASA Photo EC88-0180-2

The ablative coating was not used again on the X-15s. The coating had once been considered for use as a protective element on some surface areas of the Space Shuttles, then in the earliest days of design and engineering, but it was never adopted for that program.

Flight Summary

First glide flight; X-15 No. 1; June 8, 1959; pilot, Scott Crossfield, North American Aviation (NAA)

First powered flight; X-15 No. 2; Sept. 17, 1959; pilot, Scott Crossfield, NAA

First research flight; X-15 No. 1; Mar. 3, 1960; pilot, Joe Walker, NASA

First flight with XLR-99 engine; X-15 No. 2; Nov. 15, 1960; pilot, Scott Crossfield, NAA

Design speed; X-15 No. 2; Nov. 9, 1961; Mach 6.04 (4,093 mph); pilot, Robert White, USAF

Design altitude; X-15 No. 1; Apr. 30, 1962 246,700 ft; pilot, Joe Walker

First civilian flight above 50 miles; X-15 No. 3; Jan. 17, 1963; pilot, Joe Walker

Unofficial world altitude record; X-15 No. 3; 354,200 ft; pilot, Joe Walker

First flight with external tanks empty; X-15 No. 2; Nov. 3, 1965; pilot, Robert Rushworth, USAF

First flight with external tanks full; X-15 No. 2; July 1, 1966; pilot, Robert Rushworth

Unofficial world speed record; X-15 No. 2; Oct. 3, 1967; pilot, William Knight, USAF

Last flight; X-15 No. 1; Oct. 24, 1968; pilot, Bill Dana, NASA

There were several emergency landings that caused aircraft damage during the life of the program, but there were only two accidents that resulted in a serious injury or a fatality.

On Nov. 9, 1962, NASA pilot Jack McKay was flying X-15 No. 2 when he experienced engine failure and had to land early at Mud Lake, Nev. Without the ability to dump fuel, the aircraft was heavy and the landing gear collapsed, rolling the aircraft onto its back. McKay received back injuries, but recovered to fly again. The aircraft was rebuilt and flew again with external fuel tanks to establish the unofficial world speed record.

On Nov. 17, 1967, Air Force pilot Mike Adams was flying X-15 No. 3 on a research flight and had reached an altitude of 266,000 ft and a speed of 3,570 mph when the aircraft when into a spin. Adams recovered from the spin but could not get out of the inverted dive. He died when the aircraft crashed northeast of Johannesburg, Calif. It was the only fatality and aircraft loss in the program.

Total flight time in the program:

30 hr. 13 min., 49.2 sec

Total time above Mach: (cumulative)

Mach 1: 18 hr. 23 min. 11.6 sec
Mach 2: 12 hr. 13 min. 50 sec
Mach 3: 8 hr. 51min. 12.8 sec
Mach 4: 5 hr. 57 min. 23.8 sec
Mach 5: 1 hr. 27 min. 15.8 sec
Mach 6: 1 min. 16.8 sec

The Pilots

The 12 pilots of NASA, the Air Force, Navy, and North American Aviation who flew in the program are listed in the order of their first flights, along with their total flight numbers.

A. Scott Crossfield, NAA, 14 flights; Joseph A. Walker, NASA, 25 flights; Robert M. White, USAF, 16 flights; Forrest S. Petersen, USN, 5 flights; John B. McKay, NASA, 29 flights; Robert A. Rushworth, USAF, 34 flights; Neil A. Armstrong, NASA, 7 flights; Joe H. Engle, USAF, 16 flights; Milton O. Thompson, NASA, 14 flights; William J. Knight, USAF, 16 flights; William H. Dana, NASA, 16 flights; Michael J. Adams, USAF, 7 flights

The Aircraft Now

The No. 1 X-15, with a serial number of 56-6670, is publicly displayed in the National Air and Space Museum, Washington, D.C., next to the Wright Brothers Flyer and the Spirit of St. Louis, flown by Charles Lindbergh.

The No. 2 X-15, with a serial number of 56-6671, is publicly displayed at the Air Force Museum, Dayton, Ohio. It is displayed in its original configuration, without the external fuel tanks, though it retains the fuselage extension. The aircraft was delivered to the museum in October 1969.

The No. 3 X-15, which carried a serial number of 56-6672, was destroyed in a crash on Nov. 17, 1967. The pilot, Air Force Maj. Michael J. Adams, was killed in the accident.